EFFECT OF EARTHEN POND FISH FARMING PRACTICES ON WATER QUALITY
A CASE OF GROUP AND INDIVIDUAL FARMERS IN BUIKWE DISTRICT

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DECLARATION AND RECOMMENDATION

I, Akello Mary Goretti Registration number J21M46201 declare that this dissertation is my original work and has not been presented in this university or any other for the award of a degree.

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Recommendation

This Dissertation has been submitted with my approval as university supervisor.

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LIST OF ACRONYMS AND ABBREVIATIONS

BDLG	Buikwe District Local Government
BOD	Biochemical Oxygen Demand
DO	Dissolved Oxygen
Ec	Electrical conductivity
FAO	Food and Agriculture Organization
FNU	Formazin Nephelometric Units
GoU	Government of Uganda
IFPRI	International Food Policy Research Institute
LG	Local Government
NH4	Ammonia
NO3	Nitrates
NTU	Nephelometric Turbidity Units
pH	potential of hydrogen
SPSS	Statistical Package for Social Scientists
TDS	Total Dissolved Solids
UBOS	Uganda Bureau of Statistics

ABSTRACT

The overall objective of the study was to determine the quality of water in earthen fish ponds in Buikwe district, Eastern Uganda. The study was guided by the following specific objectives: 1) To examine the socio-economic factors of smallholder pond fish farmers in Nyenga Division; 2) determine the level of awareness on water resource use and safety practices among smallholder pond fish farmers in Nyenga Division; 3) assess the biophysical parameters of water resources used in earthen ponds in Nyenga Division; and lastly 4) assess the effect of pond effluents on the water quality in the downstream in Nyenga Division. Data on biophysical parameters was collected using a combination of water collection equipment in the forms of sterile bottles, while social economic data was collected using questionnaires and secondary data sources. Total Dissolved Solids was analyzed using standard methods 2540 B, pH by a multipurpose pH meter, BOD and DO using standard titrimetric method, turbidity by nephelometric method using a turbid meter. Concentrations of minerals - Phosphates, Nitrates and Ammonia water samples were analysed using an atomic absorption spectrophotometer (AAS). Using excel and SPSS data was analyzed and this was presented using frequencies, percentages, charts and graphs. Regression, ANOVA, t-tests and correlations were used to analyze significance of the variables. The study found that there is no variation in socio-economic characteristics of pond farmers in Nyenga Division when a t-test statistical analysis was conducted, and the results were $p<0.05$ which is statistically significant. The pond farmers are adequately aware of the water resource use and safety practices indicated by R-square value of 0.35 obtained and ($p<0.000$ & 0.010) which was confirmed by ANOVA test results ($p>0.05$); the biophysical parameters at the earthen pond inlets, middle points, and at the outlets this was proven when One-way ANOVA test indicated ($p>0.05$); and lastly, the pond effluents have not altered the water quality in the streams in Nyenga division which was revealed by the t-test analysis ($p>0.05$) for all the three villages.

CHAPTER ONE

INTRODUCTION

1.1 Background information

Due to the global increase in demand for white meat, especially fish products and decreased supply from the natural water bodies such as inland lakes and rivers, many actors have devoted their efforts to aquaculture practices (World Bank, 2007; Muringai et al., 2022). Aquaculture depends predominantly on the use of freshwater resources channeled from near water bodies and regular monitoring of water quality is a necessity. Fish cultivation also known as aquaculture consists of natural and artificial fish farming carried out in ponds (Akpotayire *et al.*, 2018). In addition to the use of ponds, fishes are also cultured in various water holding facilities such as happas, tanks, cages, raceways, etc. Water is the environment for fish and its quality determines its fitness for use and capacity to sustain the health of farmed aquatic organisms.

Lakes and rivers are some of the freshwater ecosystems that act as habits for aquatic organisms such as plankton, fish and decapod crustaceans (Tulsankar, Cole, Gagnon and Fotedar, 2021). All ecosystems can be altered by adding materials such as nutrient loadings from natural and man-made sources (Nõges *et al.*, 2016). Although natural water systems are subjected to higher nutrient loadings through rainwater runoffs, nutrients to earthen aquaculture ponds can only be limited to aquaculture management practices especially fertilizers during pond fertilization and feeding (Boyd *et al.,* 2010).

Globally, fish produced from aquaculture sector is valued at $204 billion in 2020 and is expected to reach $262 billion by the end of 2026, growing at a compound annual growth rate (CAGR) of 3.6% from 2021-2026. In many of the developing countries, the demand for fish has continued to grow (IFPRI, 2016). Given population growth, expanding urbanization, and rising incomes in the developing world, this trend is expected to continue (IFPRI, 2016). Fish production in developing countries, was estimated to increase by about 58% from 62.7 million metric tons in 1997 to 98.6 million metric tons by 2020 (Mustapha, 2017). Although there was decline in the growth of the sector in 2020 especially among the large producers – Egypt and Nigeria at 1.2 percent compared with 2019, the sector registered tremendous growth in other regions of the continent.

In the past two decades, there has been increasing interest in pond aquaculture in both rural and urban areas in Uganda (Larive International & Asigma Capital Advisory Services, 2021). This practice is becoming an integral component of sustainable agriculture. However, data from available studies (Thilza and Muhammad, 2010; Ehiagbonre and Ogunrinde, 2010; Solomon, Olatunde and Matur, 2013; Keremah, Davies and Abezi, 2014; Agbaire, Akporido and Emoyan, 2015; Mustapha, 2017; Akpotayire et al., 2018) revealed that not much has been done on the assessment of the physicochemical properties of water in different fishponds in many developing countries, Uganda inclusive. These previous investigations show that quite a few of the physicochemical properties of fishpond water were examined and also the types of examined aquaculture systems were limited. This indicates a need to assess the status of various physicochemical properties of water under different fishing systems practiced by the people.

1.2 Statement of the Problem

The need for the rapid growth of fish among fish farmers as it applies to other farming communities has led many farmers to consider pond fertilization and supplementary feeding (Moogouei *et al.* 2009) in Mbuthia (2020). Although these are beneficial to the farmers by facilitating faster growth of the fish, it is believed to be detrimental to the water quality through the accumulation of large amounts of nutrients, eventually affecting the health of users downstream and sometimes leading to fish mortality (Mbuthia, 2020; Musyoki, 2015).

Therefore, despite the importance of frequent assessment of the physicochemical properties of water, very few farmers rarely conduct these assessments owing to inadequate funds and knowledge on the value of conducting such assessments (Thilza and Muhammad, 2010; Ehiagbonre and Ogunrinde, 2010; Solomon, Olatunde and Matur, 2013; Keremah, Davies and Abezi, 2014; Agbaire, Akporido and Emoyan, 2015; Mustapha, 2017; Akpotayire *et al.*, 2018) in Orobator *et al.* (2020). This puts the fish consumers and water users downstream at risk of contracting diseases thereby affecting their health. This revealed a need to conduct a study assessing the status of various physicochemical properties of water in areas where fish farming is practiced.

With the rising earthen ponds in the Buikwe district, it is paramount to undertake a study assessing the condition of earthen ponds in terms of water quality. Water quality parameters –Water pH, DO (Dissolved Oxygen), Electric Conductivity, BOD (Biochemical Oxygen Demand), Turbidity, Total Dissolved Solids (TDS), Minerals (Phosphates (PO43-), Nitrates (NO3-) & Ammonia (NH4) were of interest for this study as key indicators of water quality. The study results are helpful in enhancing water management practices among pond farmers to improve fish productivity while reducing health hazards to water users downstream.

1.3 Objectives of the study

1.3.1 General objective

To assess the effect of earthen pond fish farming practices on stream water quality to enhance sustainable aquaculture among smallholder farmers in Nyenga Division in Buikwe District.

1.3.1 Specific objectives

1) To examine the socio-economic factors of smallholder pond fish farmers in Nyenga Division.
2) To determine the level of awareness on water resource use and safety practices among smallholder pond fish farmers in Nyenga Division,
3) To assess the biophysical parameters of water resources used in earthen ponds in Nyenga Division.
4) To assess the effect of pond effluents on the water quality in the downstream in Nyenga Division.

1.4 Hypothesis

H1: There is no variation in socio-economic characteristics of pond farmers in Nyenga Division

H2: Pond farmers are adequately aware of the water resource use and safety practices.

H3: The biophysical parameters at the inlet, middle and at the outlet of the earthen ponds do not differ.

H4: Pond effluents have not altered the water quality in the streams in Nyenga division.

1.5 Justification of the study

The study is justified owing to the large scale of earthen pond fish farming in Nyenga Division, with little or no study conducted on the biophysical parameters that determine water quality in these ponds. The area is predominantly a fish farming community with the majority of the households dependent on fish farming (BDLG, 2016). Nyenga Division alone, which has 6 parishes is reported to have 32 fish ponds.

Besides, there is less information available regarding the socio-economic characteristics of pond fish farmers, their level of awareness on the water resource use and safety practices, biophysical parameters of water resources at the pond inlets, inside and outlets; and the effect of pond effluents on the water quality in the stream.

Because of the effect of pond fish farming on the physical and biophysical environment, it is apparent that the farmers are knowledgeable on water resource use and safety practices, understand biophysical parameters in the ponds and the effect of change in these parameters not only on the quality and quantity of fish harvested, but also on the adjacent natural and human environment.

The aspect of water quality is vital in fish farming since fish productivity all revolves around water quality (FAO, 2012) cited in Mbuthia (2020). However, with the rising human population and subsequent increase in number of human activities, the pressure on environmental degradation, and for this case, water pollution has become a global concern (Obasohan and Agbonlahor, 2010) in Mbuthia (2020).

The study provides information on the socio-economic characteristics of pond fish farmers, level of their awareness on the water resource use and safety practices, biophysical parameters of water resources at the pond inlets, inside and outlets; and the effect of pond effluents on the water quality in the stream in Nyenga Division, Buikwe district. This information will be available for use by other scholars, policy makers, technocrats and policy makers in designing appropriate government policies to address issues unearthed by this study.

1.6 Scope/Limitations/Assumptions

Geographically, the study was limited to Nyenga Division, Buikwe district. The biophysical parameters that were studied are: Water pH, DO (Dissolved Oxygen), Electrical Conductivity, BOD (Biochemical Oxygen Demand), Turbidity, Total Dissolved Solids (TDS), Minerals (Phosphates (PO43-), Nitrates (NO3-) and Ammonia (NH4)).

The study was limited to pond fish farmers and as a result, farmers engaged in natural fishing bodies and concrete ponds were not of interest for this study. The study was conducted between March 2023 to February 2024.

1.7 Definition of terms used

Pond – is a physical structure of various dimensions that is established on land or constructed with industrial material to hold but slowly release its fresh water in a manner supports development of biodiversity in it. The pond in the context of this study refer to only man-made ponds intentionally made for fish farming.

Earthen ponds – In this study, are conceptualised as constructed structures from soil materials to hold but slowly release water thereby providing suitable conditions for domestication of different fish species.

Water quality – refers to the chemical, physical, biological and radiological characteristics of water.

Parameters – a numerical or other measurable factor forming one of a set that defines a system or sets the conditions of its operation.

Aquaculture – the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants.

1.8 Expected output

At the end of this study, the study is expected to generate the following outputs:

1) MSc. Thesis
2) Published paper in the peer review journal

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews literature on the variables for this study broken down into various research questions: identifying the socio-economic characteristics of pond fish farmers; determining the level of awareness on water resource use and safety practices among pond fish farmers; assessing the biophysical parameters of water resources at the pond inlets, middle and outlets; and assessing the effect of pond effluents on the water quality in the stream. A review was done on these objectives identifying existing gaps which will be filled by this study.

2.1 Socio-economic characteristics of smallholder pond fish farmers

FAO in a study conducted on production, accessibility, marketing and consumption patterns of freshwater aquaculture products in Asia (Bangladesh, Thailand, Indi, Viet Nam, China, Philippines, found that farmers' socio-economic characteristics varied from area to area, although with slight similarities. On average, FAO (2001) in a study done in Asia found that farmers' age ranged between 43 to 52 years. This did not greatly differ from the results of Khatun, Adhikary, Rahman, Sikder, & Hossain (2013) in a study in Bangladesh where most of the fish farmers 46% belonged to the age groups of 36 to 50 years. The findings did not differ from those of a study done in Kenya where the participants were composed of middle-aged fish farmers with an average age of around 43 years (Ouko et al., 2022) which is in line with findings by Muddassir et al., 2019). In a study done in Pakistan, Kumar (2015) found that out of the total 25 farmers, 44% belongs to the middle age group of 36 to 50 years followed by old age group consisting 32% farmers and 24% fish farmers belongs to young age group. It showed a shifting pattern from old age to young age which implies that aquaculture is attracting the interest of the younger generation. These studies although on similar aspects, differ in their contexts socially, economically and politically and therefore this study was conducted to assess the socio-economic characteristics of fish farmers in Nyenga division. Since none of such a study had been conducted in Nyenga, it was important to understand these characteristics to facilitate the district and other players in the sector understand how these variables can affect fish farming in the area.

Majority of the fish farmers – 41%-65% engaged in crop farming as one of their main occupations, although fish farming featured as the highest occupation in India at 43% and 95% of the households in Andhra Pradesh depended on fish farming as their occupation (FAO, 2001). This was contrary to Vietnam where only 2-4% of the households were engaged in fish culture as their occupation and where fish culture is still largely done on a subsistence level (FAO, 2001). This differed from the situation in Bangladesh where only 6% of the fish farmers were involved in fish farming as their primary occupation and 36% engaged in the sector as their secondary occupation (Khatun et al., 2013). In Kenya, Ouko et al. (2022) 54% of the fish farmers were involved in fish farming as their major occupation, with 30.8% involved in off-farm business and 15.2% in salaried employment. This implied that the majority of the fish farmers have diversified income sources and as such reduces the vulnerability of farmers to risks. In Nyenga division, over 90% of the study farmers were engaged in fish farming as their occupation an indication of the position of fish farming as engines of most developing countries.

Khatun et al. (2013) in a study done on fish farming in Bangladesh found that about 18% had no education, with 16% farmers educated to primary, 42% to secondary, 14% higher secondary and only 10% with bachelor level of education. In Pakistani, Kumar (2015) found that majority of respondents (84%) of those involved in fish production were possessing middle level of education while 8% farmers were literate up to primary level and 8% of farmer were educated to Metric and above. It infers that educated farmers were aware about new enterprises and taking advantages of schemes and programmes of state and central Government. It was also noted that few well educated and established businessmen were also taking part in fish farming practices. The findings are supported by the study done by FAO (2014) which found that farmers with higher formal education levels were more likely to attend various fish training seminars, comprehend and apply information packages. Similarly, Veliu et al., (2009) found that in Vietnam, 52.1% of the fish farmers had attained secondary level of education and farmers with a higher level of formal education more likely to adopt fish farming techniques than those with less formal education. In Buikwe district, majority of the fish farmers had primary level of education and this affected adoption of modern fish farming in terms of understanding water quality parameters, maintaining the ponds and reaping huge benefits from the sector.

During the study, FAO (2001) found that most farmers had experience of 5-15 years in all countries where the study was conducted which was attributed to the long traditional culture of fish farming (De Silva 1996) in (FAO, 2001). Both male and female engage in fish farming and in Viet Nam, female engagement was one of the highest at 56% attributed to information dissemination campaigns and training schemes (Ahmed, 1997) in (FAO, 2001). In Kenya, the minimum years of experience was 1 year while the maximum was 12 years with a mean of 3.65 years (Ouko et al., 2016). The average male engagement in fish farming was at 95%, although there were variations across the countries studied. However, a similar study found that, although female engage in fish farming, they are less engaged in fish trading owing to the widely held practice of keeping women at home. In Kenya, Ouko et al., (2022) more males were engaged in the sector (73.6%) compared to 26.1% females and possible reasons for male dominance in fish farming was attributed to the tedious and energy-sapping nature of activities involved which most women may not be able to cope with. This collaborates with findings of other previous studies in African countries where participation by women in fish farming operations varied greatly (Veliu et al., 2009). Similarly, this study found that over 60% of the participants were males compared to females explained by the masculine character of the sector favouring men against women.

