EFFECTS OF ANTHROPOGENIC ACTIVITIES ON SMALL-SCALE FISHERY OF ALBERT NILE, PAKWACH DISTRICT

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DECLARATION

I KWIYOCWINY EMMANUEL hereby declare that this dissertation titled "**Effects of Anthropogenic Activities on Small-Scale Fishery of Albert Nile, Pakwach district"** is my own work and it has not been submitted for any degree or equivalent examination in any other University, and that all sources of literature used have been indicated and acknowledged by referencing.

SIGN…………………………………………… Date ……………………………..…

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APPROVAL

It is hereby certified that the dissertation entitled "**Effects of Anthropogenic Activities on Small-Scale Fisheries of Albert Nile, Pakwach district"** has been developed by Kwiyocwiny Emmanuel under my supervision and is hereby recommended and forwarded to Directorate of Research and Graduate Training, Kyambogo University for consideration.

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DEDICATION

This dissertation is dedicated to my late father Pastore Avola (RIP) and my surviving mother Avola Joyce for they showed me the way to school at tender age and diligently supported my education. This work is equally dedicated to; my beloved wife Mrs. Kayeny Consilate Emmanuel, my lovely children such as Kacwinyrwoh Gertrude, Lengcwiny Jasmin and Munguacel Josephat, all my brothers and sisters like Grace Avola, AIP Avola Ronald to mention but a few.

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DEFINITION OF TERMS

Albert Nile is part of River Nile, stretching from Pakwach district to Moyo district in the West Nile sub-region of Uganda for about 200 Km after which River Nile proceeds to South Sudan as White Nile.

Socio-economic survey (SES) is a theoretical construct encompassing individual, household, or community access to resources, commonly conceptualized and measured by income or wealth, education, and occupation however, recent empirical work has drawn attention to the approach of supplementing or replacing information on income with direct measures of wealth, like household assets which are easy to survey.

Anthropogenic activities in this work refers to all the human actions that modify the condition of the aquatic habitat including physicochemical and biological status which enhances or inhibits fishery productivity in Albert Nile.

Fish biodiversity is the variation in life forms which can be measured through attributes such as species number and distribution, as well as taxonomic and functional diversity components of a given ecosystem.

Small scale (artisanal) fishery (SSF), is the traditional fishery that mostly involves households as opposed to large commercial fishing companies, characterized with small amount of capital and energy, relatively small fishing vessels, making short fishing trips, on shore or offshore, mainly for local consumption.

Water quality index (WQI) is a mathematical model used to transform large quantities of water quality data into a single number which summarizes different water quality.

ACRONYMS

AAS	Annual Agricultural Survey
ACF	Agriculture Credit Facility
APHA	America Public Health Association
BMU	Beach management units
BOD	Biological Oxygen Demand
CAS	Catch Assessment Survey
COD	Chemical Oxygen Demand
CPUE	Catch per unit effort
DO	Dissolved Oxygen
FAO	Food and Agricultural Organisation
FGD	Focus Group Discussions
GDP	Gross domestic Product
GHG	Green House Gas
GIS	Geographical and Information System
KII	Key Informant Interviews
LMC	Landing site Management Committee
LULCC	Land Use Land Cover Change
LVFO	Lake Victoria Fisheries Organisation
MAAIF	Ministry of Agriculture Animal husbandry and Fisheries
MO	Monofilament net
MT	Metric Tones
MU	Multifilament net
MWE	Ministry of Water and Environment
NaFIRRI	National Fisheries Resources Research Institute
NDPs	National Development plans
NEMA	National Environment Management Authority
NFA	National Forestry Authority
NGO	Non-Governmental Organization

NPA National Planning Authority

NPHS National Population and Housing Census

NWSC National water and sewerage cooperation

SDG Sustainable Development Goals

SES Socio-Economic Survey

SSF Small Scale Fisheries

TL Total length

UBOS Uganda Bureau of Statistics

UDHS Uganda Demographic House Survey

UN United Nations

UNDESA United Nations Department of Economics and Social Affairs

UNFCCC United Nation Frame Work Convention on Climate Change

UNHS Uganda National Housing Survey

USEPA United States Environmental Protection Agency

WQI Water Quality Index

WWF World Wild life Fund

ABSTRACT

Worldwide, fisheries have declined, Albert Nile total fish catch declined drastically from 5200-2790 (46%) between 2012-2021. Increasing population leads to overfishing and unsustainable land use. Unsustainable land use results into unfavorable climate. Crop failure due to unfavorable climate drive people to over fishing. Unsustainable land use equally negatively effects water quality required for fishery productivity. The study assessed; socio-economic status, land use, land cover change in the catchment, water quality and fishing pressure in small-scale fisheries of Albert Nile. A cross sectional survey design was used to assess socio-economic activities and fishing pressure. Study area was clustered to guarantee homogeneity. A total of 10 Landing sites (20%) were obtained by simple random sampling from each cluster. Disproportionate allocation was used to obtain 223 boats for sampling. 354 fishers responded to socio-economic survey questionnaires and interviews. Catch assessment survey was used to generate data on fishing pressure. Fishing boats systematically sampled, Geographical Information System techniques and tools such as Arc GIS was used to capture and analyse data on land use, land cover change. Documentary review was used to assess water quality. Findings indicated fishing as the most dominant socioeconomic activity. Many youths are dropping out of school to engage in fishing such that 60% of fishers are youth full-primary drop-out. House hold size averaged 10 person/household with 60% of fishers un able to afford 3 meals daily. The study equally revealed that wetland and wood land decreased by 37.7% and 23.5% respectively from 1995-2020. The decline in wetland and wood land has been attributed to increasing demand for agricultural land, over grassing and increased demand for charcoal and wood fuel. According to the findings, Albert Nile water was in a good state with water quality index ranging from (86.5-78.0), however, the concentration of Phosphorus (0.144±0.091mg/l) and total Nitrogen (2.26±0.44mg/l) reflected hypereutrophic status in 2020. The general increase in values for physical parameters and nutrient species over the study period is a sign of deteriorating water quality likely to hamper stock replenishment in the long run. The fishery is overexploited with 80% of fishers engaged in illegal practices characterized by intensified fishing averaging 5 days weekly and 6 hours daily. Meanwhile, Catch Per Unit Effort was as low as 7.0±4.1 kg/boat/day. Fish diversity index was high (H'= 2.31±0.09, E= 0.83±0.03 and D=0.13±0.02), though 80% of the species were categorized as pelagic or immature hence of low economic value. *Hydrocinus forskali* and *Haplochromines species* were very rare in the catch or not observed in the catch respectively. It was concluded that limited livelihood options will continue to push fishers into over fishing. unsustainable land use, land cover change will continue to drive people to mount more pressure on the fishery. The changing water quality parameters points to deteriorating water quality required for fishery productivity. Fishing pressure resulting from increased input is overwhelming with potential to disrupt stock replenishment. It was recommended that; socio-economic status of fishers be regularly analysed and used as input for participatory management; land use that is unsustainable be halted; all poverty alleviating programmes to target the fishers so as to reduce pressure on the fishery.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Albert Nile is a stretch of about 200 Km of water body from Pakwach to Moyo district in the West Nile sub region of Uganda (NAFFIRI, 2012). The catchment area of Albert Nile has a rich ecosystem dependent on its water system with small scale fisheries (SSF**)** as one of the major livelihood activities (MWE, 2016). Small scale fisheries (SSF), are the traditional form of fisheries that mostly involves households as opposed to large commercial fishing companies making short fishing trips on shore or offshore mainly for local consumption (Kittinger, 2013; Smith & Basurto, 2019). Anthropogenic effects depict all human actions that impact the fishery directly or indirectly by modifying the conditions of the aquatic habitat including physicochemical and biological status which enhances or inhibits fishery productivity (FAO, 2020). According to Pinello *et al.,* (2017), biological, economic and social considerations are all necessary for improved performance of all fisheries. Management decision in non-regards to fish stocks, ecology of the fish, market conditions and efficiency of the harvesting process may not be sustainable.

Fishery is a very important human activity globally generating livelihood in terms of income, food and employment for the riparian communities (FAO, 2017). However, the trend of fisheries has been on general decline between 2005 and 2016 as evidenced from the declined export, capture fisheries, the expected fishing potential and per capita fish consumption (MAAIF, 2017; FAO, 2017). The observed decline has been attributed to natural causes and anthropogenic impacts especially over fishing. World Wild Fund, WWF (2021) reported that a third of the global fisheries are characterized by overfishing. Capture fisheries in Africa has equally not been spared, 33% of Africa's wild fish stocks have been overexploited (Sayer *et* *al*., 2018). The high rate of malnutrition across the population in East Africa as reported by FAO (2017) could be the result of declined fisheries in a region well-endowed with water resources. For instance, EDNA *et al*. (2019) reported that fishing pressure reduced fish stocks to unsustainable levels in Lake Naivasha fishery.

Un regulated fishing effort is unsustainable, it leads to economic returns less than the costs of exploitation also known as negative resource rent (Grafton *et al.,* 2006) in which the fishers are 'the poorest of the poor', fishing only for subsistence. According to Gordon-Shaefer (1954) bioeconomic model for sustainable fisheries, there should be adequate spawning fish stock in the water to mature for future harvests (Schaefer, 1957). However, the Grafton *et al.* (2006) description of "too many boats chasing too few fish" has become the norm in most fisheries around the world with the negative consequence on fish stock.

Anthropogenic activities such as illegal un reported fishing, overfishing, use of destructive gears and pollution associated with unsustainable LULCC negatively affects fisheries (Raji et al., 2012). The negative effects of the various human activities on the fisheries are compounded as human population increases. The world population is projected to reach 8.6 billion people in 2030, 9.8 billion in 2050 and 11.2 billion people in 2100 (UNDESA, 2017). Uganda's population trend will not be an exception, as it was estimated to double from 30.7 million in 2009 to reach between 50 and 54 million people by 2025 (UBOS, 2010). Similarly, the population of Pakwach district was projected to increase from 157,835 to 182,600 people from 2014 to 2018 (UBOS, 2014). Furthermore, Pakwach district is among the districts in Uganda with high poverty index as 32.0% of the people live below poverty line compared to national average of 8.5% (UBOS, 2020 and UBOS, 2018). The district is predominantly rural based and agrarian with 85% of the population relying on the unpredictable rain fed agriculture (UBOS, 2018; ACF, 2014; Munyua *et al*., 2013). In light of the observed population characteristics of Pakwach, there is likelihood of over dependence on natural resources such as the fishery and the vegetation cover.

Fishers may not engage in over fishing by choice, in most cases, over fishing may be the only alternative to make ends meet as far as their livelihood is concerned (Beldade *et al*., 2012). The combined impact of population pressure, climate change and poverty lead to increased socio-economic vulnerability of the population. Socio-economic vulnerability forces people into over dependence and degradation of the fisheries as characterized by over fishing (Maplecroft, 2010). Degrading Albert Nile fishery will hamper the achievement of SDG1 and 2 of ending poverty and provision of improved nutrition to end hunger respectively. Un sustainable LULCC associated with over exploitation of natural resources such as the forest, wetland and other land cover types come with negative effects not only on water quality but on the fishery as well (FAO, 2018). The most obvious consequences of unsustainable LULCC are devegetation and knock on effects of climate change associated with buildup of Green House Gases (GHGs) (Kristian *et al.,* 2019). Such knock-on effects of climate change include extreme weather events such as drought, flooding among others (Obubu *et al.,* 2022).

A general decline in Uganda's vegetation cover between 1990 and 2005 has been reported by some authors such as (Gilbert *et al*., 2018), Pakwach district has not been exceptional. The ministry of water and environment (MWE) (2016) reported that, on top of population pollution in West Nile, livestock chemicals used in traditional livestock systems are not adequately disposed off. Improper disposal of such chemicals coupled with erosion means possible pollution of the Albert Nile aquatic system thus deteriorating the water quality required for fishery productivity.

Much as the co-management approach has been put in place (NAFIRRI, 2012; NEMA, 2021), the traditional top-down approach of regulating fisheries in Uganda has still remained in place (Allison, 2013). According to Pinello *et al.* (2017), the traditional top-down approach in which fish is placed before fishers is un sustainable as it does not address the root cause of livelihood related fishing pressure. The connection between socio-economic status and fishing pressure has not been appreciated in the fisheries management approach. Many studies on land use, land cover change (LULCC) in Uganda have indicated rapid devegetation (Gilbert *et al*., 2015; Falls *et al*., 2018; NFA, 2018; UBOS, 2019). Therefore, LULCC in Albert Nile catchment is going to be inevitable, however, it's associated effects both direct and in direct, on the fishery of Albert Nile has not been well examined. According to Pinello *et al.,* (2017), fisheries management decision in non-regards to fish stocks, ecology of the fish, market conditions and efficiency of the harvesting process may not be sustainable. Most studies on Albert Nile fisheries have targeted market conditions and harvesting process (Mbabazi *et al*., 2012; NEMA, 2021). Fish composition, distribution and abundance, are all dependent on water quality (Shuai, 2017). MWE, (2016) equally pointed out the need for background information on river catchment land use and socio-economics to aid better understanding of the water quality status in the Albert Nile fisheries. Studies on fishing pressure using input indicators such as frequency and duration, number of landing sites, gears, boat and fishers have been conducted in Albert Nile and other fisheries (Mbabazi *et al.*, 2012; NAFIRRI, 2012; NEMA, 2021). However, output indicators such as, catch per unit effort (CPUE), total length (TL) and species diversity have not been extensively examined especially in Albert Nile fishery.