Regarding income, farmers in China had the highest average gross household income at US$17,731 among the countries studied (FAO, 2001). Contribution of fish farming to the countries' GDP was recorded higher in India at 80% compared to Bangladesh – 15%, although the contribution of fish farming in India also varies among states with Andhra Pradesh contributing 95% while Orissa contributes only 15%. In Bangladesh, Khatun et al. (2013) found that 34% which was the highest percentage of fish farmers had average annual income of BDT 75,000 to 1,000,000 equivalent to US$740 to US$9,864 respectively. Understanding the income levels of pond fish farmers is necessary for the government to understand the position of fish farming in the sub sector for planning appropriate interventions for people in the area. This study will thus fill this gap by ensuring information on the income levels of people of Nyenga is assessed for future planning.

Majority of the fish farmers (94.3%) were involved in commercial fish production compared to only 5.7% who were involved in subsistence fish production (Jahan et al., 2015). There is an emerging commercial-scale aquaculture industry in Kenya comprising both large- and small-to medium-scale production. 61% of fish farmers had not accessed credit facilities to boost their fish farming activities while 56.4% had not accessed extension services and 80.6% were not members of fish farming groups (Ouko et al., 2022). The extension service has a vital role of increasing and improving fish production through their linkage between researchers and end-users. Olaoye et al., (2016) found that adoption of improved technologies could be easily facilitated to group of fish farmers because it is easier to demonstrate the technologies to a group than to an individual.

Regarding the stocking density for ponds and cages, the average stocking density was 3665 fish per pond/cage. Fish farmers had a minimum of 1 pond/cage and a maximum of 195 ponds/cages. The average number of pond/cage ownership was 8 ponds/cages. There was great variation in the size and number of fishponds and cages between fish farming systems within the study sites which was explained by existing conditions on each farm including the nature of soils, climatic conditions, availability of labors, building materials, investment capital, and geographical location. This was in line with previous findings about pond-based fish farming in Kenya, where the majority of smallholder farmers had a minimum of 1 pond to a maximum of 60 fishponds (Obwanga et al., 2017). Fish farmers sourced their fish feeds on an average distance of 52.52 km from the fish farms. The study also found that fish farmers were feeding their fish on average twice a day.

2.2 The level of awareness on water resource use and safety practices among pond fish farmers

In Pakistan, Muddassir *et al.,* (2019) studying awareness and adoption levels of fish farmers regarding recommended fish farming practices found that most of the population (90%) had knowledge of basic fish farming practices while about half population knew the technicalities of quality production as they relate to water and soil quality management and a half of the study population had adopted technologies. About 100% fish farmers were aware of rice powder which had an adoption rate of 96% attributed to be an integral part of the feeds. The farmers believe that failure to include rice powder in the feeds would result in small sized fish. Farmers were also largely knowledgeable of the maize gluten – 90%, fish mean and vitamins and minerals mix – 44% and 46% respectively which had an adoption rate of 12% and 7%. A study of this nature has not been conducted in Buikwe and thus whereas the levels of awareness on water resource use and safety in Pakistan is known, such study has not been done in Nyenga and being a fish farming community, conducting this study will help the government understand the levels of awareness to improve the farming conditions in the area. Besides, this data was collected using interviews contrary to this study which combines both questionnaires and interviews.

The farmers were aware and had adopted the recommended water application practices in fish ponds, although they had limited knowledge on fish diseases (Muddassir et al., 2019). The farmers also had poor fish farming extension services which implied limited knowledge of the sector and were uncertain of the fish market. The situation regarding this is unknown for Nyenga division, and conducting this study was intended to fix this gap by assessing the awareness levels of the farmers on water management and safety practices.

In a study of 300 farmers Kazal *et al.,* (2020) found that the farmers did not adopt all of the recommended improved farming practices which was attributed to inadequate farmer trainings, limited extension services, limited access to credit facilities and uncertainty of whether adoption would improve profitability of the business. The adoption levels of the farming practices in Nyenga division have not been studied and this study was aimed at understanding the levels of awareness among the farmers for better planning at the district and central government levels.

2.3 Biophysical parameters of water resources at the pond inlets, inside and outlets

The biophysical parameters that are of interest for this study and shall thus be reviewed are: Total dissolved solids (TDS), pH, temperature, alkalinity and biochemical oxygen demand (BOD) and dissolved oxygen (DO), turbidity, mineral concentration - Phosphates (PO43-), Nitrates (NO3-) & Ammonia.

Total Dissolved Solids denotes the number of dissolved solids in water and signifies the inorganic pollution load of a water system (Usha *et al.,* 2008). Total dissolved solids (TDS) measures of the combined inorganic and organic substances dissolved in water. It is also related to the electric conductivity of water thereby serving as an indicator of changes in water quality (Torrans, 2008). It should be noted that changes in the amount of TDS can be detrimental to fish life because of the effect on the flow of water in and out of the organism cell. Concentrations of TDS need to be kept to moderate levels as too high or too low concentrations are known to cause death of fish and the recommended amounts is 400ppm for freshwater fish ecosystems (Torrans, 2008). Similarly, the Environmental Policy and Planning, Department of Environment and Heritage Protection (2013) also stipulates the acceptable range of TDS for aquaculture as 20 – 450 mg/L while WHO (2003) puts the acceptable range at 500 mg/L.

Dissolved oxygen (DO) is probably the single most important water quality factor for pond owners. Oxygen is needed for the survival of fish and other aquatic organisms and this is a measure of the suitability of the ponds to support life in water (Torrans, 2008). Oxygen dissolves in water at very low concentrations measured in parts per million (ppm) and most ponds rarely have DO of more than 10ppm. Oxygen in water often comes from algae and other plants in water through a process of photosynthesis.

Biochemical Oxygen demand which is a measure of the quantity of oxygen used up by microorganisms during the process of decomposing the readily degradable organic matter in the water. It is also an indirect measure of the organic matter content of freshwater ecosystems (Torrans, 2008). The value of BOD changes over time and high BOD levels is known to cause stress among the farmed fish leading to death.

Alkalinity - is a measure of the total concentration of bases in pond water, - carbonates, bicarbonates, hydroxides, phosphates, and borates, and is expressed in ppm calcium carbonate. These bases through the react with and neutralize acids and eventually buffers changes in pH. The ideal pH of well buffered water ranges between 6.5-9 (Sipaúba-Tavares *et al.,* 2017). However, among these, the most common and important components of alkalinity are carbonates and bicarbonates. Ideal alkalinity in well-established ponds is about 100ppm, although figures ranging from 50 to 200 are in an acceptable range. With low alkalinity, any slight amount of acid can cause a substantial change in the pH. Alkalinity values which are higher than 300 ppm although harmful, often have less adverse effects on fish life, except that it can cause some commonly used chemicals such as copper sulphate to be ineffective.

pH - Alkalinity determines the initial pH of the water and adding or removing carbon dioxide alters the pond pH (Tucker, 2000). The fertilization in ponds ultimately increases water pH because of rise in growth of planktons which eventually uses up carbon dioxide. Other factors that increase water pH are: water hardness, industrial discharges, algal blooms, detergent effluents, respiration and oxidation of sulphides in sediments and carbonic acid from decomposed matter (Tessema *et al.*, (2014) in Mbuthia (2020). Note that pH of most natural waters is between 6.0 and 8.5, although dilute waters with high organic content. However, it can be even higher in eutrophic, ground water and salt lakes (Hulyal & Kaliwal, 2011) Mbuthia (2020).

Nutrients - Phosphorus and Nitrogen – should be well understood concerning their sources as their existence is related to the availability of algae and other plant life (Sipaúba-Tavares et al., 2017). Phosphates and nitrates are known to accelerate growth of water plants and animals. The decomposition of this matter is detrimental to the fish and other animal life in water by affecting light penetration, causing smell and fish mortality.

Ammonia – is another biophysical parameter that will be of interest for this study with an effect on pond water quality. Ammonia can exist in two forms: un-ionized ammonia (NH3) and ionized ammonia and ammonia if of interest for this study because of it is extremely toxic to fish life and is the predominant form of ammonia when pH is high (Sipaúba-Tavares et al., 2017). Less than 10% of the ammonia will be the toxic un-ionized form when water pH values are lower than 8 and is more present in warmer water than in cold water.

Turbidity which is another parameter of interest is the measurement of water clarity and level of transparency of water. Presence of suspended matter such as algae, plankton, sewage and silt among others are known to cause water to look cloudy (Sipaúba-Tavares et al., 2017). These substances affect light penetration in the water by scattering and absorbing light rays. Highly turbid water appear cloudy and thicker and low turbid water appear more clearer allowing more light penetration to the deeper water columns. Therefore, an increase in suspended particles per unit volume of water. Turbidity is measured in Nephelometric Turbidity Units (NTU) or Formazin Nephelometric Units (FNU). Whereas NTU represents turbidity readings captured using a white light at a 90-degree detection angle, while FNU is the correct unit when using an 860 nm light (near IR) with a 90-degree detection angle.

Chamberlin (2015) discovered, from fishpond effluent management study that dissolved oxygen, pH, ammonia, and nitrite, hydrogen sulfide, redox potential, sediments, phytoplankton, and bacterial counts are fishpond parameters that should be monitored. Depending on the stocking density, the concentration of materials, suspended solid and oxygen demanding subsistence may vary.

During the harvest time, the water in ponds is drained and the nutrients, suspended solids and BOD are the highest in discharged water. Solid matter, mainly mixture of uneaten feed, faeces, phytoplankton colonizing bacteria and dissolved matter such as ammonia, urea carbon dioxides and phosphorus are the major constituents of the effluents of fish farms (Macintosh, and Philips, 1992). A very high nutrient load can be expected in effluents during harvesting, draining and cleaning of ponds, because additional discharge of material previously bound to sediment and particulate in matter.

The biophysical parameters of water have been assessed for various fresh water ponds at the inlet, middle and outlet, for studies conducted in various parts of the world. The analysis reveals varying levels of the different biophysical parameters. It should therefore be understood that although the biophysical parameters differ from pond to pond and water body to water body, their conditions are determined by a host of factors, including but not limited to; type and size of the ponds, nature of activities taking place upstream and in the entire catchment of the fish ponds, nature of fish feeds, amount of feeds, management of the ponds, and knowledge of the pond management team including disposal of pond effluents. Nevertheless, such studies have not been conducted in Nyenga division and the purpose of this study was to assess the biophysical parameters of earth ponds in Nyenga division to ascertain the conditions of pond waters in terms of Total dissolved solids (TDS), pH, alkalinity and biological oxygen demand (BOD) and dissolved oxygen (DO), turbidity, mineral concentration - Phosphates (PO43-), Nitrates (NO3-) and Ammonia.

2.4 Effect of pond effluents on the water quality in streams

Establishment of aquaculture projects need to put into consideration factors beyond the project site to encompass the entire watershed (Boyd, 1990) due to the fact that activities in the watershed have bearing on the success of the aquaculture project (Boyd, 1995). Degradation of surrounding water quality will be faster unless proper water quality management techniques are implemented in the ever-increasing aquaculture system (Boyd, 1995).

Wastes from fish farms comprise mainly nitrogen derivatives such as nitrite and ammonia which are harmful to fish (Green, et al., 2001). Nitrite is known to hinder the oxygen carrying ability of haemoglobin, resulting in the oxidation of haemoglobin to methaemoglobin (Carnago and Alunso, 2006). Stephen and Farris (2004) noted that high ammonia levels can result into blood ammonia intoxication of fish leading to death, and damaging of downstream communities in streams where the discharges end up. Elevated ammonium levels lead to an ionic imbalance in the blood and acid-base distribution in the systems of fish (Twitchen and Eddy, 1994). The composition of waste water, nitrate and ammonia levels in Nyenga division and associated effect is not known since no study of this kind has been conducted in the area. This study was proposed to analyze the effects of pond effluents on the water quality in streams in Nyenga division.

Continuous and uncontrolled release of fishpond effluents into the streams mainly from land-based fish farms affect the aesthetic value of the stream environment (Akinrotimi, et al., 2009) evidenced by rotten smell. The discharge from the ponds can increase occurrence of disease-causing organisms that arise downstream from the affected areas. Additionally, increase in anthropogenic activities around the fish farming enterprises are known to alter habitat thereby affecting ecosystem functioning which affects the entire environment. Establishment of fish ponds have been linked to attraction of predatory species of birds, snakes, lizards and frogs coming to prey on the fish. The effect of fish pond effluents in the streams in Nyenga division is not known the results of this study was meant to assess the situation in Nyenga division and how pond effluents have affected water quality downstream.

Interruption of fish groups in the natural habitat such as streams, estuaries and wetlands is another effect of pond effluents on the receiving streams. In Nigeria, Prevost (1999) found that the discharge of pond effluents downstream was associated with changes in the natural population of a variety of species of fish in Brittanu rivers in Nigeria. This led to a reduction of the natural fish species which were unable to tolerate the pollution levels of effluents and eventually the area was colonized by pollution tolerant and foreign species of Rutilus rutilus in the trout farm influenced areas (Williams, 1992).

Eutrophication by nutrient rich fish farm effluents (Loch, et al., 1996) causing alteration in stream ecosystem. Effluents with high organic loads confirm a dominance of heterotrophic bacteria and sewage fungi suppressing the primary production (Villanueva, et al., 2000). The heterotrophic dominance is followed by an amplified primary production measured as chlorophyll. Inorganic total nitrogen and total phosphorous enrichment accounts for the rise. The heterotrophic and eutrophic alteration is frequently accompanied by a modification in the macro-invertebrates community from intolerant species upstream of the discharge point to nutrient tolerant species, signifying an ecosystem ruin (Selong and Helfrich, 1998).

Production of poisonous micro-organisms and human diseases causing vectors is another effect of pond effluents on the streams and surrounding environment. Bureau and Hua (2010) found that regular discharges of pond effluents to the streams and surrounding environment is known to kindle the making of some noxious algae such as species of cyanobacteria, dinoflagellates and diatoms. The algae production toxins can later be released in adjacent streams thereby affecting species of plants and animals, with potential to transfer human parasites and habitats of human disease carrying vectors such as mosquitoes, worms and bacteria

During fish feeding and fertilization, some feeds remain unabsorbed by fish leaving some of the feeds to remain in water. Additionally, some of the feeds end up in the water as faeces or unabsorbed and dissolved nutrients (Boyd and Tucker, 1998). This coupled with pond fertilization practices automatically increases the amounts of organic matter, suspended solids and nutrients in the ponds which in essence affects the quality of water in the streams and rivers.

Another effect is related to discharges from fish ponds comprising of mainly uneaten food, faeces, urine, slime, chemicals and medicines used in pond management activities (Bergheinm and Asgard 1996; Sindilaru, 2007). These according to Amirkolaie, 2011) can be solids and dissolved. whereas solid outflows are either able to settle or remain suspended and emanating mainly from uneaten or spilled feed and from faeces (Brinker et al., (2005), dissolved discharges are in the forms of phosphorus, ammonia, and other nutrients in the pond (Amirkolaie, 2011).

The effect of pond effluents downstream has been reviewed for various studies across the world and the results show that pond effluents affect water quality by interrupting the fish groups, changing the natural fish population, reducing fish species and eutrophication.

CHAPTER THREE

METHODOLOGY

3.1 Study location

The study was undertaken in Nyenga Division, Njeru Municipality in Buikwe district. Buikwe District lies in the Central region of Uganda, sharing borders with the District of Jinja in the East, Kayunga along in the North, Mukono in the West, and Buvuma in Lake Victoria. The District Headquarters is in Buikwe Town, situated along Kampala-Jinja Road (11kms off Lugazi). Approximately 10% of the population in the district dwell in fishery dependent communities (BDLG, 2014).