This study was based on the assumption that humans can have a negative or a positive effect on the fishery directly or indirectly by impacting on fishing pressure and land use land cover change that subsequently affect the ecology in terms of water quality in which fishery productivity occurs. In the absence of comprehensive and empirical evidence, talking about the relationship between anthropogenic effects and the fisheries of Albert Nile would be merely speculative.

1.2 Statement of the problem

Over the years, decline in fish catches and fish diversity in various water bodies in Uganda has been reported as connected to both natural and anthropogenic causes. Albert Nile registered a decline from 5500MT to 5122MT in total fish catch from 2013 to 2015 (UBOS, 2018). Increasing population puts more pressure on natural resources such as fishery and land covers. The population of Pakwach district was projected to increase from 157,835 to 182,600 people from 2014 to 2018 (UBOS, 2014). The catchment of Albert Nile in Pakwach district registered decline in woodlands, grasslands and bushlands by 55%, 13% and 23%, respectively (UBOS, 2019). Rapidily increasing population results into overcapacity associated with overfishing and unsustainable land use. Unsustainable land use results into unfavorable climate. Crop failure due to unfavorable climate drive people to over depend on the fishery. Unsustainable land use equally comes with negative effects on water quality required for fishery productivity. Despite these various human activities in the catchment of the Albert Nile, there are limited studies that have been conducted on the effects of anthropogenic activities in small-scale fishery in the study area in order to inform policy.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the study was to assess the effects of different human activities on Albert Nile fishery.

1.3.2 Specific objective

1. To assess the socio-economic activities/status of the fishers in Albert Nile fishery.
2. To determine the land use and land cover changes in catchment of Albert Nile, Pakwach district from 1995-2020.
3. To assess the water quality in Albert Nile, Pakwach district from 2005 to 2020
4. To determine the magnitude of fishing pressure in Albert Nile, Pakwach district.

1.3.3 Research question

1. What are the socio-economic activities and status of the fishers in the Albert Nile fishery, Pakwach district?
2. Has land use and land cover types changed in the last 25 years in the catchment area of Albert Nile, Pakwach District?
3. Has water quality changed from 2005-2020 in Albert Nile, Pakwach district?
4. What is the level of fishing pressure in Albert Nile fishery, Pakwach district?

1.4 Significance of the study

This study is intended to bring into the lime light the state of affairs in the SSF of Albert Nile in Pakwach district for their consideration by the different stake holders engaged in policy formulation and implementation so as to achieve sustainable management of the fisheries for economic gains, food security and improved nutrition. The sustainability of the fishery is important for a community that is overwhelmed with climate challenges and is in the recovery period from the previous Lord's Resistant Movement (LRA) war. The nearby Murchison Falls Protected Area will be saved from illegal activities of poaching. Albert Nile fishery will continue to provide refuge to species under immense pressure from lake Albert.

1.5 Scope of the study

The study was to explore the anthropogenic effects in the small-scale fishery of Albert Nile, Pakwach district. Socioeconomic parameters such as; socioeconomic activities, house hold characteristics among others were assessed. Land use and cover types distribution as well as change from one land use and cover types to another were determined from 1995-2020. Physicochemical water quality parameters (turbidity, BOD, COD, ammonium, nitrite, nitrate, TP, temperature, DO and $p^{H)}$ were assessed from 2005-2020. Fishing pressure was assessed considering input efforts such as number of; gears, canoes, landing sites, fishers and fishing duration and output efforts such as fish catch, CPUE, total length, species diversity. The study was confined in the five sub counties of Pakwach district that are traversed by Albert Nile. The study was conducted from September 2021 to April 2022.

1.6 Study limitations

The study was generally limited by the poor attitudes of the fishers towards giving their response to the researcher associated with fears of being netted on the wrong side of the law regarding illegal activities in the fishery. To them, possibly the researcher was a fisheries officer just camouflaging around. However, as a result of constant sensisitisation and rapport building this challenge was overcome thus substantial data was collected.

Obtaining authorization and data from some organizations was in most cases un necessarily delayed, in some cases there was too much restriction on data that are otherwise meant to be freely accessible. However, due to patience and constant consultations most data were obtained. At the beginning of the study, the researcher was not acquainted with most of the research protocols especially those regarding data collection, organisation and analysis, but through online interaction and physical collaborations, all ended in favor of the researcher.

1.7 Conceptual frame work

The current study will be based on the conceptual frame shown below.

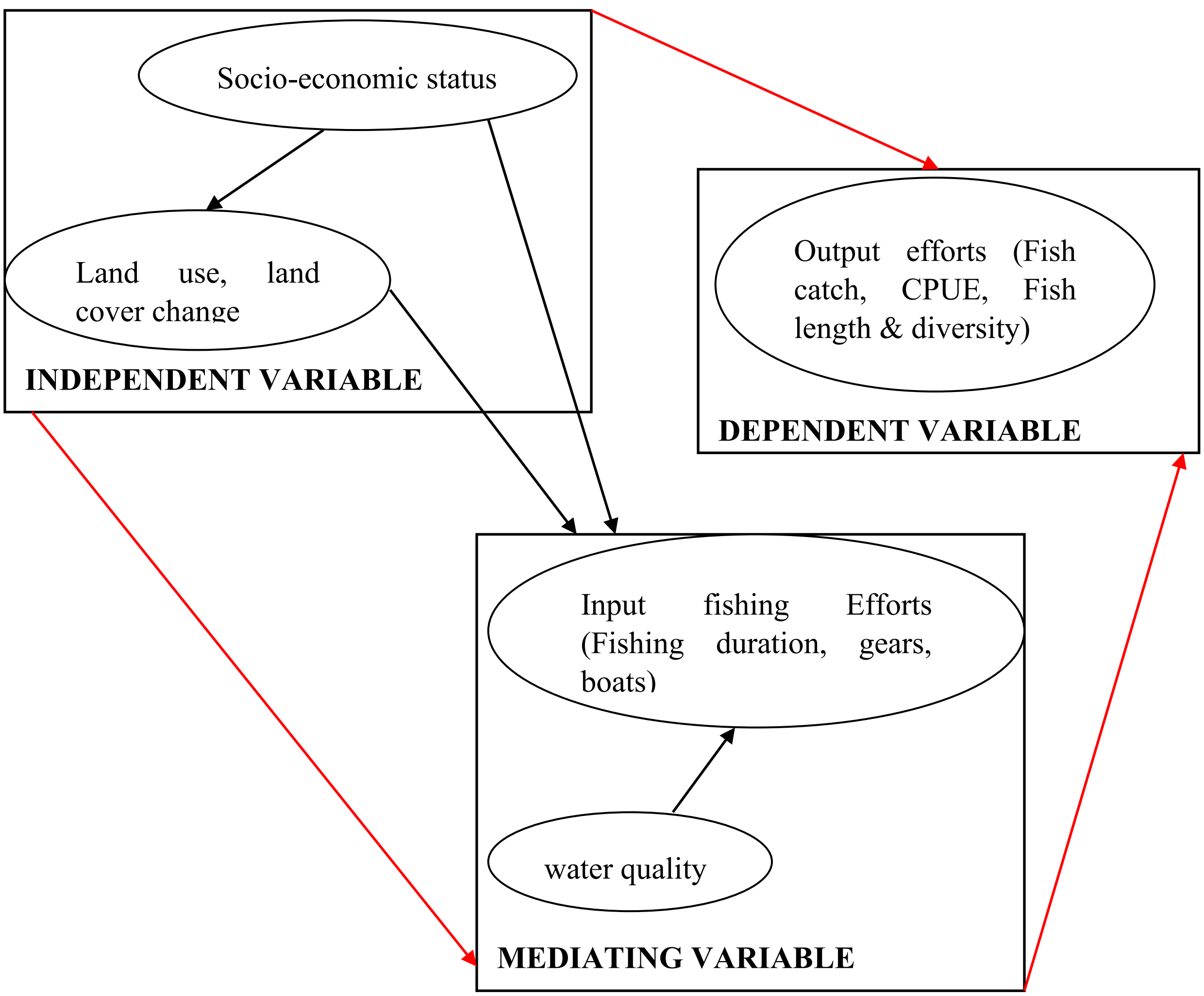


Figure 1.1: Conceptual frame

According to the above framework (

Figure *1.1*), socio-economic status associated with poverty and limited livelihood options pushes many people into the fishery leading to increased input efforts. Un sustainable land use associated with unfavorable climate impacts such as flooding negatively affects other livelihoods and forces many people into fishery thus increasing input efforts. Un sustainable land use associated with devegetation and soil erosion deteriorate water quality thus reducing fishery productivity. Reduced productivity of the fishery triggers competition among the fishers which is associated with increased input efforts. Increased input efforts in the fishery in turn negatively impact output efforts such as, catch per unit effort, fish length and fish diversity. Other factors such as Population pressure Climate and Policy regime may equally impact on output efforts, however, they were not of interest in this study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Contributions of the small-scale fisheries to livelihood

2.1.1 World wide

The contribution of Small-scale fisheries to livelihood worldwide is substantial. Around 60 million fisher folks are employed in fisheries out of which 90% are artisanal (FAO, 2020). More than 81% of the fish caught is used for local human consumption providing nutritional requirements of over 3 billion people globally especially in developing countries (World Bank, 2012; FAO, 2020). This signifies the central role played by fish as one of the most handy and inexpensive sources of protein for majority of the poor people. This is supported by Beveridge *et al*. (2013) and Béné *et al*. (2015) which contend that "terrestrial sources of animal protein" like meat button and pork contribute largely to total protein consumption for wealthier households as fish does for the poor households. FAO (2020) reported fish contributing 17 percent of worldwide animal protein intake and 6.7 percent of all protein macromolecule consumed.

2.1.2 Uganda

Uganda is well endowed with about 22.3 % of the total surface area constituted by natural water resource used for fishing thus providing abundant food and livelihood to the nation (MAAIF, 2017). Consequently, in 2017-2018 financial year, the share of fisheries sub-sector to agricultural GDP and National GDP was estimated at 12% and 2.5 % respectively (MAAIF, 2017). Almost 17 million Ugandans derive their daily protein requirements from fish translating into 50% of total animal protein intake (Allison, 2013). However, Uganda fishery is dominated by SSF accounting for over 80% of the fishers. About 136,000 fishers and additional 700,000 people are employed in fish processing, boat building, research and extension (FAO, 2017; MAAIF, 2017).

2.2 Socio-economic and environmental factors affecting small-scale fisheries in Uganda

2.2.1 Population trend in Uganda

Uganda's population is expected to reach more than 50 million by 2025, and between 83 and 105 million in 2050 (UNDESA, 2010; UBOS, 2010). According to UBOS (2014) National Population and Housing Census (UNHS), the population of Pakwach district, a catchment of Albert Nile, was projected to increase from 157835 to 182600 from 2014 to 2018 with an average growth rate of 3.1%. Also, importantly to note is that Pakwach district has high density, the district is found in Northern Uganda where the poverty index is very high, the district is predominantly agrarian relying on the un predictable rain fed agriculture for their livelihood and majority of the people live in the rural areas.

Table 2.1: Population density, poverty index, proportion of people involved in subsistence agriculture and people who are rural based (UBOS, 2018)

Population Density (persons per square kilometer)	185
Poverty Index (%)	32
People involved in subsistence agriculture (%)	85
People who are rural based (%)	80

Therefore, with such characteristics of the population (Table 2.1), there is high likelihood of relying heavily on natural resources thus putting immense pressure on resources base like the

Albert Nile fishery. This is because population pressure for instance, also leads to irreversible flooding of the rural poor into open access fisheries resulting into increased fishing effort, and the eventual degradation of fisheries resource base. However, there is uncertainty about the effects of such population trend and characteristics on small scale fishery of Albert Nile.

2.2.2 The trend of Land use and land cover change (LULCC) in Uganda

Land Use refers to different socio-economic purpose attached to land by humans while land cover can be regarded as the physical characteristics of the earth's surface including natural features such vegetation, water, soil, and all other man-made features like settlements (Rawat and Kumar, 2015). According to the National land physical asset account for Uganda (2019) report, between 1990 and 2015, agriculture-related land use systems increased by 8.56%, while land use related to woodland reduced by 11.86% compared to their original values (UBOS, 2019). In the same regard, woodlands, grasslands and bushlands reduced by 55%, 13% and 23%, respectively for Pakwach district (UBOS, 2019). If it is maintained business as usual, the annual loss of over 2% of the national wetland cover means, Uganda will have lost all its wetland by 2040. The situation is not any different for Albert Nile catchment area that has so far lost 27.7% of its wetland (Falls *et al*., 2018). The result of degrading wetland system is unregulated run offs from agricultural lands, industries and livestock into Albert Nile and other water bodies.