Buikwe District is one of the 28 administrative units of Uganda created under the local Government Act 1 of the 1997 (GoU/LG, 2014). By the act of parliament, the district was initially one of the Counties of Mukono district but later declared an independent district in July 2009 (GoU/LG, 2014). The current Buikwe district consists of three constituencies namely; Buikwe North, Buikwe South and Buikwe West. It has two Municipalities, five Divisions, eight Sub-Counties and two Town Councils. The district currently has over 1 million people of which, almost 68% derive their living from farming (UBOS, 2020).

Nyenga Division is one of the three Divisions, which form Njeru Municipality. It is located in the north shoreline of Lake Victoria close to the source of River Nile, one of the longest River in Africa. Nyenga Division in Njeru Municipality, is purposively selected, because of the numbers of smallholder pond fish farmers in the area. Out of the 77 fish farmers and 158 fish ponds in the entire Buikwe district (Buikwe District Local Government, 2021), Nyenga division has 53 earth fish ponds and 77 active farmers (including individual and group farmers) some of which are not yet stocked. According to UBOS, (2020), Nyenga Division has over 286,000 people of which 43% derive their livelihoods from agriculture.

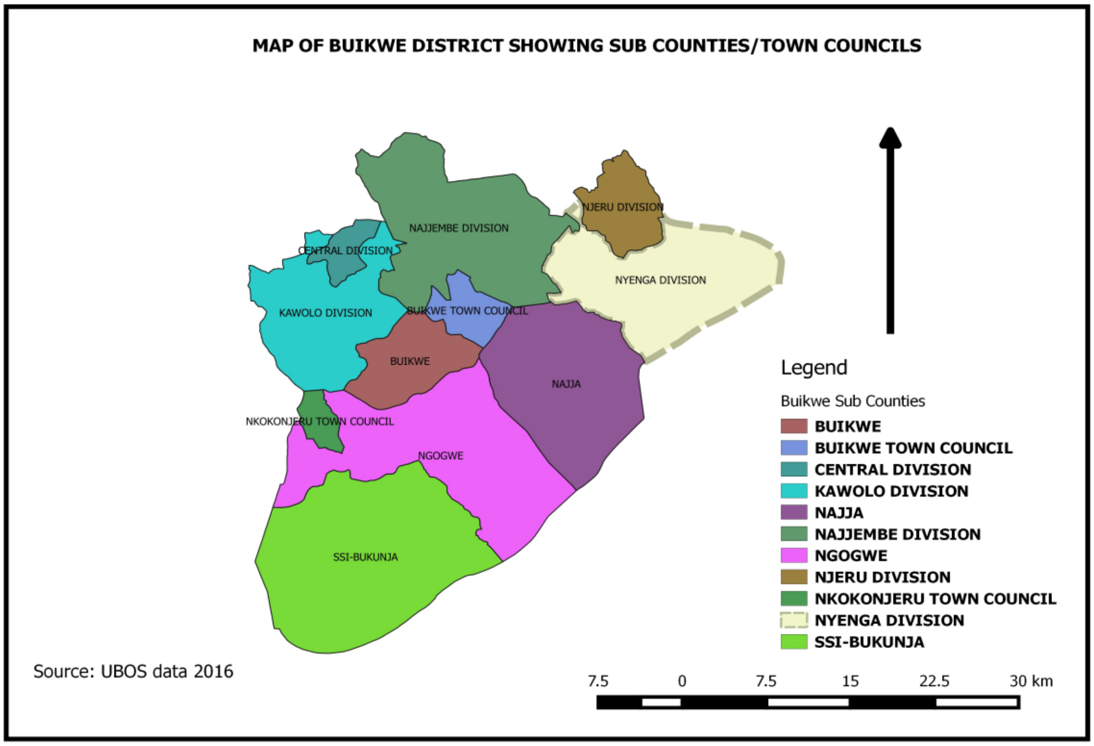


Figure 1: Map showing the study area

3.2 Topography

The northern part of the District is flat but the southern region consists of sloping land with many undulations; 75% of the land is less than 60o in slope. Most of Buikwe District lies on a high plateau (1000-1300m) above sea level with some areas along Sezibwa River below 760m above sea level. Southern Buikwe is a raised plateau (1220-2440m) drained by River Sezibwa and River Musamya.

3.3 Relief and Climate

The mean annual rainfall is 11,000mm distributed over 106 rain days, with peaks in March – May and September – November. Temperatures range between 16^{o}C and 28^{o}c throughout the year. Both relief and climate provide good potentials for investment in production of cash and food crops, horticulture and floriculture on a commercial basis. Existing commercial farms in the district also provide a good background for experience sharing for those investors who want to venture in such areas.

3.4 Vegetation

Generally, the vegetation cover is of the forest/savannah mosaic characterized by patches of dense forest (Mabira) in the south and scattered trees in shrubs and grassland of the north. Natural forests on private land and government controlled forests are a characteristic of this region. The wetland vegetation comprise of typha, miscanthus, hyparrhenia species, some cyperaceous and creepers, mostly convolvulaceae. Swamp forest tree species such as pseudospondias microcarpa, mitrogyra species, tarbementana, ficus species, bridelia micrautha and phoenix reclinata shrub vegetation include some edible plants such as psidium guava and afromonium augustifolium. The several species found in the district are utilised by the local community for food, fuel, building materials, medicines and raw materials especially for crafts.

3.5 Research design

3.2.1 Selection of study sites

Namabu, Kamuli and Nanso villages in the parishes of Namabu and Tongolo, Nyenga division were selected respectively for the study owing to the relatively large numbers of fish ponds – 53 and fish farmers (for Nyenga) in the district (Buikwe District Local Government, 2021). Of these, majority of the individual and group fish farmers have closed due to the ever-rising prices of feeds and high costs of maintaining the ponds (Pers. Communication, Nyenga Division Agricultural Officer, November, 2022; Netherlands Enterprise Agency, 2022).

In Namabu village, there are six (06) earth fish ponds owned by Namabu village fish farming development group and four (04) ponds individually owned, while in Nanso there are two (02) fish ponds owned by Nanso village fish farming group and five (05) individually owned ponds. Whereas Namabu fish farming development group has 20 members, Nanso group has 50 members (See table 1).

Table 1: Fish farming groups, Number of ponds and farmers in Nyenga Division

Group Name	**Number of earth ponds**	**Number of farmers**
Namabu village fish farming development group	06	20
Nanso fish farming development group	02	50
Kamuli	02	12
Individual earth fish pond farmers	09	05
Total pond/farmers	**19**	**87**

Source: Nyenga Division Report, 2022 and Pers. Communication with Division Agric. Officer

Because of the limited number of fish ponds (173) in entire Buikwe district and Nyenga (53 where 19 are earth ponds while 36 are cage ponds) (Buikwe District Local Government, 2021), all the 87 pond fish farmers in Nyenga division were studied to achieve the desirable level of precision. In addition, the district and sub county officials comprising the Nyenga division agricultural officer and Buikwe district fisheries officer participated in the study to obtain key information on aspects of interest to the study yielding 87 participants in the entire study, and thus all the participants were purposively selected owing to their involvement in fish farming.

Using entire population for small populations is recommended as one of the sample determination approaches in research. Ajay & Micah (2014) note that whereas this approach is disregarded by most researchers studying larger populations due to huge costs of reaching every element in the populations, it is appropriate for studies involving smaller populations of 200 individuals and below. Using this approach gives the researcher an opportunity to obtain data on every individual which in essence avoids the sampling error (Ajay & Micah, 2014).

Using simple random sampling 08 fish ponds were studied out of 19 earth fish ponds in the division because they were considered adequate for this study and these improved data quality and data representativeness. This was done by writing names of all the fish ponds on a piece of paper after which they were thoroughly mixed and 08 papers picked.

The biophysical parameters of interest for this study include: Temperature, Water pH, DO (Dissolved Oxygen), Electrical Conductivity, BOD (Biological Oxygen Demand), Turbidity, Total Dissolved Solids (TDS), Minerals (Phosphates (PO_4^{3-}), Nitrates (NO_3^-) and Ammonia (NH_3)). These were selected with the guidance of the area Local Council 1 chairpersons and the division agriculture officer.

3.2 Data collection methods

Data on biophysical parameters was collected using a combination of water collection equipment in the forms of sterile bottles, while social economic data was collected using questionnaires, key informant interviews and focus group discussions.

3.2.1 Water Sample collection and sampling

Water samples were drawn using sterile 500 ml bottles from five (08) functional earthen fishponds in Nyenga Division, Buikwe district. For quality control, each of the bottles was labeled pond 1(I/L), 1(M), 1(O/L); 2 (I/L), 2(M), 2(O/L), 3(I/L), 3(M), 3(O/L). The process was repeated for all other ponds taking into account the group and village names, to ensure the bottles are not mixed which would eventually alter the results. Before analysis, raw water samples were filtered through 0.45-μm filters intended to remove particulate matter and reduce the sample degradation.

Water samples at the inlet was collected at between 0.10-0.20 m depth, 0.5-1m in the middle of the pond, and 0.20-0.50m at the outlet. This was done due to the varying depths of water at the inlet, inside the pond and at the outlet and the varying biophysical parameters. Ward and Harr (1990) who recommends that in still and flowing water, samples should be collected at multiple sites and multiple depths because of variations in physical, chemical and biological properties at different water layers. However, during water sample collection, data collectors should avoid obtaining samples from 1-2 cm of the surface layer as this column often contains particles of dust and oils (Wilde, 2006).

Water at different points (inlet, mid and outlet) was sampled owing to the variations in water quality characteristics and collecting at varying points improves data quality in terms of varying physical and chemical properties of the fish ponds (Wilde, 2006).

The samples were collected during the morning hours between 8:00 am to 12:00 moon. This is based on the recommendation of Boehm et al. (2002) and Kwasi et al. (1999) who contend that water samples should be collected in the early morning before sunlight has had a chance to reduce concentrations of biochemical and physical elements. Effort should be made to avoid collecting samples during or immediately after rain (Kwasi, Keith, & Nigel, 1999).

The study considered both ponds with adult and young fish and both newly stocked and existing ponds. Both small and large ponds were studied regardless of the shape of the ponds. This was aimed at assessing whether there are variations in the water quality.

Since data was collected during the rainy season, this effect will be accounted for through keen observation of runoff and sedimentation matter that may be contained in the water samples at the inlet. Besides, the researcher ensured data is collected on non-rainy days of at least 04 days interval. The effect of feeds whether floating or sinking was accounted for in the samples collected inside the fish ponds when compared against the water samples collected from the inlet and at the outlet. Boyd (2004) notes that uneaten feed and metabolic wastes pollute pond water and deteriorates its quality. Although ponds can assimilate wastes through mechanical aeration, not all feed can be assimilated due to limitations in the functioning of the ponds. As a result, this leads to growth of planktonic and benthic algae especially when there are large concentrations of ammonia and phosphate. Additionally, the effect of the surrounding activities was determined from water samples collected from the various sampling points especially at the inlet for the five ponds that were studied.

After collecting pond water samples, they were stored in a cooler box to maintain it at similar temperatures and avoid contaminants from breaking down during transit. The fish pond water samples were transported to Makerere University chemistry laboratory for testing.

3.2.2 Data collection instruments for socio-economic data

Questionnaire survey - Open and closed ended questions pertaining to socio-economic characteristics of pond fish farmers, level of awareness on water resource use and safety practices among pond fish farmers, and effect of pond effluents on the water quality in the stream was administered to respondents. This is in relation to the argument by Chandan (1995) that questionnaire administration as one of the methods of data collection involves the researcher preparing a set of questions pertaining to the field of enquiry. Neuman (2003) also stresses that to learn what is important to the respondent and how he/she thinks, open ended questions are the best to get the answers. Kakooza argues that a questionnaire is often used in data collection because it is cheap and convenient for gathering information in a relatively short period of time. Mixing of open and closed ended questions enables periodic probes which are helpful in revealing the respondent's reasoning.

Interview guides – were conducted in the form of face-to-face interviews with the respondents to generate detailed and first-hand information. This involved the researcher personally interacting with the selected respondents with a set of pre-determined questions that they were required to respond one by one basis. Interview method was applied to the key informants believed to have adequate information on the subject matter – leaders of farmer groups, district fisheries officer, sub county agricultural officer and Bugungu prison farm supervisor(s). The key part of interviewing is that the researcher (the interviewer) needs to understand the meaning of the participants' responses (Kvale, 1996) so as to discover their views of specific issues (deMarrais, 2004). Babbie (1983) argues that interviewers can also provide a guard against confusing questionnaire items if the respondent clearly misunderstands the intent of a question or indicates that he or she does not understand, the interviewer can clarify matters, thereby obtaining relevant responses. Through probing, the interviewer can generate better focused answers from the respondents which guards against irrelevant and shallow responses (Wellington, and Szczerbinski, 2007). Finally, in-depth interviews facilitate the development of insights into respondents' perceptions (Hardy, 2001).

Observation checklists were used to generate data on socio-economic characteristics of pond fish farmers, level of awareness on water resource use and safety practices among pond fish farmers, and effect of pond effluents on the water quality in the stream. While moving around, it was easier to make an observation of the ways in which pond farming has altered the natural environment, while also observing aspects of levels of awareness on water resource use and safety practices among fish farmers. Using a checklist, observed aspects will be noted down which was eventually used during the report writing.

The data collection instruments (questionnaire and interview checklist) were developed and pretested on 10 respondents in January 2023 to assess their feasibility in collecting the desired information. Corrections were made and the final questionnaire and interview checklist were printed.

3.3 Data analysis

3.3.1 Laboratory Analysis

Pond water samples were analyzed for physical and chemical water quality parameters as put forward by Eaton (2005) in Orobator et al., (2020). The water parameters were measured as follows: Total Dissolved Solids (TDS) by standard methods 2540 B, pH by a multipurpose pH meter, alkalinity by titration method and biological oxygen demand (BOD) and dissolved oxygen (DO) using standard titrimetric method, turbidity by nephelometric method using a turbid meter. To determine concentrations of minerals -Phosphates (PO43-), Nitrates (NO3-) & Ammonia (NH3) in the water samples, an atomic absorption spectrophotometer (AAS) were used.

3.3.2 Statistical Analysis

This study used excel and SPSS software packages to analyze the data owing to their flexibility, convenience in accessing files, viewing workbooks, and a variety of command tools that are needed especially for this specific type of study. Descriptive statistics were generated and viewed using graphs and tables. The results from the analysis were compared with permissible values according to the World Health Organization (2009) to determine the status of the examined physical and chemical water parameters.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Socio-economic factors of smallholder pond fish farmers in Nyenga Division

The socio-economic factors of smallholder pond fish farmers in Nyenga were studied and the results are presented below.

Descriptive Statistics

4.1.1 Independent variables

The independent variables for this study were determined and descriptive statistics obtained as in the table below.

Table 2: Independent variables

Variables	Frequency	%	Mean	Min	Max	Stand. Error	Stand Dev.
Gender							
Male	55	63				0.52	0.49
Female	32	37					
Age							
18-30	12	14	47	23	57	0.10	0.94
31-40	16	18					
41-50	38	44					
>50	21	24					
Education							
Bachelor's degree	5	6	7.30	3.00	9.00	0.15	1.41
Certificate	4	5					
A'level	5	6					
O'level	23	26					
Primary school	41	47					
Never went to school	9	10					
Village							
Kamuli	20	23	2.25	1	3	0.87	0.810
Namabu	25	29					
Nanso	42	48					

Gender of Respondents

Both males or (men) and or (women) females participated in the study. 63% compared to female who were only 37%. This could have resulted from the hard tasks involved in fishing or the patriarchal systems predominant in most of Uganda’s communities that exclude women in almost all sectors. Fish reared across all the villages of Nanso, Namabu and Kamuli was tilapia owing to the high price of this fish in the market. The activities of fish farming is divided among the farmer groups in terms of feeding, cleaning and caring for the pond and feeds are bought by money pooled by all the farmers. All farmers in a group pool money on a monthly and quarterly basis which is used to buy feeds. On fishing days, all farmers converge at the pond and participate in the fishing process, count the number of fish caught. Most times the fish mongers are aware of the fishing programs and they are available on fishing days including members of the community who need fish.