The observed trend in LULCC above can be attributed to the fact that natural land cover including wetland were converted for agricultural production and other economic activities (Gilbert *et al*., 2015.). Additionally, more than 95% of Ugandans still depend on biomass energy such as dry wood and charcoal for cooking as opposed to using electricity (Blimpo *et al*., 2020; NFA, 2018) leading to mass destruction of forest and vegetation. The low uptake of Electricity in Uganda has been attributed to unavailability in some areas or electricity being too expensive for most users (Blimpo *et al*., 2020). Furthermore, climatic vagaries such as droughts and floods drastically affect crop production forcing people into cutting down trees for charcoal as the next livelihood option eventually pilling more pressure on forest cover (NFA, 2018; UBOS, 2019).

According to Kristian *et al*. (2019), the consequences of unsustainable Land use and land cover changes (LULCC) are numerous including loss of biodiversity, distresses in hydrological cycles, increase in soil erosion, and pollution loads into water bodies. Good vegetation cover promotes retention and infiltration of water into the soil, while devegetation generally results into increased runoff associated with stronger soil erosion (Mohawesh *et al*., 2015). Intensification of agriculture in Uganda is inevitable due to increasing population, land scarcity, food security to meet the growing demand of food and Uganda vision to attain middle income status (World Bank, 2016a). Whereas, land covers change in Albert Nile catchment is going to be inevitable, it's associated effects both direct and in direct, on the fishery of Albert Nile has not been well examined. LULCC assessment is necessary since it plays an important part in socioecological perspective ensuring sustained livelihood for the rural poor in terms of economic gain, food and social security as well as life support services.

2.2.3 The trend of water qualities in Albert Nile

Though recent study by Kasozi *et al*. (2016) shows that most average physicochemical parameters of Albert Nile are within acceptable limits, values of some parameters have been observed moving towards the negative extreme. Many fish species or developmental stages of a species can only survive within a certain range of conditions such as temperature, oxygen, pH, salinity, nutrients and primary productivity for successful recruitment (Bhatnagar and Devi, 2013; Xing *et al*., 2016; Shuai, 2017).

The trophic status of water bodies may be described as Oligotrophic, Mesotrophic, Eutrophic and Hypereutrophic to indicate different level of pollution. The trophic status is Oligotrophic when the water is clear and of good quality but not suitable for fish production; Mesotrophic when the water has moderate level of biological productivity most suitable for fish production; Eutrophic for water with a high level of biological productivity and not very suitable for fish production; and Hypereutrophic for bad water quality with the highest level of biological productivity that leads to fish kill due to suffocation. (Lakewatch, 2004; Obubu *et al*., 2021; USEPA, 2020).

Table 2.2: Classification of trophic status of water (Lakewatch, 2004)

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Chlorophyll-a(mg/l)	<3	3.0–7.0	7.0–40.0	>40
TP (mg/l)	<0.015	0.015–0.025	0.025–0.10	>0.1
TN (mg/l)	<0.4	0.4–0.6	0.6–1.5	>1.5

**TP-Total Phosphorus; TN-Total Nitrogen*

Depending on the range of concentration of Chlorophyll-a, total Phosphorus and total nitrogen, the trophic status of water may vary as shown in Table 2.2. Water pollution may be attributed to point sources such as industrial and domestic effluents; non-point/diffuse sources attributed to agriculture, agro-chemicals, deforestation, livestock grazing, urbanization, and atmospheric pollutants (Erle *et al*., 2010; Hassan *et al*., 2016). Whereas, many of Uganda's rivers are naturally turbid, the problem has been augmented by the high rates of soil erosion which has been responsible for high recorded levels of suspended solids (turbidity) in Albert Nile (Kasozi *et al*., 2016) which may adversely affect fish and other aquatic life. Generally, in West Nile, pollution related to agriculture, aquaculture, and industry is still low and negligible compared to pollution from livestock and population (MWE, 2016). Livestock chemical and wastes coupled with un regulated run off could possibly be polluting Albert Nile aquatic system. However, MWE, (2016) pointed out the need for background information on river catchment land use and socio-economics to aid better understanding of the water quality status in the Nile basin. Fish composition, distribution and abundance, are all dependent on water quality (Shuai, 2017). Fishing pressure being experiences by most fisheries can easily be compounded by reduced fishery productivity associated with deteriorating water quality as fishers employ all sorts of destructive measures in their competition.

2.3 Status of fisheries and fish diversity

2.3.1 Capture fisheries in the world

There has been a general decreasing trend in the fisheries observed globally (Figure 2.1) below. This decline has been attributed to overcapacity (WWF, 2020).

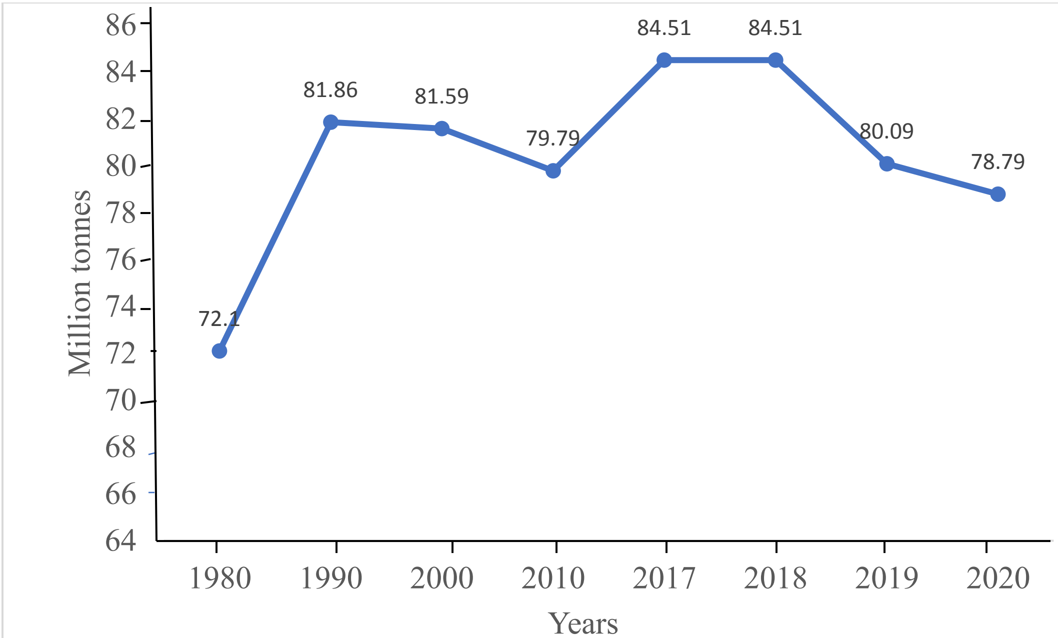


Figure 2.1: Trend in Global Capture Fisheries Production (FAO, 2018)

According to FAO (2018) and WWF (2021), a third of the global fisheries are over fished with further evidence provided by Costello *et al*. (2016) whose estimate equally has it that 68% of global fish stocks has been overexploited. Capture fisheries in Africa has equally registered declining trend due to climate change and other anthropogenic effects. According to Obiero *et al*. (2015) and Sayer *et al*. (2018), 33% of Africa's wild fish stocks have been overexploited. No wonder the Eastern African sub region was second after Southern Asia in the world with high rate of malnutrition not only among children, but across the population (FAO, 2017). More than 20% of the East African population was under nourished in 2016 (Obiero *et al*., 2015). This incidence of high malnutrition in a region quite endowed with aquatic ecosystem has been attributed to the low intake of fish with per capita consumption estimate as low as 5.3 kg in 2013 compared to the 17 kg recommended by the World Health Organization (FAO, 2017).

2.3.2 Performance of the fishery sector in Uganda

Fishery industry in Uganda has grown since late 1980s, after the long period of civil unrest. However, between 2005 and 2016 general decline was reported. For instance, fishing activities contributed 1.5 percent to GDP in 2017/18 as compared to 1.6 percent in 2016/17 financial year (UBOS, 2018). This decline has also been observed in terms of production, export, the expected potential of capture fisheries (MAAIF, 2017).

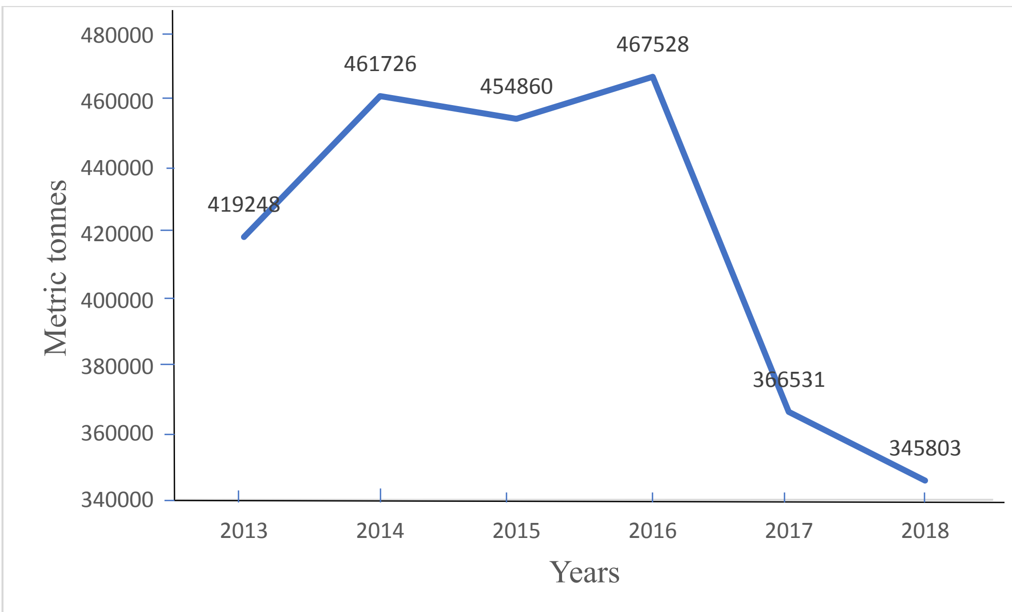


Figure 2.2: Capture fisheries in Uganda, 2013-2018 (NaFIRRI, 2020; UBOS, 2018)

The noticeable decline in production of capture fisheries in Uganda was from 467528 MT in 2016 to 345803 MT in 2018, a decline of 26% over a period of two years (Figure 2.2).

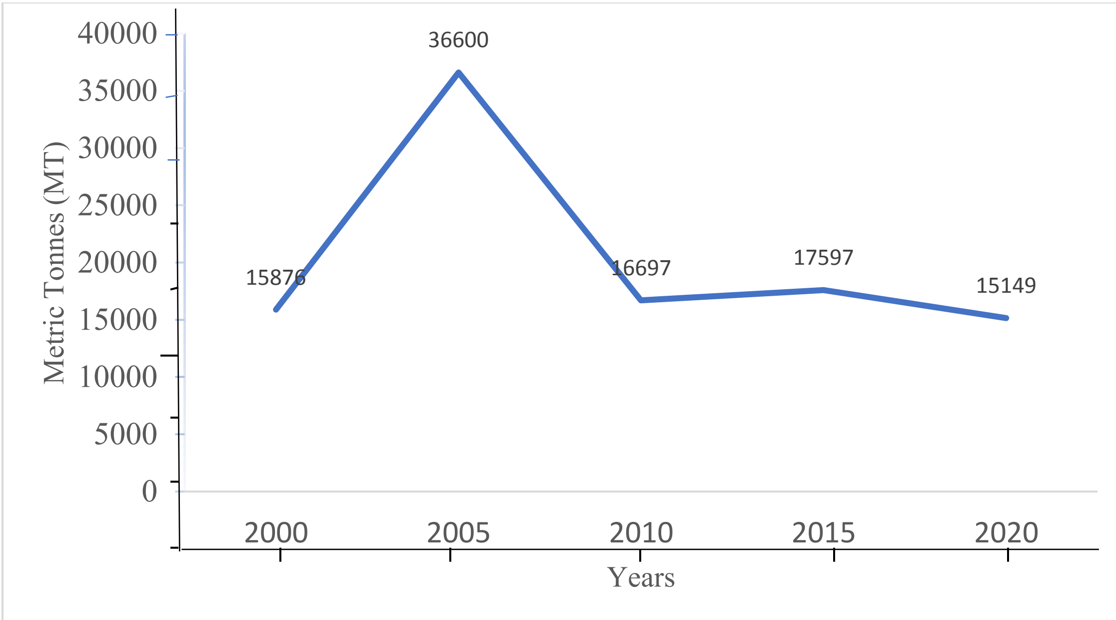


Figure 2.3: Export from fisheries in Uganda, 2000-2020 (NaFFIRI, 2020; UBOS, 2018)

The highest export ever registered by Uganda fisheries industry was 36600 MT in 2005 which unfortunately has declined to 15,149 MT in 2020 translating into 58% reduction in fish export (Figure 2.3). The decline in export could have been due to other factors such as increase in local demand and market standard; however, the impact of reduced fish stock was substantial (MAAIF, 2017). The low per capita fish consumption reported for Uganda at 10kgs per annum (MAAIF, 2017; FAO, 2017), equally points to decline in the fisheries.

2.3.3 The status of fisheries in Albert Nile

In relation to declining fisheries, the situation has not been exceptional for Albert Nile, a decline from 5500MT to 5122MT was observed from 2013 to 2015 (UBOS, 2018). According to statistics, Albert Nile makes the least contribution to fish catch in Uganda. Whereas Lake Albert contributed 44. 0%, Lake Victoria 40.0 %, and Lake Kyoga the third largest with 10.5%, in 2015 and 2016, the contribution of Albert Nile was just 1.3%

(MAAIF, 2017; UBOS, 2018). Despite of the above minimal contribution, Albert Nile fishery earned an estimated 14 billion Uganda shillings and recorded about 2700 fishing boats on 126 landing sites with fishers totaling to 4500 in 2012 (Taabu-Munyaho *et al*., 2012). Meanwhile, Pakwach district recorded the largest share, 54% of the 5,900 tones estimated annual production from the entire Albert Nile (Taabu-Munyaho *et al*., 2012). Just like other fisheries in Uganda, increasing demand for food and employment occasioned by population explosion must be increasing fishing pressure in Albert Nile with resultant degradation of resource base. Such unsustainability of the fishery poses threat to the present and future generation whose livelihood depend on fishery.

2.3.4 Fishing pressure

According to Pauly (1979) and Pauly *et al*. (1989), fishing pressure is the rate at which fish is harvested from the fish stock. Harvesting fish at a faster rate than stock replenishment results into Over fishing. Over fishing reflects economic inefficiency of the fishery in which the fishermen are both the direct contributors and victims as they are impacted by the low economic profitability of fisheries and fluctuating catches (Gordon, 1954). Overfishing has existed since pre-industrial times including the overfishing of the western Atlantic Ocean (Bolster, 2012). According to FAO (2020), global fish stocks exploited at biologically sustainable levels has been on a down ward trend, from 90% to 66.9% between 1974 and 2015 while stocks exploited at biologically unsustainable levels increasing from 10% to 33.1% over the same period.

According to Pauly (1979), Pauly (1983) and Pauly *et al*. (1989), fishing pressure can be viewed in terms of growth, recruitment, ecosystem and economic over fishing. Growth overfishing occurs when fish are caught prematurely before realising their growth potential while recruitment overfishing refers to fishery induced reduction in the number of reproducing cohorts. The combination of growth and recruitment overfishing is known as biological overfishing. Ecosystem overfishing occurs when targeted species are drastically reduced and replaced only in part by other exploitable species (Pauly, 1979), for instance when large species are instead replaced by small pelagic species in the catch. Economic overfishing occurs when the fishery is exploited at a level of effort higher than that which maximises the economic rent. Additionally, Malthusian overfishing according to Pauly *et al*. (1989), occurs when the labour supplied is surplus hence absorbing the labour comes with damaging effect on the fishery.

The consequence of fishing pressure is degradation of the resource base. In 2000, fishing pressure reduced fish stocks to unsustainable levels, leading to collapse of Lake Naivasha fishery (EDNA *et al*., 2019). Such collapse cannot only be disastrous to fish stocks, but also to the fishing communities relying on the fishery. According to Beldade *et al*. (2012), overfishing also results into fishing down the food web in that after catching all the larger fish, fishers resort to smaller fish with the hope of catching much more fish to meet demand. The fish populations as well as genetic diversity of the species decreases, making fish vulnerable to disease, and less likely to adapt to stress especially the current climate stress (Sonsthagen *et al*., 2017). Catch of smaller fish equally leads to breeding of smaller offspring that are less fecund negatively impacting the stock replenishment (Beldade *et al*., 2012). Whereas, studies on fishing pressure have been conducted using input indicators such as frequency and duration, number of landing sites, gears, boat and fishers, some output indicators such as, catch per unit effort (CPUE), total length (TL) and species diversity have been extensively examined.

2.3.5 Catch per unit effort (CPUE)

CPUE is a measure that quantifies fish caught per unit of effort of fishing activity (Harley *et al*., 2001). Such efforts may include amount of fishing time, size of gear used, number of hooks used or other unit of effort. In fisheries conservation, catch per unit effort (CPUE) is regarded as indirect measure of abundance, productivity and efficiency of previous fishing activities (Lynch *et al*., 2012; Ghosh and Biswas, 2017). The assumption is that changes in CPUE signify changes in abundance (Lynch *et al*., 2012), such that decreasing CPUE would mean overexploitation with constant CPUE on the other hand pointing sustainable harvesting (William, 2000). This makes CPUE a useful index for the level of exploitation of fishery resources to ascertain sustainability of the fishery (Karim *et al*., 2019).

CPUE data alone may not be the best indication of fisheries performance, CPUE may increase when actually the catch is mainly composed of immature and under sized species, a clear sign of degradation. But, Zeller *et al*. (2021) insists that despite of the highlighted limitations, CPUE is often a useful indicator for trend monitoring of a fishery deficient of detailed data and stock assessments and characterized by open access or management that is not sound. CPUE is also advantageous over other methods of measuring abundance since it does not interfere with routine harvesting operations, data are easily collected, easy to analyse hence decisions about stock management can also be made by the people doing the harvesting (William, 2000; Pablo & Bodmer, 2004).

2.3.6 Fish length

Fish length is measured as total length (TL), fork length (FL) or standard length (SL) (Anderson & Gutreuter, 1983). TL, FL or SL can be measured as shown in Figure 2.4 below.

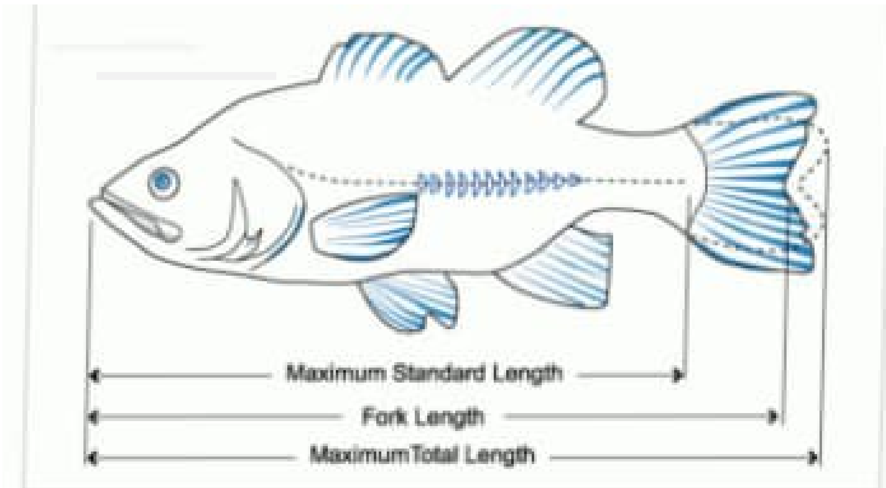


Figure 2.4: Measuring fish length (Anderson and Gutreuter 1983)

TL is measured from the anterior-most part of the fish to the end of the caudal fin rays while FL is measured from the anterior-most part of the fish to the end of the median caudal fin rays and standard length is measured from the tip of the lower jaw to the posterior end of the hypural bone (Figure 2.4). According to Hixon *et al*. (2014), fish length influences many ecological processes such as index of fish biomass, fecundity as well as the trophic position of the species. Large size fishes contribute disproportionately to fisheries productivity due to much economic return on greater weight, high fecundity and larval quality. Sustainability of small size fish can be quite uncertain given the seasonal fluctuations and low beach value (Allendorf and Hard, 2009).

2.3.7 Fish Biodiversity in Uganda

Fish Biodiversity is a major determinant of ecosystem productivity, stability, and biotic resistance, and an important proxy to conservation status and management decisions (Cleland, 2011; Midgley, 2012; Tilman *et al*., 2014). The water bodies of Uganda are rich in fish biodiversity with diversity of at least 500 unique and mostly endemic species (Ibale, 1998). However, with the current rate of decline in fish stocks, critical fish species are getting endangered or extinct and require conservation measures to be taken. For instance, important dominant riverine Species such as *Alestes baremose, Labeo victorianus* and *Citharinus citharus* are already endangered or their populations have been reduced to uneconomic levels and are requiring deliberate effort to preserve them (MAAIF, 2017). Whereas, NaFIRRI Frame survey (2012) indicated Albert Nile as multi species fishery, the same survey highlighted the changing proportion in the catch.

2.3.8 Diversity indexes

Diversity indexes provide information not only on the number of species present but also scarcity and commonness of species in a community. This can be quite a valuable tool for quiding evidence-based decision making (Maguran, 2004 and Sultana *et al*., 2018). According to Shannon (1949); Shannon and Weaver (1963); Haper (1999); Maguran (2004); Ramos *et al*. (2006) and Rosina *et al*. (2014), species diversity can be evaluated using indexes such as Shannon (H'), Evenness (E) and Dominance(D) index.

Shannon diversity index, H' is a combined measure of species richness and evenness and ranges from 0-3 with 0 signifying lowest diversity meaning only one species is present; 3 signifies highest diversity value meaning many species are present. Species evenness, E is a measure of species distribution in the habitat and ranges from 0-1 with 0 being lowest evenness and 1 being highest evenness. Dominance index, D is a measure of the abundance of the commonest species and ranges from 0-1 with 0 showing lowest dominance meaning that the habitat is shared by the maximum number of species and 1 indicating highest dominance meaning that only one species dominates the habitat. Therefore, H' is low under strong dominance of one single species and higher as the number of species increases in an assemblage, especially if they are evenly distributed (Maguran, 2004; Ramos *et al*., 2006 and Rosina *et al*., 2014). The combined assessment of species diversity and biomass can give clear outline of the population structure that exists in the water bodies (Saha *et al*., 2018).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

The study was conducted in Pakwach district, located on the western part of Albert Nile, in West Nile sub region of Uganda. From the northern end, Lake Albert pours it water into Albert Nile that runs from Pakwach district and other districts up to Moyo district, a distance of about 200 Km. Fishery is one of the major economic activities besides other livelihood activities such as subsistence farming of crops, animal rearing and petty trade.

The study was conducted in five sub counties of Pakwach district traversed by Albert Nile. The sub counties included; Pakwach town council, Panyimur, Pakwach, Panyango, and Wadelai sub county (Figure 3.1) below. The sampling units included; Ogal, Wangkadu Kuba Wicawa, Pajobi, Amor jukal, Padhoch, Jacan, Akello and Mutir shown by GPS points on the map of study area (Figure 3.1) below.

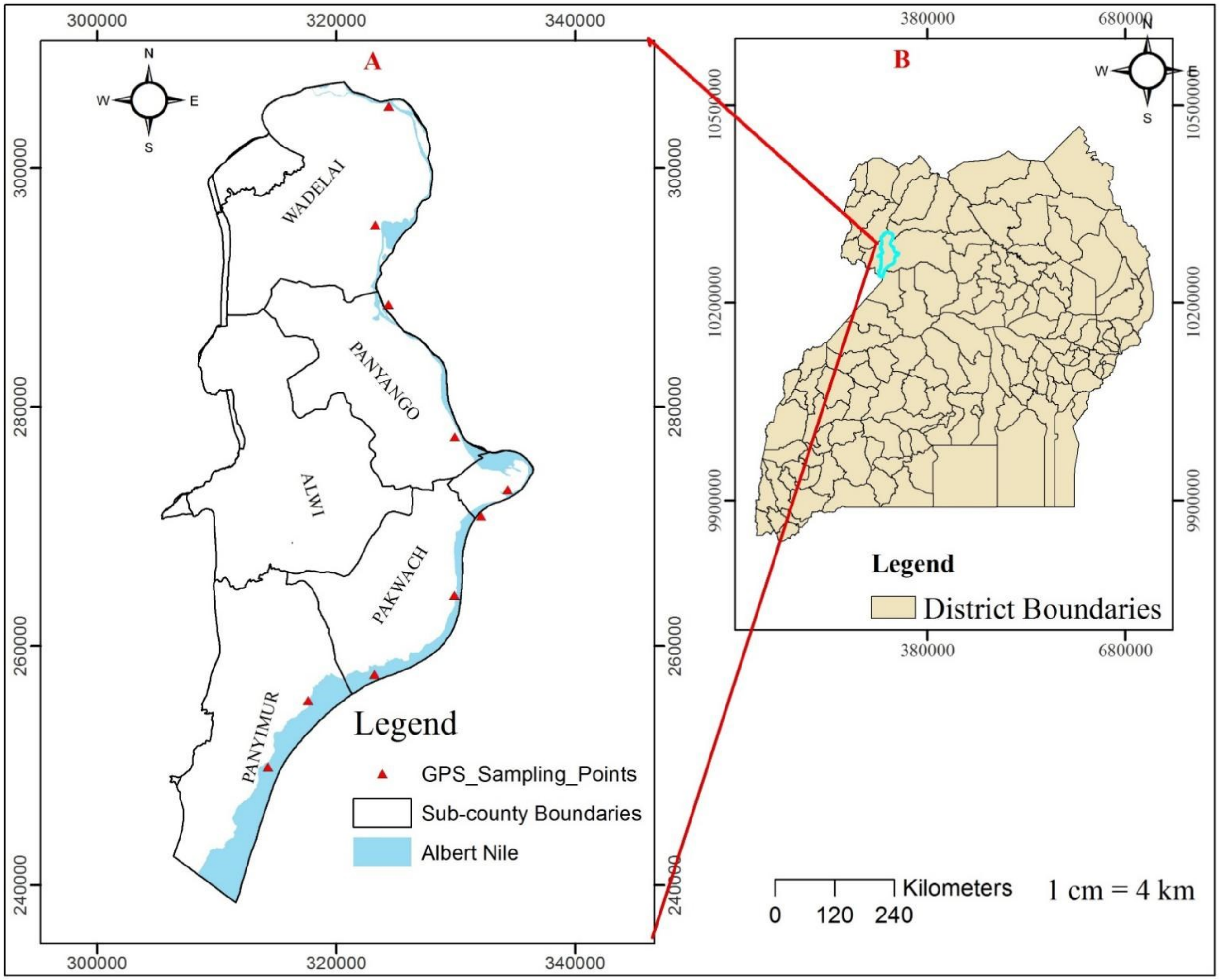


Figure 3.1: Study area (A: Pakwach district and sampling points along Albert Nile; B: Pakwach on the map of Uganda)

3.2 Study design

The study adopted both cross-sectional survey and longitudinal survey to gather detailed information from the population (Kothari, 2004), employing both qualitative and quantitative approach to collect and analyse data for detailed description of the state of the problem.