Age of Respondents

Majority of the respondents 44% were aged 41-50 years compared to the least 14% who were aged 18-30 years. There was no statistical difference between the age of respondents and source of income implying that people of all age groups studied, obtained income from almost similar sources (r_s=0.34; p>0.05) there was no peculiar age group that obtained income from engaging in only one activity, but rather all obtained income from various income sources. Contrary, in a study done by Muddassir et al. (2019) majority of the participants (70%) belonged to the age group - 30–50 years, followed by those aged 50 years and above who were 16.03% and the young age group (up to 30) who were 14.04% of total sample population. Nevertheless, the engagement in fishing of people aged 41-50 years could have resulted from the vast experience in the sector and

Education level

The education of participants was studied and majority of the people who participated in the study were educated to primary school level (47%) and the least (5%) had certificate level of education which indicates low schooling levels in the study area and possible reason most of the participants were involved in the informal sector, which could be attributed to low willingness to attend school due to poor attitude about education, with more time allotted to engaging in business for short term gains. In a different study conducted by Muddassir et al (2019) it was found that 29% of the respondents were illiterate, while the rest – 71% were literate with majority educated to primary, secondary and high school levels.

People educated up to university degree earned more income than those with low levels of education which can be attributed to the better business planning and better fish ponds management and associated returns. However, a slightly higher number of people with primary schooling also earned higher incomes in the ranges of 500,000 – 1,000,000 and >1,000,000. A test of statistical significance Spearman correlation was run and the results indicated that there was a statistical difference between education and income $r_s = 0.171$; $p<0.05$.

Village of Respondents

The respondents who participated in the study were from three villages and the majority were from Nanso village 48% compared to 23% who were from Kamuli village. The selection of the participants was based on the number of fish farmers from each of the villages. Households in Nanso earned more average household income than other villages. For instance, out of 87 participants, 33 people from Nanso earn income of 100,000 – 500,000 UGX compared to 25 from Namabu and 20 from Kamuli. Similarly, it is only in Nanso where households earned income of more than 500,000 UGX. This was confirmed by the spearman Correlation Coefficient ($R = 0.329$) and $p<0.05$.

4.1.2 Dependent variables

The dependent variables in the socio-economic characteristics of the respondents were: source of livelihoods, other livelihood sources, average monthly income and years spent in fishing business as in the table below.

Table 3: Dependent variables – spearman correlation coefficient

Correlations

			Average monthly income	Years spent in fishing	Source of livelihood	Additional source of income
Spearman's rho	Average monthly income	Correlation Coefficient	1.000	.053	-.201	-.085
		Sig. (2-tailed)	.	.626	.062	.434
		N	87	87	87	87
	Years spent in fishing	Correlation Coefficient	.053	1.000	-.123	.022
		Sig. (2-tailed)	.626	.	.258	.836
		N	87	87	87	87
	Source of livelihood	Correlation Coefficient	-.201	-.123	1.000	.356**
		Sig. (2-tailed)	.062	.258	.	.001
		N	87	87	87	87
	Additional source of income	Correlation Coefficient	-.085	.022	.356**	1.000
		Sig. (2-tailed)	.434	.836	.001	.
		N	87	87	87	87

**. Correlation is significant at the 0.05 level (2-tailed).

Source of livelihood

The source of livelihood for the participants were studied and it was found that the biggest livelihood source is fish farming which takes up over 90% of the people who participated in the study, with less than 10% obtaining their livelihoods from other sectors. This is of course due to the fact that the target participants for this study were fish farmers. The low engagement with government and other non-government sectors could be explained by the low education levels (with less than 20% of the population educated up to the ordinary level) prevalent among most fishing communities in Uganda. Using spearman's rho, analysis showed that there is no statistical difference between source of livelihood and other factors: average monthly income ($p=0.62$), years spent in fishing ($p=0.258$), source of livelihood ($p>0.05$), except additional source of livelihood ($p<0.001$). These findings do not differ from the study done by Muddassir et al. (2019) where 46% of the fishing community obtained their livelihood from fish farming, while 7% obtained their livelihoods from crop growing and animal rearing (Muddassir et al., 2019).

Additional household income sources

Other income sources for the study participants were studied and crop growing topped the list of other sources of income with 60% of the participants in the sub sector, while the rest were equally distributed in animal rearing (17%), offering casual labour (10%), employed in private company (10%) and the least (2%) working for NGOs. This indicates that although fish farming is a major activity in Nyenga Division, households are equally involved in other sectors for their livelihoods to shelter themselves from the effects of fluctuation in fish farming business. Spearman's rho was conducted and the results revealed that there no statistical significance between additional sources of income and average monthly income (p=0.434), years spent in fishing (p=0.836), except source of livelihood (p=0.001).

Average monthly income

It was important to understand the average monthly household incomes as a means of assessing the welfare of the participants and assess the relationship between household incomes and other variables. Most households – 51% earned an average monthly income of <100,000 UGX and majority – 56% had spent > 5 years in the fishing business implying that majority of the households engaged in fish farming live on less than USD$1 per day, in case their only source of income is fish farming. Spearman's rho correlation coefficient was conducted and the results indicated that there was no statistical relationship between average monthly income and all other variables; years spent fishing (p=0.626), source of livelihood (p=0.62) and additional source of income (p=0.434).

Years spent in farming

It was important to investigate the number of years participants had spent in fish farming so as to determine the relationship between years spent in farming against incomes and knowledge of farming among others. Majority 56% of the participants had spent over 5 years in fishing compared to the least 5% who had spent less than 5 years in fishing. Spearman's rho test revealed that there is no statistical relationship between years spent in fishing and average monthly income (p=0.626), source of livelihood (p=0.258), and additional source of income (p=0.836).

A t-test statistical analysis was conducted to test the hypothesis that "*there is no variation in socio-economic characteristics of pond farmers in Nyenga Division*" and the results were $p<0.05$ which is statistically significant. As a result, the null hypothesis is rejected and the conclusion is that there is variation in the socio-economic characteristics of pond farmers in Nyenga.

4.2 Objective two: Level of awareness on water resource use and safety practices among smallholder pond fish farmers in Nyenga Division

The second objective of the study was to determine the level of awareness on water resource use and safety practices among smallholder pond farmers in Nyenga Division. This was achieved by first addressing the level of awareness on water resource use and later presenting on the safety practices among smallholder pond farmers. The level of awareness on water resource use was measured using seven factors or statements that required respondents either agree or disagree answer to each of the statements that were used to measure the level of awareness. The agree or disagree answers were measured using percentages as opposed to frequencies as presented in the table above.

Table 4: Level of awareness on water resource use and safety practices

Level of awareness on water resource use	Agree/Yes N=87	Disagree/ No N=87
I know the use of artificial fertilizers in the pond affects the water quality	89	11
I know it is not right to discharge effluents from the pond to open places and streams around the pond	74	26
I only apply feeds that can be completed by the fish	54	46
Use of herbicides to clear weeds around ponds destroys the environment	82	12
I have knowledge about diseases that affect fish	57	43
I have knowledge about biophysical parameters that affect water quality	53	47
Fish can grow well when the quality of water is good	97	3

Source: Field data

Note: Total represent percentages

Of the measures of the level of awareness on water resource use, the majority of the participants (97%) indicated that fish grow well when the quality of water is good which is an indication of the high level of knowledge by the community on water resource use. The community of Nyenga are aware that when the quality of water is bad, the fish cannot grow well. However, the findings revealed that a proportionately smaller number of the fishing community – 53% had knowledge about the biophysical parameters that affect water quality which is a significant factor as far as water resource use and pond fish farming is concerned. The biophysical parameters of water ecosystems are of paramount importance to fish farmers because without such knowledge it becomes almost impossible to manage pond fish farming.

Chi-square and Cranmers' V tests of relationship were run for each of the variables measuring the level of awareness against the respondents' socio-economic characteristics. The statistics were only significant for gender and using artificial fertilizers in the pond affects the water quality; and I know it is not right to discharge effluents from the pond to open places and streams around the pond ($p<0.05$), with more men knowing it is not right to discharge effluents in open places and streams than women. The fertilizer used by the farmers were chicken droppings, cow dung and on a limited extent NPK. Tests between gender and other measures of the level of awareness of water resource use were not significant ($p>0.05$) including; I only apply feeds that can be completed by the fish; use of herbicides to clear weeds around ponds destroys the environment; I have knowledge about diseases that affect fish; I have knowledge about biophysical parameters that affect water quality; fish can grow well when the quality of water is good. This revealed that the level of awareness on water resource use was least related to gender and being a female or male did not influence the respondents' views regarding knowledge of the water resource use.

The level of education was related to four out of seven variables that were used to measure awareness on water resource use ($p<0.05$). These included; whether respondents knew it is not right to discharge effluents from the pond to open places and streams around the pond; I only apply feeds that can be completed by the fish; I have knowledge about diseases that affect fish; and I have knowledge about biophysical parameters that affect water quality. This implied that more educated people were more aware of water resource use and safety practices than uneducated or less educated people. The rest of the measures of awareness were not related to the level of education of the participants ($p>0.05$). This implies that although education was a factor in determining the level of awareness of water resource use, those with high levels of education and low levels of education did not differ in their levels of awareness.

There was a relationship between years spent in fishing and all the measures of awareness about water resource use ($p<0.05$) - whether the use of artificial fertilizers in the pond affects the water quality; I know it is not right to discharge effluents from the pond to open places and streams around the pond; use of herbicides to clear weeds around ponds destroys the environment; I have knowledge about diseases that affect fish; i have knowledge about biophysical parameters that affect water quality; and fish can grow well when the quality of water is good. Farmers with many years in fishing had more knowledge on water resource use and safety measures than new farmers. The findings could have been influenced by the knowledge acquired by the farmers which reveals that the more the years spent in an activity the more the participants were aware about the water resource use.

Age and village of the respondents were not related to their views regarding the measures of awareness about water resources use ($p>0.05$). All farmers' knowledge levels on water resource use did not differ across the three villages studied and among 87 respondents who participated in the study. This could have been influenced by factors such as passion and interest rather than age and village. In a related case, Muddassir et al., (2019) found that there was a highly significant association between age of the respondents and their awareness level of recommended fish production practices.

Most farmers were aware about the water resource use with majority 89% aware that use of fertilizers in the ponds affect the water quality, 97% were aware that to obtain better yields, the water quality needed to be good and 82% knew that use of herbicides to clear weeds around ponds destroys the environment through pollution and killing important nutrients for the fish. The knowledge levels among the farmers could have been influenced by the relatively many years most farmers had spent in the business (>5 years). Other factors could have been the presence of the Nyenga Division team including some from the district such as Community Development Officer, the Division Agents, the Fisheries officers, and other private sector actors/staff of NGOs could have played a role in enhancing the farmers' knowledge on water resource use.

Regression analysis was run to assess whether there is a relationship between the dependent variable – using artificial fertilizer in ponds affect water quality against the socio-demographic variables (independent variables) of the participants – sex, age, source of livelihoods, additional sources of income, level of education, village, average monthly income and years spent in fishing business. The regression analyses are about whether the respondents agreed with, or have knowledge about the various statements. The analysis revealed that one of the independent variables – sex, age, source of livelihood, additional source of income, education level, village of respondents, average monthly income, years spent in fishing explain 17% of the dependent variable implying that 83% of the variation in the dependent variable is explained by other factors as seen in the model summary table (See Appendix 3.1). The analysis revealed that among the independent variables, only sex was significant $p=0.010<0.05$ compared to Age ($p=0.51$), source of livelihood ($p=0.20$), additional source of income ($p=0.46$), highest education level ($p=0.45$), village ($p=0.21$), average monthly income ($p=0.22$) and years spent in fishing ($p=0.16$) which are greater than 0.05 (See Appendix 3.2 Table of Coefficients).

Another variable for which regression analysis was conducted was "whether the respondents knew that it is not right to discharge effluents from the pond to open places and streams around the ponds". Regression analysis showed that the independent variables years spent in fishing, additional source of income, age, village, level of education, source of livelihood and average monthly income could only explain 17% of the dependent variable (R^2 =0.17) implying that 83% of the dependent variable is explained by other factors (See Appendix 3.3 Regression Model Summary). The regression analysis revealed that more people who had spent more years in fishing knew that it is not right to discharge effluents from the pond to open places and streams around the ponds ($p=0.02<0.05$). Other factors – sex ($p=0.17>0.05$), age ($p=0.24>0.05$), source of livelihood ($p=0.19>0.05$), additional source of income ($p=0.79>0.05$), level of education ($p=0.87>0.05$), village of respondents ($p=0.68>0.05$), and average monthly income ($p=0.55>0.05$) (See Appendix 3.4), did not have any bearing on the dependent variable.

Regression R-square value of 0.8 revealed that independent variables – years spent in fishing, additional source of income, age of respondents, village of respondents, highest level of education, sex, source of livelihood and average monthly income could only explain 8% of the dependent variable which implies that absence of a relationship between the independent and dependent variables since 92% of the dependent variable is explained by other factors (Appendix 3.5 Regression Model Summary). The coefficient table shows that there was no relationship between all independent variables – sex, age, source of livelihood, additional source of income, level of education, village, average monthly income and years spent in fishing ($p>0.05$) and whether fish farmers apply feeds that can be completed by fish (See Appendix 3.6 Table of Coefficients). This implies that application of feeds was not influenced by age, sex, source of livelihood, additional source of income, level of education, village of respondents, average monthly income and years spent in fishing.

Regression was also conducted to assess whether farmers are aware that the use of herbicides to clear weeds destroys the environment and an R-square value of 4% was obtained revealing that the independent variables could only explain 4% of the dependent variable indicating absence of a relationship between the dependent and independent variables (See Appendix 3.7 Regression Model Summary). This was confirmed by the coefficients table which showed that the there was no relationship between the dependent variable - Use of herbicides to clear weeds around ponds destroys the environment, and independent variables (See Table of Coefficients in Appendix 3.8).

On whether the participants had knowledge about biophysical parameters that affect water quality, the regression analysis obtained an R-square value of 0.35 (See Table of

Model Summary in appendix 3.11). These results indicate that independent variables only explained 35% of the variation in the dependent variable while 65% was explained by other factors. This revealed that only years spent in the fishing business was significantly related to the dependent variable "I have knowledge about the biophysical parameters that affect water quality ($p=0.000<0.05$) (See Table 15 Coefficients in Appendix 3.12). Therefore, the hypothesis that pond farmers are adequately aware of the water resource use and safety practices is accepted.

The dependent variable - fish can grow well when the quality of water is good was not significant for all the independent variables – Sex (p=0.41), age (p=0.09), source of livelihood (p=0.35), additional source of income (p=0.10), highest education level (p=0.36), village of respondents (0.09), average monthly income (p=0.69), and years spent in fishing (p=0.32) (See Appendix 3.14).

While these results can be true, conclusions should be made with caution. Frost (2017) argues that obtaining small R^2 does not always imply absence of relationships and significance and similarly, high R^2 values are not always a guarantee of significance of the results. This is due to multiple factors that can explain the results contrary to the variables involved.

4.3 Objective three: Biophysical parameters of water in earthen ponds in Nyenga Division.

A total of nine (09) different biophysical parameters were analyzed. The analysis was based on samples obtained from earth fish ponds in the three villages of Nyenga – Nanso, Kamuli and Namabu where groups of farmers are engaged in aquaculture as presented in table 18. The samples were taken at three different points in each of the three sites where samples were collected; at the inlet, mid-point and outlet. This was done for all the three sites except Nanso village where only one inlet and one outlet was considered for the three ponds in the area. The reason for this was that the three ponds in Nanso had same inlet and outlet and there was therefore no reason to obtain samples at each pond inlet and outlet.