3.3 Study population

The study population included all the stake holders of this SSF such as the beach management units (BMU), fisher folks, boat owners and crew members who actually go fishing, fish processors, and fisheries extension service providers of the government or non-governmental organization (NGO). The population consisted of 4577 fishers from 54 officially recognized landing sites using1376 boats for fishing activities.

3.4 Sampling procedure and sample size

The study area was clustered into five sub counties (Table 3.1) basing on geographical segregation and fishing locations to guarantee homogeneity in terms of socio-economic activities, fishing gears and fishing methods used. The sampling units included landing sites in the five sub counties of Pakwach district purposively sampled as they are traversed by Albert Nile. A total of 10 Landing sites were obtained by simple random sampling procedure from each stratum translating to 20% as outlined in Lake Victoria Fisheries Organisation (LVFO) (2007b) and previously used by Nakiyende *et al.* (2012) and Taabu-Munyaho *et al.* (2013) in the same study area.

Table 3.1: Sample size determinations

Stratum	Landing site	Samples	Boats	Samples	Fishers	Samples
Panyimur SC	10	2	531	52	1386	108
Pakwach SC	11	2	233	47	970	75
Pakwach TC	12	2	223	45	868	67
Panyango SC	13	2	232	47	888	68
Wadelai SC	8	2	157	32	465	36
Grand total	**54**	**10**	**1376**	**223**	**4577**	**354**

**SC-Sub County; TC-Town Council*

A total of 354 respondents for socio-economic survey (SES) were sampled according to Krejcie and Morgan. (1970) sample size determination (Table 3.1). Since the population parameters for boats was not well established, disproportionate allocation of the sample size in the strata (Pinello *et al*., 2017) was used to obtain 223 boats for sampling in line with the limits of budget constrain. With this strategy, the sample was adequate to fit within the budget limit, minimize the variance of each stratum and give assurance that the sample mean and sample standard deviation are approximately normally distributed about the population mean and population standard deviation. The overall response rate was high, 96.78%, quite adequate to provide the required information during the study period

3.5 Data capture procedure

3.5.1 Capture of socio-economic status data by Socio-economic survey (SES)

Questionnaires and interviews for socio-economic survey were administered by the researcher to respondents selected by systematic random sampling, this gave every fisher similar probability of participation. Both nominal and ordinal scale were used, nominal scale was used to capture gender, occupation while ordinal scale was used to capture age, opinions of fisher folks about their socio-economic status such as socioeconomic activities, house hold characteristics and status of fishery (Amin, 2005). The study equally sought the perception of the community in the Albert Nile catchment regarding drivers of LULCC, species that are threatened by the current LULCC and possible solutions.

3.5.2 Land use land cover change (LULCC) data

3.5.2.1 Capture of satellite imageries

Three Landsat imageries of collection 2 Level 1 for 1995, 2011 and 2020 of GLOVIS were downloaded from the USGS Earth Explorer using shapefile of Pakwach district as the area of interest (AOI). Landsat 5TML (Thematic Mapper) imageries were obtained for 1995 and 2011, while for 2020, Landsat 8Oli (Operational Land Imager) imagery was obtained. (https://earthexplorer.usgs.gov accessed 20 May, 2022).

Table 3.2: Details of satellite images captured

Imagery	Period of data acquired	Path/Row	Cloud cover (%)
Landsat 5TM	March 31, 1995	172/058	2
Landsat 5TM	July 01, 2011	172/058	4
Landsat 8Oli	June 06, 2020	172/058	3

**TML-Thematic Mapper; Oli-Operational Land Imager*

Using ArC GIS, all imageries were georeferenced WGS84 datum and UTM zone 36N projection; less than 10% cloud cover, path 172 and row 058 and spatial resolution 30 m (Table 3.2), large enough to visualize LULCC (Rawat *et al*., 2015; Zhang *et al*., 2017; Kapute *et al*., 2019; Kilama *et al*., 2020). Interval of more than 10 years was used so as to generate sufficient LULCC data. In reference to rainfall pattern that positively influences vegetation characteristics and enhance spectral analysis, all imageries acquired were between the months of March and July (Table 3.2) which coincide the period of first rainy season in the study area (UBOS, 2018).

3.5.3 Data for water Quality Parameters

The study relied on secondary data to perform trend analysis as previously used by Sayed Rashad *et al*. (2019) and Obubu *et al*. (2021). Secondary data for Albert Nile water quality from 2005 to 2020 were collected from ministry of water and environment (MWE) and National water and sewerage cooperation (NWSC) and review of published work. Albert

Nile is under Upper Nile Water Management Zone, one of the four hydrological management zones for water quality monitoring by MWE in Uganda (MWE, 2012). MWE is mandated by the government to monitor water quality in Uganda, both MWE and NWSC follow ISO17025 standards (MWE, 2012). Although many parameters could be used to assess water quality, only selected physicochemical parameters (turbidity, BOD, COD, ammonium, nitrite, nitrate, TP, temperature, DO and $p^{H)}$ were used in this study to compute water quality index (WQI) required for informed decision making about the overall water quality in the entire Albert Nile for fish productivity (Badr *et al.,* 2013 & Ismail *et al*., 2016).

3.5.4 Catch Assessment Survey (CAS) to capture data on fishing pressure

According to Pinello *et al*. (2017), fishery independent methods such as frame survey, experimental trammel nets, cast net and gill nets are useful for detailed studies, but most are expensive, require expertise knowledge. Therefore, study on Albert Nile had to rely on fishery-dependent data capture methods such as CAS as viable alternative (Hossain *et al*., 2013; Headley 2020). CAS indicators included input efforts such as number of; legal and illegal gears, canoes, landing sites, fishers and fishing duration and output efforts such as fish catch (tones), CPUE (kg/boat/trip), total length for the indicator species, species diversity as outlined in LVFO (2007b). Accordingly, fish samples for some of the CAS indicators were freshly caught fish acquired from the fishers as part of their normal fishing activities outside protected areas. Exhaustive Systematic random sampling procedure was used to sample fishing boats as previously used by Hossain *et al*. (2013) and Desouky (2016). Consideration was given to the different fishing methods/gear operation mode such as active, passive and drift/tembea. The following proportion of the different boat-gears types were sampled, 24.2%

Multifilament nets (MU), 37.4% Monofilaments nets (MO), 17.8% Basket traps (BT), 17.8% hooks (HK) and 2.7% boat seine (BS).

Data on input efforts such as number of; legal and illegal gears, canoes, landing sites, fishers and output efforts such as fish catch (tones) were obtained from fisheries authorities and review of previous literature while data on input efforts such as fishing duration (hours) and CPUE were purely firsthand information obtained from the fishers at the landing sites.

3.5.4.1 Catch Per Unit Effort (CPUE)

Since Albert Nile is a multi species fishery, most of the gears are used to target many fish species, CPUE was obtained by standardised weighing of all fish species caught per boat per fishing trip. Fish specimens were blotted by clothing material made of cotton wool and placed in perforated basket for weighing to the nearest 0.1g using 100-kg spring weighing scale as outlined in Richard & Othina (1975); Mengist and Fakana (2020).

3.5.4.2 Total length

Total length (TL) of the fish specimens were measured using meter board to the nearest 0.1 cm from the anterior-most part of the fish to the end of the caudal fin rays as outlined in Laevastu (1965), Anderson and Gutreuter 1983, Taabu-Munyaho *et al*. (2012) and Nakiyende *et al*. (2013). Three indicator species namely, Nile tilapia *(Oreochromis niloticus)*, Nile perch (*Lates niloticus*) and Alestes (*Alestes baremose)* were considered for length measurement. The presence of the above indicator species in Albert Nile system has been reported by some studies for example (FAO, 1984) and their biology have been extensively studied both within and outside Uganda (Khallaf *et al*., 1986; Makori *et al*., 2017). Systematic random sampling was used to sample the fish specimens for TL measurement. Fish caught per trip were mixed very well and 10–30% specimens were collected as outlined in Raza *et al*. (2022).

3.5.4.3 Species abundance and diversity

The fish specimens were segregated and identified to species level using external morphological characteristics and identification keys (Fischer and Whitehead, 1974; Shafi; Quddus, 1982; Talwar and Jhingran, 1991; DeBruin *et al*., 1995; Hossain *et al*., 2007). Integrated Photo-based Online Fish-Identification System (IPOFIS) was equally used, which is a photo-based online fish identification system that integrated three methods: visual inspection, dichotomous keys, and a multi-attribute query procedure (Fischer, 2013).

3.5.4.4 Sampling sites for Catch Assessment Survey

Sampling sites for Catch Assessment Survey (CAS) was selected using stratified and simple random sampling design for purpose of homogeneity. Homogeneity was achieved by geographical segregation for different vessels and gears targeting different species. Whereas a vessel may not always be in the same geographical area, at least this categorization helps to place the landing sites in the least-wrong category. Homogeneity reduces variability thus sample size can be reduced without serious effect on precision in the estimates of population parameters (Levine *et al*., 2008).

3.5.4.5 Sampling intervals for Catch Assessment Survey

Sampling of fish species was conducted from October 2021 to January 2022 fortnightly, twice a month for a period of four months targeting wet months of October and November, dry months of December and January, dark moon phase and bright moon phase. According to

UBOS (2018), the months with dry season in the study area include; December, January, February, July and August while the wet season months include March April, May, June, September October and November. According to the moon cycle, the dark moon phase is the period when the portion of the moon lit by sun light decreases while, bright moon phase is the period when bigger portion of the moon is lit by the sun.

3.6 Data collection tool

Interview, observation and questionnaire guide, measuring board, weighing scale, GIS and GPS were some of the tools.

3.7 Variables measured

3.7.1 Socio-economic survey (SES)

Socio-economic survey (SES) was meant to capture opinions and perspectives of the fisher folk on the different socio-economic activities they are engaged in and their general socio-economic status. Socio-economic survey was conducted using questionnaires, Key Informant Interviews (KII), observations and Focus Group Discussions (FGD) with all the fisheries stakeholders. Range of variables were considered such as; literacy level, ownership of assets such as land, socio-economic activities and access to financial facilities as outlined in (Jones and Kapiyo, 2011).

3.7.2 Land Use and Cover Changes (LUCC)

Images for LULCC for Albert Nile catchment area (Pakwach district) for 1995, 2011 and 2020 were obtained and characterized using GIS.

3.7.3 Water quality parameters

The following parameters, turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium, nitrite, nitrate and total phosphorous (TP), temperature, dissolved oxygen (DO) and p^H were considered for calculating WQI of Albert Nile.

3.7.4 Catch Assessment Survey (CAS)

CAS indicators included total length, species diversity and efforts i.e., input efforts such as number of; legal and illegal gears, canoes, landing sites, fishers and fishing duration. Output efforts included; fish catch (tones), CPUE (kg/boat/trip).

3.8 Treatment, presentation and analysis of results

3.8.1 Socio-economic survey

Socio-economic survey data was transcribed, sorted and classified into themes and then coded so as to include as much information as possible and avoid omitting any details as emphasized by Mugenda (2003) and Creswell (2009) and to triangulate the study findings. All data on socio-economic survey were organized in Microsoft excel and statistical package for social scientists (SPSS) to compute descriptive statistics such as percentages, means, standard deviations, range and graphs for presentation.

3.8.2 Land use land cover change

3.8.2.1 Image enhancement and processing

Images enhancement and processing were accomplished using image analysis tool of ArcGIS 10.8. The district layer for sub setting the imageries to AOI was clipped using geoprocessing tool of ArcGIS 10.8 from district map produced by UBOS (2016). Image enhancement and processing technique such as improved appearance, georeferencing, masking cloudy areas, band composition and sub setting to Area of Interest (AOI) were done to improve accuracy of the classification. Image enhancement and processing are necessary to avoid distorting imageries statistics, overall classification accuracy and affiliation between satellite acquired data and biophysical phenomena (Rawat and Kumar, 2015). Brightness and contrast of the imageries were improved thus optimizing imageries for viewing and interpreting.

3.8.2.2 Image Classification

Image classification is the process of extracting information classes from a multiband raster image useful for producing thematic maps such as land cover maps. It involves categorising all pixels in a digital image using their spectral pattern into one of the several themes or classes of land use and cover types (Lillesand and Kiefer, 1994; Eastman, 1995). Both supervised and unsupervised classification method of the image analysis tool in ArcMap 10.8 were used to classify the imageries. It is very rare for unsupervised classifications to have unclassified pixels especially if the parameters are set correctly. The images were individually displayed in natural color composite using a band combination of 3, 2, and 1 for Landsat 5TM and 4, 3, and 2 for Landsat 8Oli. The reflectance values of each image in the false colour composite were used to develop the spectral signature of each class.

During Iso cluster unsupervised classification, a minimum class size of 20 and sample interval of 10 were used to produce 20 classes that eventually were merged depending on obvious relationships and reclassified to give 4 major land use and cover classes. Unsupervised classification was used to give an idea regarding the overall land use and land cover cluster of pixels for supervised classification. For supervised classification, spectral signature of each class was developed by digitizing the training samples and assigning each class to a different colour for easy differentiation. A statistical characterization of the reflectance of each class was developed using maximum likelihood supervised classification using several selected regions of interest (ROI) based on delineated land use and classes. Maximum likelihood classification algorithm considers the spectral variation within each category and the overlapping covering of the different classes of land use and land cover (Rientjes *et al*., 2011; Rawat and Manish, 2015). The result of both supervised and un supervised classification by image analysis tool in ArcMap 10.8 was land cover maps for 1995, 2011 and 2020 with the respective land cover types distribution in percentages.

3.8.2.3 Post classification Image enhancement

Noise appearance from the classified image was sorted by generalization techniques such as majority filtering, smoothing class boundaries and removing isolated regions (Peter. E, 2011), all were done to increase the smoothing effect of the classified images.

3.8.2.4 Accuracy Assessment and Kappa statistics

Both accuracy assessment and Kappa statistics are meant to verify the quality of image classification result usable for change detection analysis (Rawat and Kumar, 2015). Accuracy assessment for 1995, 2011 and 2020 images were done using spatial analyst tools of ArcMap 10.8 by point-based approach to generate ground truth points from each classified image. Ground truth points were distributed to polygons of each cover type by stratified random sampling design, large areas were allotted higher number of points. 200 ground truth points were considered for the four delineated land class to increase accuracy of the assessment (Weng, 2009). With the aid of contingency tables, misclassification rates were summarized for each land cover type to compute overall accuracy by dividing the total for correctly classified pixels by the total of pixels in the error matrix.

Confusion matrix was developed to compute Kappa index and evaluate the accuracy assessment (Cohen, 1960). Kappa test is calculated using predefined producer and user ratings as follows (Behera *et al*., 2012; Mahmud and Achide, 2012):

$$K = \frac{P\ (A) - P(E)}{1 - P(E)}$$ ………………………………………………………………………… **Equation 3.1**

where $P(A)$ is the number of times the k raters agree and $P(E)$ is the number of times the k raters agree by chance. User accuracy is the probability that pixels in images represent specific class on the ground, while producer's accuracy indicates the probability that a pixel being correctly classified. Kappa value ranges between -1 and 1, 1 indicating perfect agreement between classification results and ground truth results. The result of both point based accuracy assessment and kappa statistics were then presented in the form of percentages.

3.8.2.5 Change Detection

Change detection gives fine details regarding changes associated with land use and land cover. Areas under each land cover type in Km^2 was obtained by converting the classified raster image to vector using spatial analyst tools in ArcMap 10.8. Comparison was made between two independently classified images using post classification detection protocol to identify qualitative and quantitative land use change pixel-by-pixel using cross-tabulation. Using temporal image differencing change detection procedure, the first date image was subtracted from the second date image:

$$K = F - I$$ ………………………………………………………………… **Equation 3.2**

$$A = \frac{(F - I)}{I} * 100$$ ………………………………………………………………………… **Equation 3.3**

where K is magnitude of changes, A is percentage of changes, F is first data, and I is reference data (Mahmud and Achide, 2012; Rawat and Kumar, 2015).

The outputs of temporal image differencing change detection were maps indicating change from one land type to another between 1995-2011 and 2011- 2020. Change from one land type to another was expressed in terms of magnitude, percentage and graph.

3.8.3 Water quality parameters

The values for the different physicochemical parameters for Albert Nile water were assessed from 2005 to 2020 so that trend analysis could be done. Descriptive statistics such as range, standard deviation and graphs of Ms excel were used to present the findings on physicochemical parameters. One way-ANOVA test was conducted to test for the significance of change in values of the different physicochemical parameters from 2005 to 2020. To ascertain the validity of the findings on physicochemical parameters, correlation test was conducted on DO and BOD. Both One way-ANOVA and correlation test were done in SPSS.

The following empirical equation were used to calculate water quality index (WQI) (Pesce and Wunderlin, 2000).

$$WQI = \frac{K\sum iCiWi}{\sum iWi}$$ ....**Equation 3.4**

Where, k is a subjective constant representing the visual impression of the water, but was not considered so as to avoid subjective evaluation (Stambuk- Giljanovic, 1999; Badr *et al.*, 2013).

Table 3.3: Relative weight (Wi) and Normalisation factor (Ci) for water quality index calculation. (Simoes et al., 2008; Sanchez et al., 2007; Pesce and Wunderlin, 2000)

Parameters	Wi	Normalization factor Ci										
		0	10	20	30	40	50	60	70	80	90	100
pH	1	1 –14	2 – 13	3 – 12	4 –11	5 – 10	6 – 9.5	6.5 – 7	7 – 9	7– 8.5	7 – 8	7
Temperature	1	>45/<-6	45/-6	40/- 4	36/-2	32/0	30/5	28/10	26/12	24/14	22/15	21/16
Turbidity	2	>100	≤100	<80	<60	<40	<30	<25	<20	<15	<10	<5
DO	4	<1. 0	≥1. 0	>2. 0	>3. 0	>3. 5	>4. 0	>5. 0	>6.0	>6. 5	>7. 0	≥7. 5
BOD- 5	3	>15	≤15	<12	<10	<8	<6	<5	<4	<3	<2	<0.5
COD	3	>150	≤150	<100	<80	<60	<50	<40	<30	<20	<10	<5
Ammonium	4	>1.25	≤1.25	<1.00	<0.75	<0.50	<0.40	<0.30	<0.20	<0.10	<0.05	<0.01
Nitrite	2	>1.00	≤1. 00	<0.50	<0.25	<0.20	<0.15	<0.10	<0.05	<0.03	<0.01	<0.005
Nitrate	2	>100	≤100	<50	<20	<15	<10	<8.0	<6.0	<4.0	<2.0	<0.5
Total Phosphorus	1	>0.30	<0.30	<0.20	<0.175	<0.15	<0.125	<0.10	<0.075	<0.05	<0.025	<0.025

**Ci- Normalization factor; Wi- Relative weight; DO- Dissolved Oxygen; BOD- Biological Oxygen demand; COD- Chemical oxygen Demand*

Ci, the normalization value assigned to each parameter on a scale from 0 to 100, with zero for poor quality water, and 100 for perfect water quality (Table 3.3). Wi, the relative weight assigned to each parameter according to its relevance, 4 was assigned to DO and ammonium and parameters such as temperature and pH assigned minimum value of 1 (Table 3.3). WQI was then classified on a scale ranging from 0 – 25, 26 – 50, 51- 70, 71 – 90 and 91 – 100 as very bad, bad, medium, good and excellent respectively (Pesce and Wunderlin, 2000). Uganda does not have its own WQI (Nasser Kasozi, 2016; Obubu et al., 2021), therefore, a default reference WQI adopted by Pesce and Wunderlin (2000) was used.

3.8.4 Catch Assessment Survey

Data on both input efforts and output efforts organized into Ms excel or SPSS for analysis, interpretation and presentation.

3.8.4.1 Input efforts

Data on number of fishing gears, canoes, landing sites and fishers from 2012 to 2021 were presented using range and graphs while data on fishing frequency were presented using percentage, mean, standard deviation and mode.

3.8.4.2 Output efforts

Data on total length of the three indicator species were organized into frequency table and Ms excel functions such as range, percentage and graphs were used to present the data. Mean, standard deviation and graph were used to present finding on CPUE. Correlation test was done to show the relationship between CPUE and fishing frequency. Species abundance was obtained by counting and recording all the fish of specific species in spatial and temporal terms. Count, mean, standard deviation, range, percentage and graphs were used to present findings on spatial and temporal species abundance. One way-ANOVA test was done to determine significance in difference in species composition among the different landing sites. Student's t-test was done to determine significance in the difference in species composition between wet and dry months or dark and bright moon phase. Furthermore, two way-ANOVA was done to ascertain the effect of interaction between moon phase and rain factor on species composition. Species diversity was assessed using four different indices namely, Shannon–Wiener diversity, Evenness, richness and Dominance Indices in spatial and temporal terms (Shannon, 1949; Shannon and Weaver, 1963; Haper, 1999; Ramos *et al*., 2006).

3.8.4.2.1 Shannon Weiner diversity index

Shannon Weiner diversity index (H') was calculated by the formula:

$H' = -\sum pi \ln pi$ ………………………………………………………………… **Equation 3.5**

Where; pi is the proportion of individuals of species i, = ni/N, ni is the number of individuals of species i and N is the total number of individuals in the community.

3.8.4.2.2 Buzas and Gibson's evenness

Buzas and Gibson's evenness was measured by: E = eH/S or H/log S… **Equation 3.6.** Where H is Shannon Weiner index and S is the total number of species.

3.8.4.2.3 Dominance index

Dominance index was measured by: $D= \sum_i (ni/n)^2$ ……**Equation 3.7** where ni is number of individuals of species i, n is number of species. To validate the findings on spatial and temporal species diversity index, correlation test was done to show the relationship between H' and E or H' and D. All statistical analyses were done at 95% level of confidence.

CHAPTER FOUR: RESULTS

4.1 Socio-economic activities and socio-economic status of the fishing community

4.1.1 Sources of livelihood

Findings from the socio-economic survey showed that the fishing community were involved in a number of socio-economic activities such as farming, service provision and formal employment alongside fishing. Out of the different socio-economic activities, fishing was the one with a much more direct effect on the fisheries of Albert Nile fisheries.

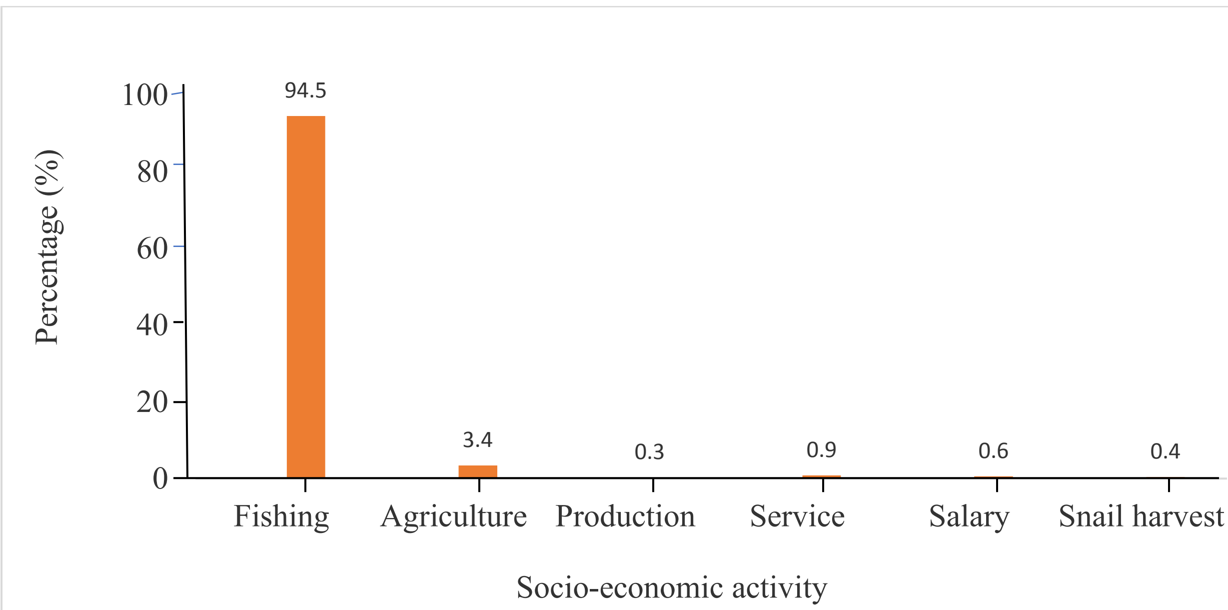


Figure 4.1: Main socio-economic activities for livelihoods (Survey, 2021)

Over 90% of the respondents were dependent on the fishery as the main socio-economic activities for their livelihood (Figure 4.1). Some of the respondents (3.4%) were engaged in other forms of agriculture such as animal rearing and gardening as their main source of livelihood. Some of the youth, (0.4%) engaged in harvesting of snails from beneath the water were disrupted due to flooding and Bilharzia (*Schistosoma ssp*) infestation.