The parameters obtained from the analysis of water samples were compared against the Standard Water Quality Requirements for Fish Farming as below.

Table 5: Standard Water Quality Requirements

Water Quality Criteria	Recommended Value (Range)	Source
pH	5.5-10.0	Davis (1993), WHO (2003), Stone and Thomforde (2004)
Ec	30 to 5,000µS/cm	Stone and Thomforde (2004)
DO	3-5	Das (2019)
BOD	3 – 20 mg/l	Boyd (2003)
Turbidity	30-80	Das (2019), Stone and Thomforde, 2004
TDS	0.13 mg/l 400ppm	Davis (1993) James (2000)
Nitrate (NO3)	16.9 mg/l	Schewatz and Boyd (1994)
Phosphorous	0.03-2	Das (2019), Stone and Thomforde, 2004
Ammonia	0-0.05ppm	Das (2019)

The biophysical parameters are discussed with reference to the water quality standards for fish ponds presented in the table above.

Electric conductivity (Ec) which is a measure of the saltiness of water measured in microsiemens per centimeter (uS/cm) is supposed to be in the ranges of 0 – 50,000 uS/cm, while fresh water conductivity ranges between 0 to 1,500 uS/cm (Boyd, 1979) but in some polluted waters it may reach 10,000 µs/cm and seawater has conductivity around 35,000 µs/cm and above. For this study, the Ec was in the ranges of 75 – 620, with 75 uS/cm as the minimum and 620 uS/cm as the maximum. The results conform to the World Health Organization (WHO) guidelines for drinking water which recommends conductivity levels of 700 uS/cm (WHO, 2003). The minimum EC was in the middle of pond A in Namabu village while the maximum was at the inlet of pond 3 in Nanso village. As fish differ in their ability to maintain osmotic pressure, therefore the optimum conductivity for fish production differs from one species to another. Stone and Thomforde (2004) suggested the desirable range of 100-2,000 µs/cm and acceptable range of 30-5,000 µs/cm for pond fish culture. This reveals that extent of salt and therefore conductivity in all ponds in the study locations was within the recommended levels.

The pH for the three study sites/villages in Nyenga division ranged from 6.8 to 7.5 which falls within the recommended pH values for fish ponds of 6.0 to 9.0. The least pH 6.8 was recorded in Namabu village in the middle of ponds 1, 3, Nanso pond 1 and 2 inlets, while the maximum value of 7.5 was at the inlet of pond 2 in Kamuli village. Research has it that the closer the pH is to 7.0, the more the water is favourable for fish, whereas ponds with pH less than might result in small fish sizes as it is associated with fish stuntedness, and sometimes smaller to even no fish populations in the ponds (Swistock, 2022). The results from this study thus implies that the ponds in Buikwe have ideal pH suitable for fish farming since it was closer to 7.0. However, the findings of this study are different from a study conducted in Benin by Orobator, et al., (2020) found that the pH content in pond 1 (6.39) was the only one closest to the range of values from 6.5 - 8.5 recommended by WHO (2009).

Turbidity across all the three study sites in eight (8) ponds ranged from 0 – 340 NTU with 0 values recorded at five points; i.e. the outlet of pond 2, inlet of pond 1, inlet of pond 2, and middle of pond 1 in Nanso village. Values less than 10 NTU were recorded at the inlet of Namabu village (6 NTU), outlet of pond 1 (8 NTU), middle part of pond 2 (8 NTU) and middle part of pond 3 (8 NTU) in Nanso village. The maximum turbidity values 340 NTU at the outlet of pond 3 in Namabu village.

Australian Capital Territory (2001) reports water standards pertaining turbidity revealing that water with a turbidity of 1 NTU is considered crystal clear, water at 5 NTU has a tiny trace of discolouration, and water at 100 NTU is brown and opaque (Australian Capital Territory, 2001). The standard is less than 10 NTU for rural streams and rivers and less than 30 NTU for urban lakes and ponds (Australian Capital Territory, 2001). The recommended turbidity for fish farming by the World Fish Center (Beveridge et al. 2010) is 30 – 40 cm which is approximately equivalent to 15 – 24 NTU. Typical turbidity values of >10 NTU is considered to cause short-term stress to aquatic life while values >100 NTU is considered unsafe for most aquatic life.

Total Dissolved Solids (TDS) which is a measure of chemical ions dissolved in water was in the ranges of 0 to 340 mg/l with 0 mg/l recorded at four points in Nanso village; Nanso A inlet and middle point, and Nanso 2 inlet and outlet, while the maximum point

640 was at the outlet of Namabu pond 3. According to water standards, water bodies of TDS above 1,000 mg/l are considered to be associated with water quality problem, with <300 mg/l considered excellent, 300 – 600 good, 600 – 900 fair and 900 – 1,200 poor and >1,200 unacceptable (James, 2000; Munni et al. 2013). The results therefore imply that pond water in all sites studied was good to excellent which could have resulted from the frequent water replenishment by farmers which is done after every time they catch fish from the ponds.

Dissolved Oxygen for all study sites fell in the range of 5 mg/l to 6.2 mg/l with the minimum recorded at the middle point of pond B in Namabu village and maximum values recorded at the inlet of pond 1 in Nanso village, middle point of pond A Namabu village and outlet of pond 1 in Kamuli village. The results were similar to the findings of a study conducted by Musa et al (2020) who found that DO for the fish wastewater ranged between 5.8 - 7.0 mg/L while the source water from the borehole and river had values ranging between 4.0 and 5.0 mg/L and 8.0 mg/L respectively. The recommended DO in fresh water is 5 – 11.5 mg/l (Musa et al. 2020). This implies that the DO in the studied earth fish ponds is within the recommended values, which could have resulted from the periodic maintenance of the ponds by the farmers and the financial motivation associated with better management of ponds.

Biochemical Oxygen Demand (BOD) in this study ranged from 2 – 5 mg/l. The recommended BOD for fish pond water is 0 – 30 mg/l although concentrations up to 50 milligrams per liter are sometimes allowed (Boyd, 2001). This implies that the BOD in earth ponds in Buikwe were in the recommended ranges for fish farming. Clerk (1986) reports that BOD values 2 – 4 mg/l indicates absence of pollution in water while values >5 mg/l reveals worrying pollution levels. However, studies differ on the BOD values that are appropriate for aquaculture. For instance, Santhosh and Singh (2007) recommended optimum BOD level for aquaculture of < 10 mg L-1 but the water with BOD of 10-15 mg L-1 can be considered for fish culture. On the other hand, Bhatnagar and Singh (2010) suggested the BOD <1.6mg L-1 level is suitable for pond fish culture while Ekubo and Abowei (2011) recommends aquatic system with BOD levels between and 2.0 mg L-1 clean; 3.0 mg L-1 fairly clean; 5.0 mg L-1 doubtful and 10.0 mg L-1 definitely bad and polluted.

Phosphorous (PO_4) based on the results of this study ranged from 0 – 0.35 mg/l. The typical phosphorous desirable range for surface waters is 0.01 to 2.0 mg/l while the acceptable range is <3 mg/l (Das, 2019). The findings therefore are an indication of low pollution of water in the ponds since the values were within the recommended <3 mg/l (Stone et al., 2013).

Nitrate (NO_3) in the study ranged from 0.03 to 0.162 mg/l. The desirable limit is 0 – 2 mg/l while the acceptable limit is <4 mg/l (Ehiagbonare and Ogunrinde, 2010). This implies that the findings of this study are within the desirable and recommended limit (Meck, 1996; Gebremichael & Fantahun, 2019). Nitrate is relatively non-toxic to fish and is only of concern when concentrations are exceedingly high (> 90 mg/L) (Austin et al 2016). A nitrate concentration from 0 to 200 mg/L are acceptable in a fish pond and is generally low toxic for some species whereas especially the marine species are sensitive to its presence. According to Stone and Thomforde (2004) nitrate is relatively nontoxic to fish and does not cause any health hazard except at exceedingly high levels (above 90 mg/L). Santhosh and Singh (2007) described the favourable range to be 0.1 mg/L to 4.0 mg/L in fish culture water.

Ammonia for this study ranged from 0 – 0.95 mg/l. In this study, 0 mg/l was recorded in the middle part of pond 1 in Namabu, and values that fell in the recommended values of 0.02 – 0.05 were recorded in the middle part of pond 1, Kamuli and middle part of pond 2, Namabu village. Ammonia in other fish ponds was above the recommended values with negative implications for fish. It is recommended that ammonia in fish farming should be 0.02 – 0.05 mg/l (Das, 2019). Ammonia in the range of >0.1 mg/l is reported to cause gill damage in fish and thus the values should be below 0.1 mg/l. Ammonia above 0.1 mg/l is also known to destroy mucous-producing membranes, lead to poor feed conversion, reduced fish growth, and reduced disease resistance (Tumwesigye et al., 2021). According to Kausar and Salim (2006), 0.1 to 0.3 mg/L of ammonia is sub lethal while 0.6–2.0 mg/L is lethal. MAAIF (2018) notes that the maximum limit of Ammonia concentration for aquatic organisms to be 0.1 mg/L.

However, 0.2 mg/L total unionized Ammonia is acceptable and un-ionized Ammonia of less than 0.05 mg/L is safe for many tropical fish species. The high concentration of Ammonia in this study could be associated with over-feeding of the fish, irregular de-silting of ponds, and nutrient enrichment from agricultural fields (runoff).

To further understand the biophysical parameters of earth fish ponds, additional statistics average mean Ec, Average mean pH, standard deviation of Ec, standard deviation of pH and standard error, minimum and maximum Ec and pH were computed and presented in Table 6 below.

Table 6: Average Mean Ec, pH, Standard Deviation of Ec, pH and standard error

	Pond	**Average mean Ec (µS/cm)**	**Average mean pH**	**STDEV Ec**	**STDEV Ec**	**Standard error**	**Max Ec**	**Min Ec**	**Max pH**	**Min pH**
Kamuli	Pond 1	144	7.07	14.36	0.29	8.29	552	110	7.23	6.93
	Pond 2	170	7.23	22.94	0.25	13.25				
Namabu	Pond 1	110	6.93	48.01	0.12	27.72				
	Pond 2	114	7.13	43.92	0.23	25.36				
	Pond 3	115	6.93	43.62	0.12	25.18				
Nanso	Pond 1	516	7.00	71.60	0.20	41.34				
	Pond 2	481	7.07	119.53	0.25	69.01				
	Pond 3	552	7.07	59.43	0.21	34.31				

Source: Field data

The average mean Ec for 8 ponds in Kamuli, Namabu and Nanso ranged from 110.33 – 552 (µS/cm) with the lowest values recorded in pond 1, in Kamuli village and the highest value recorded in pond 3 in Nanso village which was within the standard values of 30 – 5,000 mS/cm according to Stone and Thomforde, 2004. The average mean pH was 6.93 – 7.23 which is in the standard range of 5.5-10.0 and all the minimum and maximum pond average mean values were in Kamuli village of pond 1 and pond 2 and pond 3 of Namabu village respectively.

The standard deviation for Ec and pH varied from 14.36 to 119.53 and 0.12 to 0.29 respectively, with pond 1 in Kamuli having the lowest Ec values and highest values in pond 2 in Namabu village and pond 3 Namabu village. The lowest pH values were in pond 1 of Kamuli village and pond 3 of Namabu village, while the highest values were in pond 1, Kamuli village. The standard deviation error for the various ponds varied from 8.29 in pond A of Kamuli village to the highest 69.01 in pond 2 of Nanso village. The maximum and minimum Ec were 552 and 110 respectively while the maximum and minimum pH were 6.93 and 7.23 respectively.

4.3.1 Comparison of the biophysical parameters of earthen fish ponds across the sites of Kamuli, Namabu, and Nanso villages.

A comparison was made of the biophysical parameters of earthen fish ponds across all the three villages in which data was obtained. The data is presented for each of the villages indicating the variations in the variables (See Tables 7 and 8 and Figure 2).

Table 7: Biophysical parameters of earthen fish ponds in Kamuli village

Parameters	Kamuli village						
	Pond 1			Pond 2			Standard Water Quality Values
	Inlet	**Mid**	**Outlet**	**Inlet**	**Mid**	**Outlet**	
Ec	160	138	133	159	196	154	30-5,000µS/cm
pH	6.9	6.9	7.4	7.5	7.2	7	5.5-10.0
DO	6	5.8	6.2	5.9	5.6	5.4	3-5
BOD	3	2	3	3	3	3	3-20 mg/l
TDS	80	69	66	79	98	77	30-400 mg/l
Turbidity	24	42	20	22	84	22	30-80
PO4	0	0.04	0.01	0	9.13	0	0.03-2
N03	0.09	0.11	0.11	0.1	0.15	0.14	16.9 mg/l
Ammonia	0.14	0.04	0.08	0.13	0.12	0.06	0-0.05 ppm

Source: Field data

In Kamuli village, two ponds were studied and among the parameters studied, pond 2 had the highest Ec of 196 Ec µS/cm recorded at the inlet while pond 1 had the lowest Ec of 133µS/cm at the outlet. Highest pH of 7.5 was at the inlet of pond B and lowest 6.9 at the inlet and middle of pond A. The highest DO - 6.2 mg/l was at the outlet of pond 1, and lowest – 5.4 mg/l at the outlet of pond 2. This could have been caused by the accumulation of water at the outlet with reduced speed of flow causing water stagnation. The Ec for all ponds in Kamuli were within the WHO recommended levels of less than 700 µS/cm (WHO, 2003) while Das (2019) recommends DO of above 5.0 mg/l.

BOD lowest value 2mg/l was at the middle of ponds 1 and 2, and at the inlet and outlet of pond 2, and highest values 3mg/l were recorded at the inlet and outlet of ponds A which is within the recommended values of <10mg/l, although Das (2019) argues that <1.6mg/l of BOD is suitable for pond farming while 2.0mg/l in ponds indicates clean ponds. TDS were highest – 80mg/l at the inlet and lowest – 66mg/l at the outlet of pond 1, and high (98mg/l) at the middle and low – 77mg/l at the outlet.

Turbidity values of 84 NTU was registered at the middle of pond 2, while the least values – 20 NTU were recorded at the outlet of pond 1. When compared with the standard for pond water which should be <30 NTU, indicates that water was turbid at the middle of pond 2, while the rest of the ponds were within the recommended standards (Australian Capital Territory (2001). No phosphorous – 0 mg/l was recorded at the inlets of ponds 1 and 2, and at the outlet of pond 2 which is within the recommended standards of 0.1 mg/l (Australian Capital Territory (2001). Nevertheless, caution should be exercised in relying on these comparisons since the findings of the Australian Capital Territory might differ in geography, physical and biochemical composition, not excluding the socio-economic characteristics of the Australian context. The influence of such factors might have a bearing on the findings.

The maximum ammonia was at the inlet of pond 1 - 0.95 mg/l while the minimum was 0.14 at the inlet of pond 2 and this is within the recommended standards of 0.1 mg/l to 0.6 mg/l (Das, 2019). Nitrates were highest – 0.15 mg/l at the middle of pond 2 and lowest – 0.09 mg/l at the inlet of pond A which is within the recommended standard of 0.1 to 4.0 mg/l (Das, 2019).

Table 8: Biophysical properties of earth fish pond in Nanso village

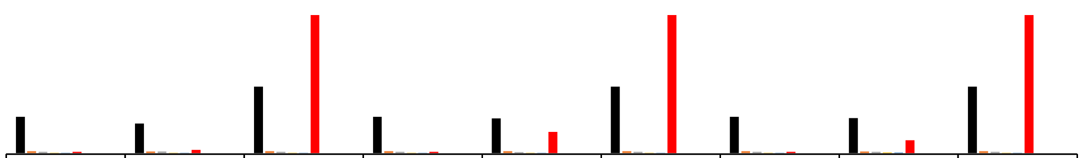
Parameters	Nanso village									
	Pond 1			Pond 2			Pond 3			Standard Water Quality Values
	Inlet	**Mid**	**Outlet**	**Inlet**	**Mid**	**Outlet**	**Inlet**	**Mid**	**Outlet**	
Ec	585	520	442	619	414	410	620	510	526	30-5,000µS/cm
pH	6.8	7.2	7	6.8	7.1	7.3	7.3	6.9	7	5.5-10.0
DO	4	4	3	4	5	5	5.2	5.2	6	3-5
BOD	4	4	3	4	5	5	5	4	5	3-20 mg/l
TDS	297	310	221	309	207	205	310	255	263	0.13 mg/l
Turbidity	0	0	8	0	8	0	80	8	10	30-80
PO4	0.14	0.08	0.22	0.35	0.12	0.1	0.12	0.15	0.14	0.03-2
N03	0.06	0.03	0.06	0.11	0.04	0.05	0.07	0.07	0.16	16.9 mg/l
Ammonia	0.95	0.65	0.18	0.14	0.19	0.4	0.19	0.28	0.65	0-0.05 ppm

Source: Field data

In Nanso village where three ponds were studied, the highest Ec of 620 µS/cm was recorded at the inlet of pond C and lowest – 410 µS/cm at the outlet of pond 2, all within the standard range of 100 to 2,000 µS/cm (Das, 2019). Highest pH values of 7.3 was at the outlet and inlet of ponds 2 and 3, and lowest pH values of 6.8 at the inlet of pond A which is outside the recommended standard of 20 mg/l to 400 mg/l. DO was highest at the outlet of pond C – 6.0 mg/l and lowest at the outlet of pond 1 - 3.0 mg/l which is within the recommended standards of 3 – 5 mg/l with the exception of pond 3 which was outside the acceptable and desirable range (Das, 2019). BOD was highest – 5.0 mg/l at the mid and outlet of pond 2 and the outlet of pond 3 – 5.0 mg/l and lowest at the outlet of pond 1 – 3.0 mg/l which is in the recommended range (Das, 2019).

TDS was least in ponds 2 outlet (205m/l), and 1 outlet (221m/l), and highest in ponds 1, middle (310m/l), 3 inlet and 2 inlet (See Figure 2). Turbidity was lowest at the inlet, mid of pond 3, inlet and outlet of pond 2. Phosphorous was lowest 0.08 at the mid of pond 3 and highest 0.35 mg/l at the inlet of pond 2. Nitrates were highest – 0.11 mg/l at the inlet of pond 2 and lowest – 0.03 mg/l at the mid-point of pond 1. Ammonia was highest – 0.18 mg/l at the outlet of pond 1 and lowest – 0.14 mg/l.

In Namabu, the variations in the parameters is presented as in Figure 2 below.



	Inlet	Mid	Outlet	Inlet	Mid	Outlet	Inlet	Mid	Outlet
	Pond 1			Pond 2			Pond 3		
Ec	91	75	165	91	87	165	91	88	165
pH	7	6.8	7	7	7.4	7	7	6.8	7
DO	5.6	6.2	5.6	5.6	5	5.6	5.6	5.5	5.6
BOD	3	3	3	3	3	3	3	4	3
TDS	3	3	3	3	3	3	3	4	3
Turbidity	6	10	340	6	54	340	6	34	340
PO4	0	0	0.19	0	0.21	0.19	0	0.04	0.19
N03	0.08	0.04	0.11	0.08	0.07	0.11	0.08	0.11	0.07
Ammonia	0.06	0	0.11	0.06	0.05	0.11	0.06	0.06	0.11

Figure 2: Biophysical properties of earth fish ponds in Namabu village

The results indicate that turbidity was highest mainly at the outlets of all the three pond sites studied reaching 340 NTU which is far above the recommended standard of 30-80 NTU (Bhatnagar and Devi, 2019). EC was highest 165 µS/cm at the outlets of ponds 1, 2 and 3, and least at the middle points of all ponds studied all within recommended standards (Das, 2019).

One-Way ANOVA Test was conducted to assess whether there are statistically significant differences between means of the biophysical parameters for the different sample points (inlet, middle and outlet) and three study villages of Namabu, Nanso and Kamuli. The ANOVA test results for the parameters which were studied in Nyenga village showed that the test was not significant; ($F(23, 168)=0.643$; $p=0.893$) which is greater than 0.05 ($p>0.05$) indicating that there is no difference between the means among groups that were studied.

One-Way Test ANOVA was run for each of the eight sites studied obtained from three villages where the study took place and the results revealed that there was no statistically significant difference between the three groups for across all the eight sites (p>-0.05); Nanso pond 1 (F(2,21)=0.041, p=0.960); pond 2 (F(2,24)=0.116, p=0.891); pond 3 (F(2,24)=0.050;p=0.951); Kamuli pond 1 (F(2,24)=1.512, p=0.241); pond 2 (F(2,24)=1.276, p=0.298); pond 3 (F(2,24)= 1.345, p=0.279); Namabu pond 1 (F(F2,24)= 0.023, p=0.977); pond 2 (F(2,24)= 0.183, p=0.833) (See Appendices 4.15-5.22). Therefore, the hypothesis that "*the biophysical parameters at the inlet, middle and at the outlet of the earthen ponds do not differ*" is accepted.

4.4 Objective 4: Effect of pond effluents on the water quality in the downstream in Nyenga Division

4.4.1 Effect of pond effluents on water quality based on biophysical water parameters

Samples obtained from the inlet, middle and outlets of the ponds were subjected to laboratory tests and analyzed for the changes in the water quality parameters. The results are presented for each of the three villages where samples were collected as presented in the tables below. The water samples from each of the three study sites were analyzed against the data obtained from downstream of each of the ponds studied and the results are also presented.

Table 9: Water quality parameters of Earth ponds in Nanso village

Parameters	Nanso village									
	Pond 1			Pond 2			Pond 3			Downstream
	Inlet	Mid	Outlet	Inlet	Mid	Outlet	Inlet	Mid	Outlet	
DO	6.2	5.4	5.2	5.6	5.5	5.6	5.2	5.2	6	4.1
TDS	297	310	221	309	207	205	310	255	263	241
Turbidity	0	0	8	0	8	0	80	8	10	0.001
PO4	0.14	0.08	0.22	0.35	0.12	0.1	0.12	0.15	0.14	0.09
N03	0.057	0.03	0.06	0.107	0.041	0.051	0.072	0.071	0.162	0.01
BOD	4	4	3	4	5	5	5	4	5	3
NH4	0.95	0.65	0.18	0.14	0.19	0.4	0.19	0.28	0.65	0.07
Ec	585	520	442	619	414	410	620	510	526	413
pH	6.8	7.2	7	6.8	7.1	7.3	7.3	6.9	7	6.4

Source: Field data

In Nanso, Ec was high at the inlets of both ponds, although the values were higher in ponds 2 (619, 414, 410) and 3 (620,510, 526) in µS/cm. pH increased substantially in ponds 1 and 2 at the outlets (6.8-7), (6.8-7.3) respectively. Increases were further observed for BOD in pond 2 from 4-5 mg/l compared to other ponds where it either decreased or remained constant; DO in pond 3 from 5.2 – 6 mg/l at the inlet, middle and outlet; turbidity from 0 to 8 in pond 1; phosphorus in all ponds from 0.14 – 0.22 in pond 1 and from 0.12-0.14 in pond 3; nitrates at the inlet and outlet from 0.057-0.06 in pond 1 and from 0.072-0.162 in pond 3 which automatically alters the content and quality of water downstream; and lastly ammonia in pond 3 from 0.19 to 0.65.

The increases in these water parameters could have resulted from the variations in the parameters owing to internal and external factors (Meng, et al., 2022). Factors such as amount of water inflows and outflows, source of water inflows, amount of dead organic matter, plants and animals, environmental activities, photosynthetic activities etc account for the increases in water quality parameters in the ponds. Sallenave (2019) for instance argues that most of the dissolved phosphorus find its way in the water through fertilizers, animal waste, decayed plants, soil erosion and run off and siltation.

One-way ANOVA was conducted to determine whether there were differences between mean of groups studied in Nanso. The results indicated that there is no statistical difference between means of the groups of ponds and the sites studied ($F(8, 63)=0.062$; $p=0.999$ (See Appendix 5.1 ANOVA results Nanso village).

Table 10: Water quality parameters Earth ponds in Namabu village

Parameters	Namabu village									
	Pond1			Pond2			Pond3			Downstream
	Inlet	**Mid**	**Outlet**	**Inlet**	**Mid**	**Outlet**	**Inlet**	**Mid**	**Outlet**	
DO	5.6	6. 2	5.6	5.6	5	5.6	5.6	5.5	5.6	2.2
TDS	45	37	82	45	48	82	45	44	82	78
Turbidity	6	10	340	6	54	340	6	34	340	14
PO4	0	0	0.19	0	0.21	0.19	0	0.04	0.19	0.07
N03	0.083	0.041	0.113	0.083	0.071	0.113	0.083	0.11	0.113	0.06
BOD	3	3	3	3	3	3	3	4	3	4
NH4	0.06	0	0.11	0.06	0.05	0.11	0.06	0.06	0.11	0.22
Ec	91	75	165	91	87	165	91	88	165	130
pH	7	6.8	7	7	7.4	7	7	6.8	7	7.3

Source: Field data 2023

TDS increases were observed across all the three ponds; 45-82, although there were variations for middle point values (See table 8). Increases were similarly observed with turbidity in all ponds in Namabu for both inlet, middle and outlets; pond 1 (6; 10; 340); pond 2 (6; 54; 340) and pond 3 (6; 34; 340); phosphates in ponds 1 (0; 0; 0.19) and 3 (0; 0.04; 0.19); nitrates across all three ponds, but mostly in pond2 1 (0.083; 0.041; 0.113) and 3 (0.083; 0.11; 0.113); BOD only in pond 3 (3; 4; 3); Ammonia mainly in ponds 2 (0.06; 0.05; 0.11) and 3 (0.06; 0.06 and 0.11); Ec mainly in ponds 2 (91; 87; 165) and 3 (91; 88; 165), and pH mainly in ponds pond 2 (7; 7.4; 7) (See Table 9).

Possible factors for the increases in water quality parameters are: water temperature, oxygen, carbon dioxide, sunlight, decayed organic matter, eutrophication due to siltation from the surrounding environment, amount of plants and animals in the ponds, among others. The effect of fertilizers used in the ponds could have promoted the development of planktonic algae, which provide food for many fish. Fertilization could have also led to the development of animals which feed on algae and it helps in supplying food for the fish and increasing the growth rate. However, Mramba and Kahindi (2023) note that fish pond practices such as daily feed input, and fertilisation significantly compromises water quality. The decomposition of organic matter such as unutilized fish feeds and fish droppings is known to use oxygen in respiration while giving out carbon dioxide, nitrogen, phosphate, ammonia into the water thereby encouraging growth of plants.

One-way ANOVA was conducted to determine whether there were differences between mean of groups studied in Nanso and the results indicated that there is no statistical difference between means of the groups of ponds ($F(5,42)=0.485$; $p=0.785$ (See Appendix 5.2: ANOVA results Kamuli village).

The water quality parameters of earth fish ponds in Kamuli where two fish ponds were studied are presented in the table below

Table 11: Water quality parameters Earth ponds in Kamuli village

Parameters	Kamuli Village						
	Pond 1			Pond 2			Downstream
	Inlet	Mid	Outlet	Inlet	Mid	Outlet	
DO	6	5.8	6.2	5.9	5.6	5.4	3.4
TDS	80	69	66	79	98	77	62
Turbidity	24	42	20	22	84	22	4
PO4	0	0.04	0.01	0	9.13	0	0.02
N03	0.09	0.106	0.109	0.096	0.146	0.139	0.03
BOD	3	2	3	3	3	3	3
NH4	0.14	0.04	0.08	0.13	0.12	0.06	0.02
EC	160	138	133	159	196	154	70
pH	6.9	6.9	7.4	7.5	7.2	7	6.6

Source: Field data 202

In Kamuli village, increases were observed in DO in pond 1 (6 and 5.8 to 6.2), TDS increases were in pond 2 (79 to 98). Increases in parameter contents were also observed in turbidity in pond 2 (22 to 84), phosphates in pond 2 (0 to 9 then to 13), although no phosphates were observed at the outlet of pond 2; Nitrates in pond 2 (0.098 to 0.146); Ec in pond 2 (154 to 196); pH in pond 1 (6.9 to 7.4). Increases in these parameters could have been caused by fish droppings, decayed organic matter, amount of sunlight, water temperature, aeration, photosynthetic activity, carbon dioxide, the high content of plants and animals, silt from runoff water from upstream farming with high fertilizer content that alter the water content.

However, there were observed decreases in Ammonia in pond 2 (0.13 to 0.06) which could be explained by the high levels of plants in the pond, and no supply of feeds to the fish. Sergeant (2014) found that the presence of algae in aquaculture ponds caused a reduction in ammonia. The ponds in Namabu were not well maintained and pond 2 was particularly overgrown with grass, and this could have been the cause of reduced ammonia in the middle and at the outlet of the pond.

One-way ANOVA was conducted to determine whether there were differences between mean of groups studied in Namabu and the results indicated that there is no statistical difference between means of the groups of ponds (F(5,42)=0.133, p=0.984 (See ANOVA results for Namabu village in appendix 5.3).

To determine the effect of pond effluents on water quality downstream, the parameter values in the ponds were analyzed against the values obtained downstream of the ponds studied in Kamuli, Nanso and Namabu as below.

Table 12: Water Quality Parameters downstream the study ponds

	Villages, STDev, Av. Mean, Max., Min.						
Parameters	Nanso	Kamuli	Namabu	STDEV	Av. Mean	Max	Min.
DO	4.1	3.4	2.2	0.96	2.67	4.1	0.96
TDS	241	62	78	99	120	241	62
Turbidity	0.001	4	14	7.21	6.30	14	0.00
PO4	0.09	0.02	0.07	0.04	0.05	0.09	0.02
N03	0.01	0.03	0.06	0.03	0.03	0.06	0.01
BOD	3	3	4	0.58	2.64	4	0.58
NH4	0.07	0.02	0.22	0.10	0.10	0.22	0.02
EC	413	70	130	183.18	199.05	413	70.00
pH	6.4	6.6	7.3	0.47	5.19	7.3	0.47

Of the water quality parameters studied downstream, DO was highest - 4.1 in Nanso and lowest - 2.2 in Namabu village, with STDEV - 0.96, average mean - 2.67, maximum - 4.1 and minimum - 0.96. TDS was highest - 78 in Namabu and lowest - 2 in Kamuli village, with STDEV - 43.59, Average mean - 31.65, Maximum and minimum values of 78 and 2.0 respectively. Turbidity was higher in Namabu and lowest in Nanso village.

The standard deviation was 7.21, Average mean - 6.30, maximum value - 14 and minimum of 0. Note that, though the highest DO was in Nanso at 4.1, it was still within the recommended range of 3-5 mg/l. Below and above these values, can result into detrimental effects by causing death of the fish.

Phosphorous was higher in Nanso - 0.09 and lowest - 0.02 in Kamuli village, with STDEV - 0.04, average mean - 0.05, maximum - 0.09 and minimum - 0.02. Nitrate was highest in Namabu and lowest in Nanso village, with STDEV - 0.03, average mean - 0.03, maximum - 0.06 and minimum - 0.01. BOD was highest in Namabu - 4 and lowest with equivalent values - 3 in both Nanso and Kamuli villages. BOD had STDEV of 0.58, mean average - 2.64, maximum - 4 and minimum - 0.58.

Ammonia was highest in Namabu - 0.22 and lowest - 0.02 in Kamuli village, with STDEV of 0.10, average mean of 0.10, maximum value of 0.22 and minimum value of 0.02. Ec was highest in Namabu - 130, and lowest - 70 in Kamuli village, with STDEV - 183.18, average mean - 199.05, maximum - 413 and minimum - 70. Lastly, pH was highest in Namabu - 7.3 and lowest - 6.4 in Nanso, with STDEV - 0.47, average mean - 5.19, maximum - 7.3 and minimum - 0.47.