Plate 4.1: People deriving livelihood from the fishery (Survey, 2021)

At the different landing sites, many people were deriving their livelihood from the fishery of Albert Nile (Plate 4.1)

4.1.2 Sex composition

The study findings indicated that both men and women of various age categories were actively engaged in range of activities in the different landing sites. The sector is predominately characterized by dominance of males (84%) as seen in Fig. 4.3.

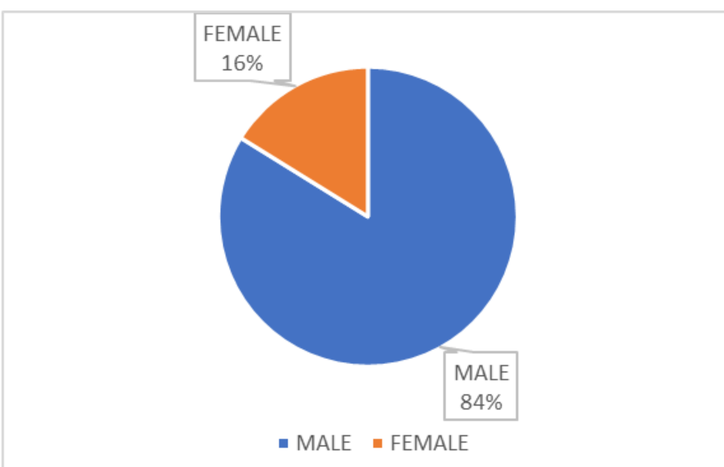


Figure 4.2: Gender representation for Albert Nile fishery (Survey, 2021)

Overall, women were under represented constituting just 16% compared to 84% male (Figure 4.2). However, women dominated in post-harvest handling of fish such as fish processing at 53% compared to 47% for men.

4.1.3 Age of the fishers

The survey further revealed that the fishery is dominated by the youthful participants as presented below.

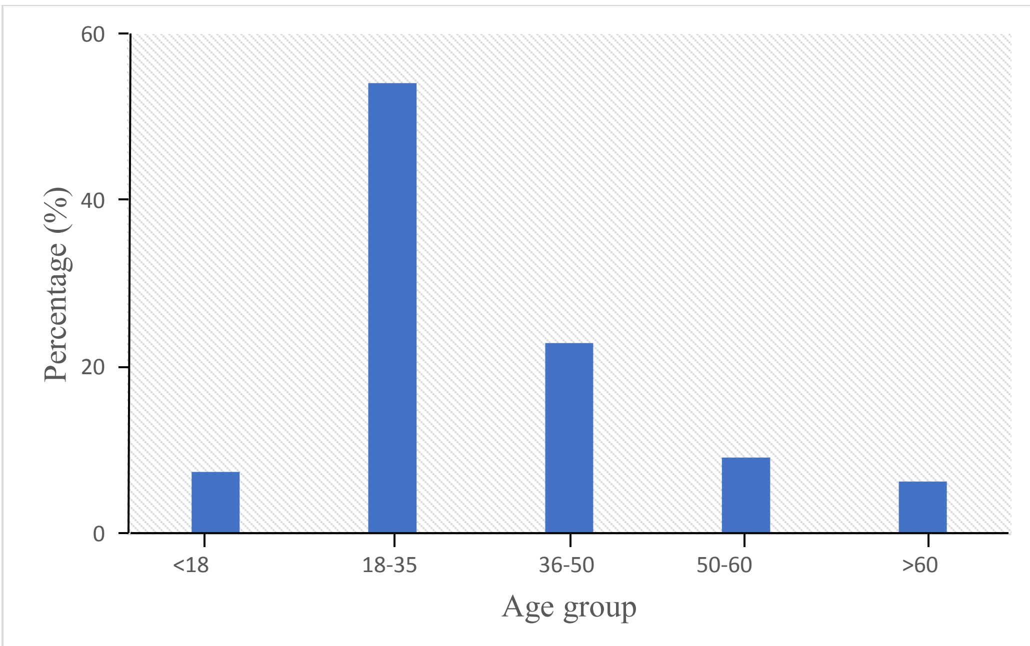


Figure 4.3: Age of fishers in Albert Nile fishery (Survey, 2021)

More than 50% of the respondents were of youth full age, ≤ 35 years of age (Figure 4.3).

4.1.4 Education level of Respondents

According to the survey, most fishers are illiterate or primary school drop-out.

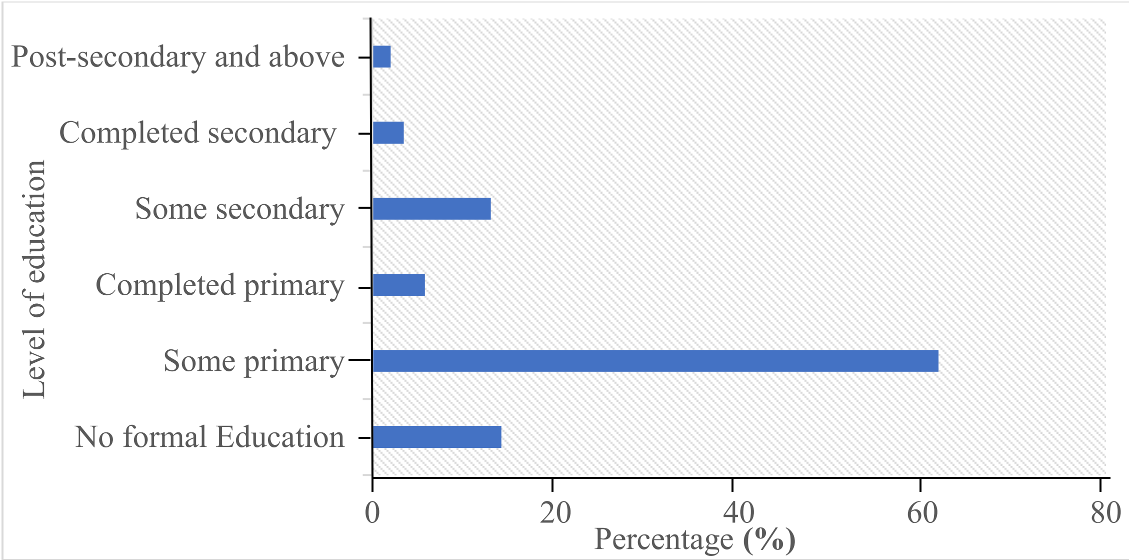


Figure 4.4: Literacy level for fishers in Albert Nile fishery (Survey, 2021)

About 14% have never gone through the formal school system and 60% are primary school dropout. The few who attempts secondary education also drop out prematurely (Figure 4.4).

4.1.5 Household size of the fishery respondents

It was revealed from the survey that house hold sizes are large. Most fishers are failing to provide adequate meals of at least 3 times in a day to their families.

Table 4.1: House hold sizes for fishers in Albert Nile fishery (Survey, 2021)

Number of House Hold members	Percentage (%)
1-2	1.7
3-4	3.5
5-6	6.4
7-8	28.1
9-10	19.1
11-12	16.2
13-14	17.1
15 above	7.8

The study further revealed a mean household size of 9.8 ± 3.3 and a mode of 8.4 (Table 4.1). It was revealed from the survey that house hold sizes are large, most fishers are failing to provide adequate meals in their families, more than 60% of the fishers reportedly could not afford to provide the minimum adequate meals of three times per day in their families.

4.1.6 Housing typology

The most common housing typology in the study area was found to be the mud-wattle type (temporary structures).

Plate 4.2: Housing typology for fishers in Albert Nile fishery (Survey, 2021)

More than 70% of the fishers resided in shelter made of mud and wattle (Plate 4.2). However, at least, more than 50% of the house hold could afford mattresses with or without bed to sleep on.

4.1.4 Asset ownership

The survey findings indicated that most fishers especially the youths were lacking assets especially fishing assets and land. Only 5% possessed accounts with commercial banks, the rest in local savings however, less than 50% could afford to save periodically. Fishers earn averagely 2.6 USD with the range of 1.2-5.2 USD per fishing trip. Only 18% had ever received information on financial literacy. Since the actual fishing activity is dominated by men, most fishing assets such as fishing gears and boats are owned by men though some few women (0.9%) were found to be owning some of the fishing assets.

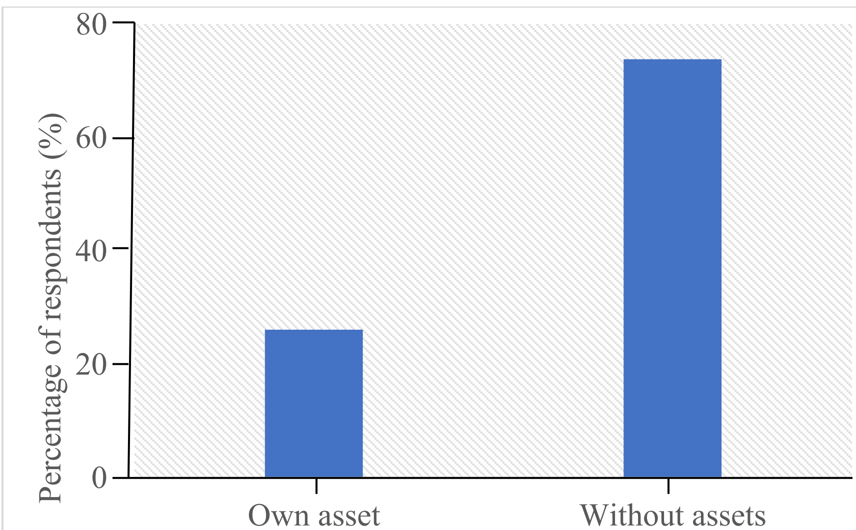


Figure 4.5: Fishing asset ownership for fishers in Albert Nile fishery (Survey, 2021)

About 70% do not own fishing assets such as boats and fishing gears **(**Figure 4.5), a large proportion of the asset-less fishers are youth. About 90% of the fishers own land inherited from their ancestors, however, much of the land is fragmented equivalent to ≤ 1 acre.

4.1.5 Management and governance of Albert Nile fishery

The survey revealed that more than 80% of the fishers were not registered with the Landing site Management Committee (LMC). Less than 50% of the fishers were aware about the fishing rules and regulation. For the landing sites sampled, 30% had toilet coverage, coverage for safe water was 0%, 10% had fish slab, 30% had house/shelter for the fishers and 40% had good road network for accessibility.


(a)


(b)

Plate 4.3: Facilities at landing sites of Albert Nile fishery (a) destructions caused by flood, (b) fish spread on the ground (Survey, 2021)

Facilities at many landing sites such as shelter, toilets, fish slabs were flooded, fish were spread on the ground (Plate 4.3b) due to lack of fish slab at most landing sites. Common methods of fish preservation included traditional methods such as smoking using local kiln, salting and sun drying. Schools and Health facilities were near to fishers' community.

4.2 Land use Land cover change (LULCC) in catchment area of Albert Nile, 1995-2020.

4.2.1 Land use and cover classes

Following preliminary field survey and documentary review, four major land use and cover classes were identified for Albert Nile Catchment in Pakwach district.

Table 4.2: Land use and cover classes in Albert Nile catchment

Class name	Description
Open water	Including all water bodies such as rivers, lakes and stream.
Wetland	Permanent or seasonal water flooded ecosystem.
Vegetation/woodland	All areas with grasses, widely spaced trees, shrubs or bush.
Crop land/farm land	Agricultural/cultivated land, built up areas and bare land

The major land use and cover classes included open water, wetland, wood land and agricultural land (Table 4.2).