T-test was conducted to assess the effect of pond effluents water quality downstream of the ponds in Kamuli, Nanso and Namabu and the results are presented comparing each pond samples with downstream data (See Appendix 5.4 t-test sample). The analysis revealed that the impact of pond effluents on water quality downstream was not significant ($p=0.23>0.05$). This could have resulted from the few fish ponds – only three within the radius where the study was conducted. Analysis in pond 2 against downstream samples also indicated that the pond effluents do not have a significant effect on downstream waters ($p=0.23>0.05$) (See Appendix 5.4).

The test results for pond 3 in Kamuli are presented in Appendix 5.6 t-Test-sample for pond 3, Kamuli. Appendix 5.6 results show that pond 3 effluents in Kamuli village did not have a significant effect on water quality downstream ($p=0.23>0.05$), and this could be explained by the few earth fish ponds in the area and enlightenment of the farmers on safety and fish pond care and management.

In Nanso village, the farmer group had three interconnected ponds that obtained its water from a stream flowing adjacent the ponds and the results of the t-test analysis are presented in Appendix 5.7 of t-Test sample. The t-test results showed that the pond1 effluents did not have a significant impact on water quality downstream ($p=0.98>0.05$) and this could be explained by the level of awareness farmers have on pond management, and limited farming activities upstream among others (See appendix 5.7)

The t-tests of Pond 2 Nanso village was conducted and the results are presented in Appendix 5.8 which revealed that there was no significant effect of pond effluents on the water quality downstream ($p=0.95>0.05$) (See Appendix 5.8). Possible reasons for the results might be the design of the pond which was constructed far above the ground level and a layer of grass planted along the fish pond, and limited farming activities in the catchment which all might have reduced the degradation of pond water.

Pond 3 statistical variables and results on the impact of pond effluents downstream are presented in Appendix 5.9. The water quality downstream showed that the pond effluents did not have a significant impact revealed by the t-test results ($p=0.84>0.05$), (See Appendix 5.9) and possible reasons are the good pond management practices and limited pond concentration in the area.

In Namabu village, two ponds were studied and the t-test results and other statistical variables are presented in Appendix 5.10. Statistical t-test results for pond1 in Namabu indicated that the pond effluents did not have significant impact on downstream ($p=0.98>0.05$) (See Appendix 5.10), which could have been due to factors such as better pond management practices among other factors.

Pond 2 laboratory results for Namabu village were analyzed and the t-test results were $p=0.98>0.05$ which revealed that the pond effluents did not have significant impact on downstream. This therefore confirms the hypothesis that "*pond effluents have not altered the water quality in the streams in in Nyenga division*". The results could have resulted from good pond management practices observed at the farm and factors in the catchment such as good land management practices, and limited farming activities which do not degrade the environment.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. The first objective of the study was to examine the socio-economic factors of smallholder pond fish farmers in Nyenga Division. Regarding this objective, the study concludes that majority of smallholder pond fish farmers in Nyenga were males. Fishing was majorly done by middle-aged people 41-50 years. Most fish farmers were from Nanso village and fish farming is the mainstay of the people of Nyenga division. Most people in Nyenga division are educated up primary education and half of the people earn average monthly income of <100,000 UGX. As a result, the null hypothesis is rejected and the conclusion is that there is variation in the socio-economic characteristics of pond farmers in Nyenga division. Despite the above findings, the socioeconomic factors of smallholder pond farmers revealed by this study cannot be taken to apply to the whole of Nyenga division, as these factors might differ from parish-to-parish and village to village. Although, some of the characteristics might hold for some parishes, and villages, the variables might differ due to varying socio-economic and political factors at play in each of the locations. The relatively small sample studied, three villages in the entire division implies that this study might have missed out on other key data that could have changed the results of this study. Nevertheless, the reliability of the data presented in this study based on the robustness and validity of the research instruments and tools and methods used cannot render the conclusions unreliable.

2. The second objective of the study was to determine the level of awareness on water resource use and safety practices among smallholder pond fish farmers in Nyenga Division. Regarding this objective, it can be concluded that the levels of awareness on water resources use and safety practices among smallholder fish farmers was high. Therefore, the hypothesis that pond farmers are adequately aware of the water resource use and safety practices is accepted ($p<0.000$). It should however be noted that though the study findings revealed that most of the fish farmers were aware about water resource use and employed safety practices during fishing and pond management, the limited research period within which data was collected and the limited fish ponds studied could have affected the nature and breadth of data collected. However, in the context of the three villages studies – Kamuli, Nanso and Namabu, it can be vividly concluded that the farmers were enlightened about water resource use and employed adequate safety practices in pond management.

3. The third objective of the study was to assess the biophysical parameters of water resources used in earthen ponds in Nyenga Division. The biophysical parameters that were assessed and used to measure the quality of pond water in Nyenga division: Electric conductivity, pH, turbidity, Total Dissolved Solids, Dissolved Oxygen, Biochemical Oxygen Demand, Phosphorous, Nitrate, and Ammonia were within the recommended standards, and despite slight variations in ammonia, this was not significant revealed by the ANOVA results ($p>0.05$). Therefore, the hypothesis that "*the biophysical parameters at the inlet, middle and at the outlet of the earthen ponds do not differ*" is rejected implying that there were variations in the biophysical parameters at the inlet, middle and outlet. Despite these results, it should be noted that these results could have been affected by the socio-economic activities in the catchment of the ponds in the three villages of Kamuli, Nanso and Namabu. This is in addition to the variations in the pond management practices by the farmers which also affects the biophysical parameters of the water in the ponds.

4. The fourth and last objective of the study was to assess the effect of pond effluents on the water quality in the downstream in Nyenga Division. Based on the findings of this study, it can be concluded that the pond effluents did not affect the water quality downstream in Nyenga division revealed by the t-test analysis ($p>0.05$) for all the three villages of Nanso, Namabu and Kamuli. Therefore, the hypothesis that "*pond effluents have not altered the water quality in the streams in in Nyenga division*" is accepted. The factors for the limited effect of pond effluents on the water quality downstream could have resulted from the good land management practices or the limited catchment in the pond catchment area, and possibly good pond management practices among the fish farmers. However, the results might have been affected the occurrence of heavy rains during the study and the limited number of earth fish ponds that were study.

Nevertheless, owing to the methodological robustness, soundness, reliability and validity of the instruments, the results from this study should be considered true.

This study contributes to the body of knowledge revealing that there is variation in the socio-economic characteristics of pond farmers in Nyenga division with more males involved in fish farming than women and these were aged 41-50 years. The participants were mainly from Nanso village, with primary level of education and an average monthly income of <100,000 UGX. The small holder fish farmers in Nyenga division had high levels of awareness on water resource use and safety practices. The biophysical parameters that were assessed and used to measure the quality of pond water in Nyenga division; Electric conductivity, pH, turbidity, Total Dissolved Solids, Dissolved Oxygen, Biochemical Oxygen Demand, Phosphorous, Nitrate, and Ammonia were within the recommended WHO standards. Pond effluents from farmers' activities did not significantly affect the water quality downstream in Nyenga division. These were confirmed by testing the hypotheses and either accepting the hypotheses or rejecting the hypotheses.

5.2 Recommendations

The government through the Ministry of Agriculture, Animal Industry and Fisheries working alongside Buikwe District Local Government should design the fishing community empowerment program aimed at enhancing incomes of the farming community in regard to the socio-economic characteristics of the fishing community. This was because while investigating the socio-economic factors of smallholder farmers which was the first objective of the study, the average incomes for the fishing community was <100,000 UGX by 51% of the people who participated in the study. This implies that on average, each household earns less than US$ 1.

In addition, Buikwe District Local Government should design a special education program for the people of Nyenga division regarding water resource use and safety practices because although most people indicated that they aware water resource use and safety practices, fish farmers in Nanso were not taking good care of the ponds and all the three ponds were actually poorly managed. Besides, the farmers who participated in the study during pond water collection entered the ponds without safety gears. This is indicative of the limited self-awareness about the water resource use and safety practices among pond fish farmers in Nyenga division.

Related to the above, the fish pond maintenance practices should be emphasized in Nyenga to help farmers run well maintained fish ponds. This is because, with the exception of Kamuli where farmer groups had maintained their ponds, in other villages the ponds were not maintained and in Namabu village, the ponds were overgrown with vegetation which affects the quality of fish harvested. This was indicative of poor group management, lack of supervision and commitment by the town agents, community development officer and group leaders.

Buikwe District Local Government field extension team should earmark Nyenga division for more engagements with communities to increase education campaigns on fish farming, business dynamics, book keeping and generally financial management. This can be undertaken by the town agents, community development officers, fisheries officers, commercial officers. This should be done to advance fish farming as business that can uplift people from poverty and commercial farming as opposed to subsistence farming. Related to this, will be improving the people's attitude as most farmers are still stuck on grants from government which will not emancipate them. A mindset change program can be designed aimed at informing communities of the need to get the best out of the government support rather than thinking the government will give lasting support to the communities.

The Fisheries department should engage earthen fish pond farmers in Nyenga division on monitoring of the biophysical parameters in ponds. This is because whereas the farmers knew about the need to maintain the fish ponds, the interviews showed that the farmers have not made efforts to periodically monitor pond biophysical parameters as a means of ensuring better pond management. This is majorly caused by the inadequate returns from the pond fish farming business in the area.

The policy makers should consider mandating pond fish farmers to conduct routine water quality monitoring to assess the water quality parameters aimed at reducing the effect of earthen pond fish farmers from negatively affecting water quality in and adjacent the fish farming areas.

The conclusions from this study can only hold for the study area of Nyenga parish and Nyenga sub county and cannot be held to be true for the entire Buikwe district. This is due to the limited sample size of 89 persons that participated in the study. As a result, this study recommends a detailed study that integrates other sub counties in Buikwe district assessing the effect of pond fish farming on water quality parameters. This would allow the conclusions to hold true for the entire district.

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Appendix 1: Research instruments
Questionnaire: Socio-economic characteristics of pond fish farmers, level of awareness and effects of effluents discharge on the streams.

A) Socio-economic characteristics of pond fish farmers

1. Sex of the respondent Male ☐ Female ☐

2. What is the source of livelihood for your household?

Livelihood	Tick
Employed in government agency	
Employed in NGO	
Employed in private company	
Fish farming	
Others mention …………………..	

3. What is another source of income your household is engaged, apart from fish farming?

Livelihood	Tick
Employed in government agency	
Employed in NGO	
Employed in private company	
Crop growing	
Others mention ………………..	

4. What is your highest level of education attained

Education level	**Tick**
PhD	
Master's degree	
Bachelors' degree	
Diploma	
Certificate	
A level	
O' level	
Primary school	
Never went to school	

5. What is your average monthly income?

Monthly income	**Tick**
<100,000	
100,000 – 500,000	
500,001 – 1,000,000	
1,000,001 – 5,000,000	
> 5,000,000	

6. How many years have spent in fish farming?

No of years	**Tick**
<1 year	
<3 years	
<5 years	
>5 years	

B) Level of their awareness on the water resource use and safety practices

7) What knowledge do you have about water resource use?

	Level awareness	Agree	Disagree
1	Use artificial fertilizers in the pond affects the water quality		
2	I know it is not right to discharge effluents from the pond to open places and streams around the pond		
3	I only apply feeds that can be completed by the fish		
4	Use of herbicides to clear weeds around ponds destroys the environment		
5	I have knowledge about diseases that affect fish		
6	I have knowledge about biophysical parameters that affect water quality		
7	Fish can grow well when the quality of water is good		

8) What is your level of awareness about safety practices during fish farming as they relate to the following?

No	Level of awareness	Agree	Disagree
1	I put on safety clothes when I am entering the pond		
2	I regularly clean my pond		
3	Employed in private company		
4	Only mature fish are collected during fishing		
5	I use the recommended fishing nets		
6	All unwanted materials in the pond are removed		

C) Effect of pond effluents on the water quality in the stream in Nyenga parish, Nyenga Division, Buikwe district

9) What is the effect of pond effluents on the water quality in streams in this area?

Effect of pond effluents on the water quality	**Tick**
Pond effluents introduce exotic invasive plant and animal species in the streams	
Change degrades the water quality of streams	
Kill plants and animals in the streams and adjacent areas	
Bring about smell in the area	
Poor management of pond effluents can transmit diseases to human beings	

Interview guide

1. What knowledge do you have about water resource use?
2. Would you argue that you are highly knowledgeable in pond water resource use management?
3. What is your level of awareness about safety practices in fish farming as they relate to the following?
4. Would you argue that you are highly knowledgeable about safety practices in fish farming?
5. Why would you say you are highly knowledgeable about safety practices in fish farming?
6. Where do farmers discharge pond effluents?
7. Are you aware that the discharges from ponds affect the environment?
8. What is the effect of pond effluents on the water quality in streams in this area?
9. What aspects of the natural and built environment are affected by pond effluents?
10. Are there measures that have been instituted to ensure the discharges do not affect the environment?

Observation checklist

1. Color of water in the pond and streams
2. Health of vegetation
3. State of areas where effluents are discharged
4. Application of feeds to the ponds
5. Smell around the ponds
6. Safety practices/their absence to guard against water contamination

Appendix 2: Tables

Appendix 5.12: Biophysical parameters of water quality in Nyenga Division

SAMPLE	Ec µS/cm	pH	Turbidity NTU	TDS mg/l	DO mg/l	BOD mg/l	PO4 mg/l	NO_3 mg/l	Ammonia mg/l
KAMULI pond 1 Inlet	160	6.9	24	80	6	3	0	0.09	0.14
KAMULI pond 1 Middle	138	6.9	42	69	5.8	2	0.04	0.106	0.04
KAMULI pond 1 Outlet	133	7.4	20	66	6.2	3	0.01	0.109	0.08
KAMULI pond 2 Inlet	159	7.5	22	79	5.9	3	0	0.096	0.13
KAMULI pond 2 Middle	196	7.2	84	98	5.6	3	9.13	0.146	0.12
KAMULI pond 2 Outlet	154	7	22	77	5.4	3	0	0.139	0.06
NAMABU pond 1 Inlet	91	7	6	45	5.6	3	0	0.083	0.06
NAMABU pond 1 Middle	75	6.8	10	37	6.2	3	0	0.041	0
Namabu Pond 1 Outlet	165	7	340	82	5.6	3	0.19	0.113	0.11
Namabu pond 2 inlet	91	7	6	45	5.6	3	0	0.083	0.06
NAMABU pond 2 middle	87	7.4	54	48	5	3	0.21	0.071	0.05
Namabu pond 2 outlet	165	7	340	82	5.6	3	0.19	0.113	0.11
Namabu pond 3 inlet	91	7	6	45	5.6	3	0	0.083	0.06
NAMABU pond 3 Middle	88	6.8	34	44	5.5	4	0.04	0.11	0.06
NAMABU pond 3 Outlet	165	7	340	82	5.6	3	0.19	0.113	0.11
NANSO pond 1 Inlet	585	6.8	0	297	6.2	4	0.14	0.057	0.95
NANSO pond 1 middle	520	7.2	0	310	5;4	4	0.08	0.03	0.65
NANSO pond 1 Outlet	442	7	8	221	5.2	3	0.22	0.06	0.18
NANSO pond 2 Inlet	619	6.8	0	309	5.6	4	0.35	0.107	0.14
NANSO pond 2 middle	414	7.1	8	207	5.5	5	0.12	0.041	0.19
NANSO pond 2 Outlet	410	7.3	0	205	5.6	5	0.1	0.051	0.4
NANSO pond 3 inlet	620	7.3	80	310	5.2	5	0.12	0.072	0.19
NANSO pond 3 middle	510	6.9	8	255	5.2	4	0.15	0.071	0.28
NANSO pond 3 Outlet	526	7	10	263	6	5	0.14	0.162	0.65
Minimum	75	7.5	340	310	6.2	5	9.13	0.162	0.95
Maximum	620	7.5	340	310	6.2	5	9.13	0.162	0.95
Standard Deviation	205.50	0.22	75.21	106.21	0.36	0.88	2.02	0.04	0.25
Average mean	304.6	7.1	38.6	155.1	5.6	3.6	0.6	0.1	0.2
Standard Error	45.95	0.05	16.82	23.75	0.08	0.20	0.45	0.01	0.06

Source: Field data 2023

Appendix 3: Statistics for objective Two

Appendix 3.1: Regression Model Summary of Predictors of "using artificial fertilizer in ponds affect water quality"

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.407[a]	.166	.080	.308

Predictors: (Constant), Years spent in fishing, Additional source of income, Age of respondents, Village of respondents, Highest level of education, Sex of respondents, Source of livelihood, Average monthly income.

Appendix 3.2: Coefficients Independent variable against the dependent Variable "using artificial fertilizer in ponds affect water quality"

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.426	.417		3.422	.001	.596	2.255
	Sex of respondents	.209	.079	.316	2.648	.010	.052	.366
	Age of respondents	-.023	.035	-.070	-.660	.511	-.093	.047
	Source of livelihood	-.099	.077	-.152	-1.279	.205	-.252	.055
	Additional source of income	.029	.039	.085	.736	.464	-.049	.106
	Highest level of education	-.020	.026	-.086	-.760	.450	-.071	.032
	Village of respondents	.054	.043	.138	1.266	.209	-.031	.140
	Average monthly income	-.058	.047	-.162	-1.234	.221	-.151	.035
	Years spent in fishing	-.049	.034	-.157	-1.426	.158	-.117	.019

a. Dependent Variable: Using artificial fertilizer in ponds affect water quality

Appendix 3.3: Regression Model Summary of the predictors of "I know it is not right to discharge effluents from the pond to open places and streams around the ponds".

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.414[a]	.171	.086	.424

a. Predictors: (Constant), Years spent in fishing, Additional source of income, Age of respondents, Village of respondents, Highest level of education, Sex of respondents, Source of livelihood, Average monthly income.

Appendix 3.4: Coefficients (independent variables against the dependent variable "I know it is not right to discharge effluents from the pond to open places and streams around the ponds".

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.515	.574		2.639	.010	.372	2.658
	Sex of respondents	-.151	.109	-.165	-1.386	.170	-.367	.066
	Age of respondents	-.057	.048	-.124	-1.177	.243	-.153	.039
	Source of livelihood	.140	.106	.155	1.314	.193	-.072	.352
	Additional source of income	-.014	.054	-.031	-.266	.791	-.121	.093
	Highest level of education	-.006	.036	-.019	-.168	.867	-.077	.065
	Village of respondents	-.025	.059	-.045	-.415	.679	-.143	.093
	Average monthly income	.039	.065	.078	.596	.553	-.090	.167
	Years spent in fishing	-.106	.047	-.246	-2.244	.028	-.200	-.012

a. Dependent Variable: I know it is not right to discharge effluents from the pond to open places and streams around the ponds.

Appendix 3.5: Regression Model Summary of the predictors of I only apply feeds that can be completed by fish

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.288[a]	.083	-.011	.504

a. Predictors: (Constant), Years spent in fishing, Additional source of income, Age of respondents, Village of respondents, Highest level of education, Sex of respondents, Source of livelihood, Average monthly income

Appendix 3.6: Coefficients of independent and dependent variable - I only apply feeds that can be completed by fish

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.791	.683		2.624	.010	.432	3.150
	Sex of respondents	.153	.129	.148	1.181	.241	-.105	.410
	Age of respondents	-.034	.057	-.065	-.584	.561	-.148	.081
	Source of livelihood	-.067	.126	-.066	-.528	.599	-.319	.185
	Additional source of income	-.082	.064	-.155	-1.276	.206	-.209	.046
	Highest level of education	-.024	.042	-.067	-.566	.573	-.109	.061
	Village of respondents	.042	.071	.069	.602	.549	-.098	.183
	Average monthly income	.060	.077	.107	.781	.437	-.093	.213
	Years spent in fishing	.045	.056	.093	.805	.423	-.067	.157

a. Dependent Variable: I only apply feeds that can be completed by fish

Appendix 3.7: Regression Model Summary of independent and dependent variable - Use of herbicides to clear weeds around ponds destroys the environment

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.214[a]	.046	-.052	.400

a. Predictors: (Constant), Years spent in fishing, Additional source of income, Age of respondents, Village of respondents, Highest level of education, Sex of respondents, Source of livelihood, Average monthly income

Appendix 3.8: Coefficients of independent and dependent variable - Use of herbicides to clear weeds around ponds destroys the environment

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.282	.541		2.368	.020	.204	2.359
	Sex of respondents	.080	.102	.099	.776	.440	-.124	.284
	Age of respondents	.045	.046	.112	.993	.324	-.045	.136
	Source of livelihood	-.082	.100	-.104	-.822	.414	-.282	.117
	Additional source of income	.048	.051	.117	.941	.349	-.053	.148
	Highest level of education	-.011	.034	-.039	-.323	.748	-.078	.056
	Village of respondents	-.004	.056	-.009	-.074	.941	-.115	.107
	Average monthly income	-.037	.061	-.086	-.612	.543	-.158	.084
	Years spent in fishing	-.021	.045	-.055	-.470	.640	-.110	.068

a. Dependent Variable: Use of herbicides to clear weeds around ponds destroys the environment

Appendix 3.9: Model Summary of independent variables and dependent variable I have knowledge about diseases that affect fish

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.632[a]	.400	.338	.405

a. Predictors: (Constant), Years spent in fishing, Additional source of income, Age of respondents, Village of respondents, Highest level of education, Sex of respondents, Source of livelihood, Average monthly income

Appendix 3.10: Coefficients of independent and dependent variable I have knowledge about diseases that affect fish

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.770	.548		1.406	.164	-.320	1.861
	Sex of respondents	.033	.104	.032	.321	.749	-.173	.240
	Age of respondents	.061	.046	.119	1.320	.191	-.031	.152
	Source of livelihood	.094	.102	.093	.926	.357	-.108	.296
	Additional source of income	.025	.051	.048	.489	.626	-.077	.127
	Highest level of education	.112	.034	.317	3.288	.002	.044	.180
	Village of respondents	-.049	.057	-.080	-.865	.390	-.162	.064
	Average monthly income	.045	.062	.081	.729	.468	-.078	.168
	Years spent in fishing	-.259	.045	-.536	-5.750	.000	-.349	-.169

a. Dependent Variable: I have knowledge about diseases that affect fish

Appendix 3.11: Model Summary of independent variables and dependent variable I have knowledge about biophysical parameters that affect water quality

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.591[a]	.350	.283	.425

a. Predictors: (Constant), Years spent in fishing, Additional source of income, Age of respondents, Village of respondents, Highest level of education, Sex of respondents, Source of livelihood, Average monthly income

Appendix 3.12: Coefficients of independent and dependent variables - I have knowledge about biophysical parameters that affect water quality

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.826	.576		1.434	.155	-.320	1.972
	Sex of respondents	.037	.109	.036	.342	.733	-.180	.254
	Age of respondents	.056	.048	.109	1.166	.247	-.040	.153
	Source of livelihood	.109	.107	.107	1.025	.308	-.103	.322
	Additional source of income	.057	.054	.108	1.053	.296	-.051	.164
	Highest level of education	.055	.036	.155	1.542	.127	-.016	.127
	Village of respondents	-.010	.059	-.016	-.164	.870	-.128	.109
	Average monthly income	.089	.065	.159	1.373	.174	-.040	.218
	Years spent in fishing	-.242	.047	-.496	-5.109	.000	-.336	-.148

a. Dependent Variable: I have knowledge about biophysical parameters that affect water quality

Appendix 3.13: Fish can grow well when the quality of water is good

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.374[a]	.140	.051	.179

a. Predictors: (Constant), Years spent in fishing, Additional source of income, Age of respondents, Village of respondents, Highest level of education, Sex of respondents, Source of livelihood, Average monthly income

Appendix 3.13: Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.826	.576		1.434	.155	-.320	1.972
	Sex of respondents	.037	.109	.036	.342	.733	-.180	.254
	Age of respondents	.056	.048	.109	1.166	.247	-.040	.153
	Source of livelihood	.109	.107	.107	1.025	.308	-.103	.322
	Additional source of income	.057	.054	.108	1.053	.296	-.051	.164
	Highest level of education	.055	.036	.155	1.542	.127	-.016	.127
	Village of respondents	-.010	.059	-.016	-.164	.870	-.128	.109
	Average monthly income	.089	.065	.159	1.373	.174	-.040	.218
	Years spent in fishing	-.242	.047	-.496	-5.109	.000	-.336	-.148

a. Dependent Variable: I have knowledge about biophysical parameters that affect water quality

Appendix 3.14: Coefficients of independent and dependent variable Fish can grow well when the quality of water is good

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.166	.242		4.815	.000	.684	1.648
	Sex of respondents	.038	.046	.101	.831	.408	-.053	.129
	Age of respondents	.035	.020	.186	1.732	.087	-.005	.076
	Source of livelihood	-.042	.045	-.113	-.939	.351	-.131	.047
	Additional source of income	.038	.023	.198	1.679	.097	-.007	.083
	Highest level of education	-.014	.015	-.107	-.926	.357	-.044	.016
	Village of respondents	-.044	.025	-.193	-1.746	.085	-.093	.006
	Average monthly income	-.011	.027	-.054	-.405	.687	-.065	.043
	Years spent in fishing	-.020	.020	-.111	-.996	.323	-.059	.020

a. Dependent Variable: Fish can grow well when the quality of water is good

Appendix 4: Statistics for objective three

Appendix 4.15: ANOVA for Nanso village pond 1

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3067.234	2	1533.617	0.040519	0.960366	3.4668
Within Groups	794839.3	21	37849.49			
Total	797906.6	23				

Appendix 4.16: ANOVA for Nanso village pond 2

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6891.651	2	3445.826	0.115977	0.890992	3.402826
Within Groups	713071.4	24	29711.31			
Total	719963	26				

Appendix 4.17: ANOVA for Nanso village pond 3

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3764.897	2	1882.449	0.050348	0.950999	3.402826
Within Groups	897334.3	24	37388.93			
Total	901099.2	26				

Appendix 4.18: ANOVA Namabu pond 1

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	111.7772	2	55.8886	0.023033	0.977252	3.402826
Within Groups	58235.7	24	2426.487			
Total	58347.47	26				

Appendix 4.19: ANOVA pond 2

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1266.694	2	633.3472	0.183154	0.833793	3.402826
Within Groups	82992.26	24	3458.011			
Total	84258.96	26				

Appendix 4.20: ANOVA Kamuli pond 1

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	15364.91	2	7682.454	1.51164	0.240812	3.402826
Within Groups	121972.7	24	5082.196			
Total	137337.6	26				

Appendix 4.21: ANOVA Kamuli Pond 2

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13300.07	2	6650.033	1.275552	0.297539	3.402826
Within Groups	125122.9	24	5213.454			
Total	138423	26				

Appendix 4.22: ANOVA Kamuli pond 3

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13914.87	2	6957.436	1.345194	0.279432	3.402826
Within Groups	124129.7	24	5172.071			
Total	138044.6	26				

Appendix 5: Statistics for Objective Four

Appendix 5.1: ANOVA results Nanso village

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18573.81	8	2321.726	0.062102	0.999847	2.089185
Within Groups	2355313	63	37385.92			
Total	**2373887**	**71**				

Appendix 5.2: ANOVA results Kamuli village

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	498.4257	5	99.68514	0.485204	0.785316	2.437693
Within Groups	8628.902	42	205.4501			
Total	**9127.328**	**47**				

Appendix 5.3: ANOVA results for Namabu village

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2152.7999	5	430.56	0.132625	0.98399	2.437693
Within Groups	136350.55	42	3246.442			
Total	**138503.35**	**47**				

Appendix 5.4: t-Test: Two-Sample Assuming Equal Variances

	Pond1 Kamuli	*Downstream Kamuli*
Mean	74.68	18.21
Variance	14999.18	880.01
Observations	8	8
Pooled Variance	7939.60	
Hypothesized Mean Difference	0	
Df	14	
t Stat	1.27	
P(T<=t) one-tail	0.11	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.23	
t Critical two-tail	2.14	

Appendix 5.5: t-Test: Two-Sample Assuming Equal Variances

	Kamuli pond2	*Downstream Kamuli*
Mean	74.68	18.21
Variance	14999.18	880.01
Observations	8	8
Pooled Variance	7939.60	
Hypothesized Mean Difference	0	
Df	14	
t Stat	1.27	

P(T<=t) one-tail	0.11
t Critical one-tail	1.76
P(T<=t) two-tail	0.23
t Critical two-tail	2.14

Appendix 5.6: t-Test: Two-Sample Assuming Equal Variances

	Kamuli pond3	*Downstream Kamuli*
Mean	74.68	18.21
Variance	14999.18	880.01
Observations	8	8
Pooled Variance	7939.60	
Hypothesized Mean Difference	0	
Df	14	
t Stat	1.27	
P(T<=t) one-tail	0.11	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.23	
t Critical two-tail	2.14	

Appendix 5.7: t-Test: Two-Sample Assuming Equal Variances for Nanso village

	Pond1 Nanso	***Downstream Nanso***
Mean	85.18	82.95
Variance	26611.23	24808.45
Observations	8	8
Pooled Variance	25709.84	
Hypothesized Mean Difference	0	
Df	14	
t Stat	0.03	
P(T<=t) one-tail	0.49	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.98	
t Critical two-tail	2.14	

Appendix 5.8: t-Test: Two-Sample Assuming Equal Variances

	Nanso pond2	*Downstream Nanso*
Mean	78.48	82.95
Variance	22989.84	24808.45
Observations	8	8
Pooled Variance	23899.14	

Hypothesized Mean Difference	0	
Df	14	
t Stat	-0.06	
P(T<=t) one-tail	0.48	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.95	
t Critical two-tail	2.14	

Appendix 5.9: t-Test: Two-Sample Assuming Equal Variances

	Nanso pond3	*Downstream Nanso*
Mean	101.49	82.95
Variance	37658.74	24808.45
Observations	8	8
Pooled Variance	31233.60	
Hypothesized Mean Difference	0	
Df	14	
t Stat	0.21	
P(T<=t) one-tail	0.42	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.84	
t Critical two-tail	2.14	

Appendix 5.10: t-Test: Two-Sample Assuming Equal Variances

	Namabu Pond1	*Namabu Pond1*
Mean	28.70	29.21
Variance	2274.19	2346.47
Observations	8	8
Pooled Variance	2310.33	
Hypothesized Mean Difference	0	
Df	14	
t Stat	-0.02	
P(T<=t) one-tail	0.50	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.98	
t Critical two-tail	2.14	

Appendix 5.11: t-Test: Two-Sample Assuming Equal Variances

	Namabu pond2	*Downstream Namabu*
Mean	32.90	29.21
Variance	3075.40	2346.47
Observations	8	8
Pooled Variance	2710.94	

Hypothesized Mean Difference	0
Df	14
t Stat	0.14
P(T<=t) one-tail	0.44
t Critical one-tail	1.76
P(T<=t) two-tail	0.89
t Critical two-tail	2.14

Appendix 5.12: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.591[a]	.350	.283	.425

a. Predictors: (Constant), Years spent in fishing, Additional source of income, Age of respondents, Village of respondents, Highest level of education, Sex of respondents, Source of livelihood, Average monthly income

Appendix 6: Field data collection photos

Researcher and her team identifying the right point where to collect water samples in Namabu village

Pond set up in Nanso village

Researcher and Assistant taking records

Researcher taking stock of the water samples collected

Researcher and Namabu fish keeping community at the fish ponds

Data collection team taking records at Nanso Group ponds

Data collector assessing the appropriate sampling point at one of the fish ponds in Namabu


View of the downstreams at Kamuli fish pond

Researcher observing one of the water samples immediately after being obtained