4.2.2 Land cover maps

Result from the classification of the Landsat imageries indicated four land use and cover classes as shown in (Figure 4.6) below

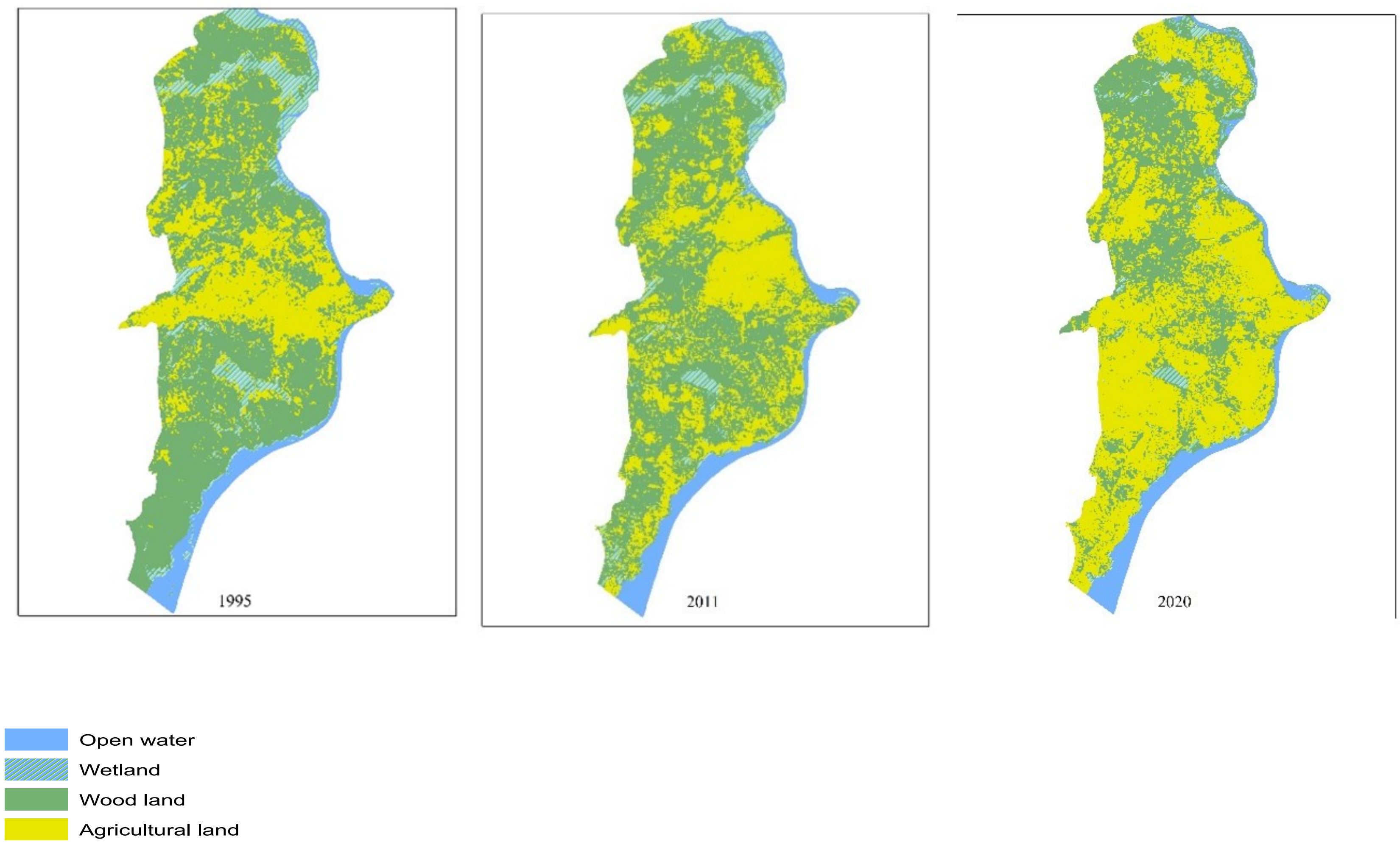


Figure 4.6: Classified land cover maps for Albert Nile catchment (1995, 2011 and 2020 respectively)

Four land cover types were obtained from the classification of Landsat imageries for 1995, 2011 and 2020, namely; Open water, wetland wood land and agricultural area (Figure 4.6). Contribution by built up areas and bare land to LULCC in the study area were quite insignificant, they are assumed to add up the composition of agricultural land use.

4.2.3 Accuracy Assessment

All imageries classifications and kappa statistics were well within allowable limits. The accuracy of the classifications were 91.9%, 86.1%, and 93.2%, for 1995, 2011, and 2020 respectively. Meanwhile, the kappa statistics were 0.91, 0.82, and 0.92 for 1995, 2011, and 2020 respectively (Table 4.3). According to Weng (2009), the minimum level for accuracy assessment in identification of LULCC for remotely sensed data should be at least 85%.

Table 4.3: Accuracy assessment

Sensor	Overall accuracy	Kappa statistics
Landsat 5TM-1995	91.9	91
Landsat 5TM-2011	86.1	82
Landsat 8Oli-2020	93.2	92

**TML-Thematic Mapper; Oli-Operational Land Imager*

1.2.4 Land cover distribution from 1995-2020

The catchment area was found to be equivalent to 1039 Km^2. There was consistent increase in Agricultural land at the expense of wetland and wood land area over the study period from 1995 to 2020 while area covered with open water remained relatively constant.

Table 4.4: Land cover distribution in Albert Nile catchment between 1995 – 2020

Land cover types and percentage							**Magnitude of change**		**Net gain/loss**
cover type	1995		2011		2020		1995-2011	2011-2020	1995-2020
cover type	Km^2	%	Km^2	%	Km2	%	Km^2	Km^2	Km^2
Open water	70	6.74	74	7.1	72	6.9	4	-2	2
Wetland	90	8.66	72	6.9	34	3.3	-18	-38	-56
Wood land	599	57.7	538	52	360	35	-61	-178	-239
Agric land	280	26.9	355	34	573	55	75	100	293
Total	**1039**		**1039**		**1039**				

The contribution of wetland to the total area in the catchment of Albert Nile declined consistently from 8.7% to 3.3% between 1995 and 2020 (Table 4.4). The case was not any different for wood land that was the largest land cover type with a share of 57.7% in 1995 reducing to contribute 35% of the total catchment area in 2020 (Table 4.4). As wetland and wood land declined, agricultural land increased from 26.9% to 55% of the total catchment area in 2020 (Table 4.4).

4.2.5 Land cover change detection

From the finding, significant changes detected were between wood land to agricultural land.

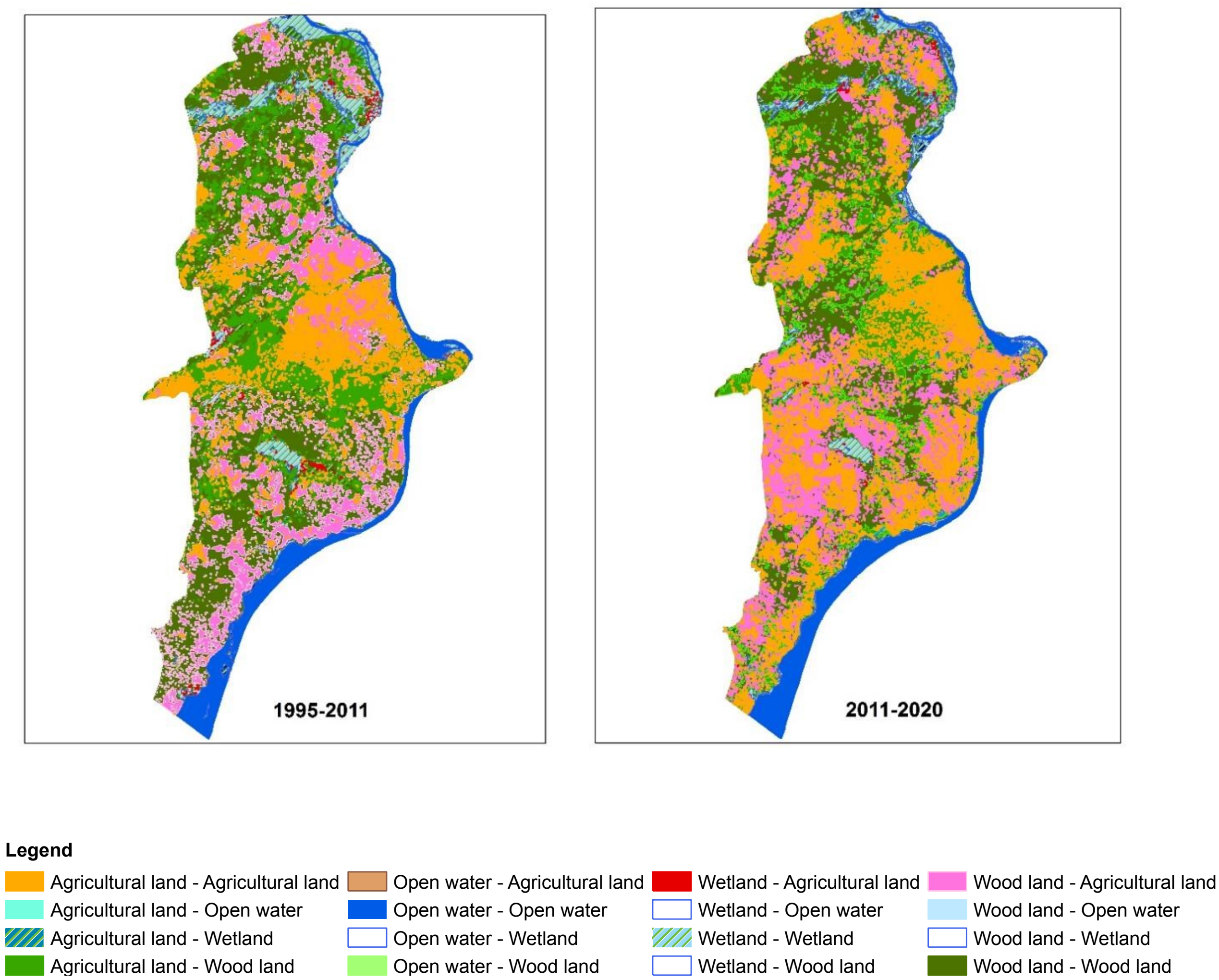


Figure 4.7: Change detection maps 1995-2011, 2011-2020 for Albert Nile catchment.

The decrease in wetland, wood land and increase in agricultural land was more pronounced between 2011 and 2020 compared to 1995 and 2011 (Figure 4.7). Whereas agricultural land was also converted to wood land, the change from wood land to agricultural land was much.

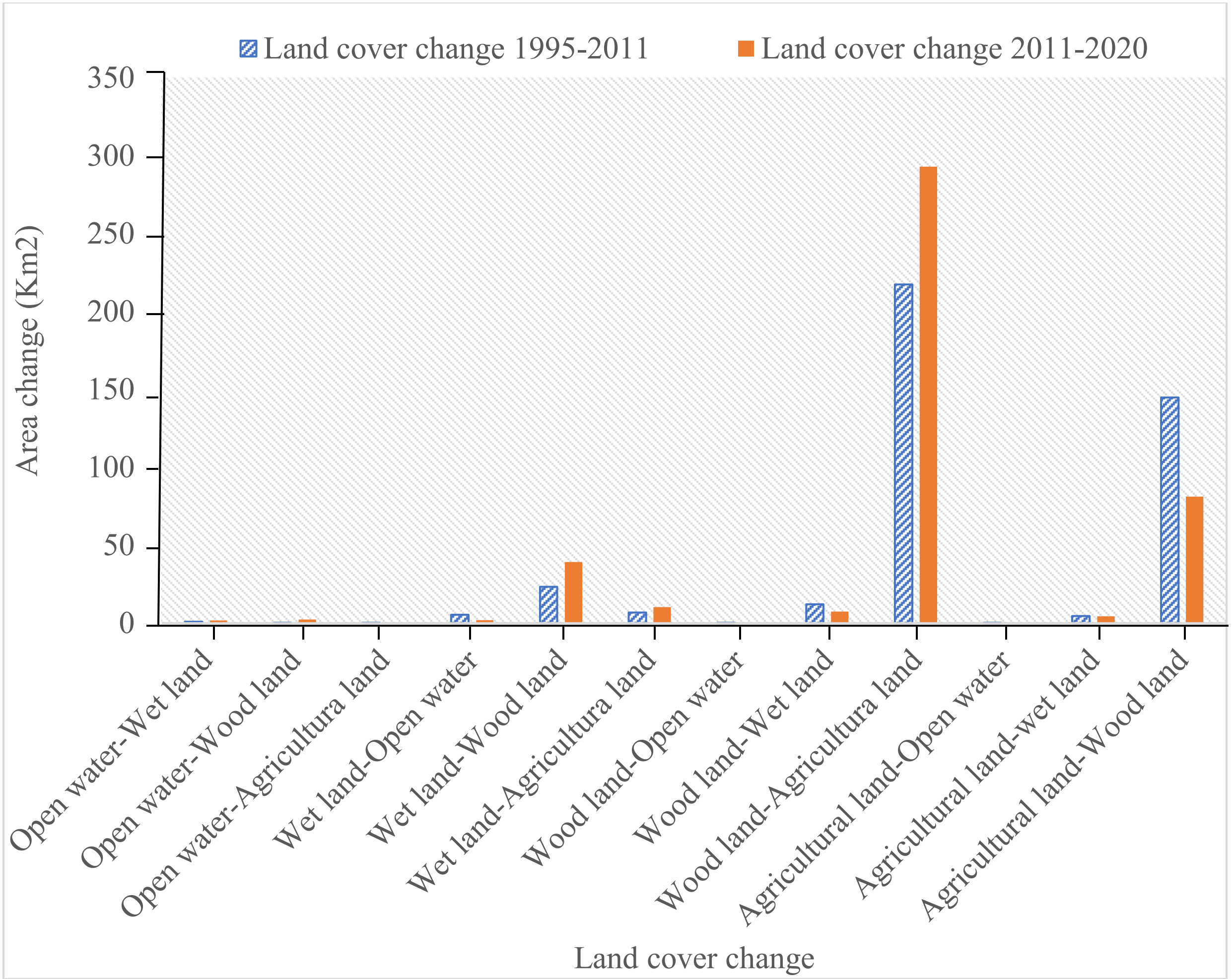
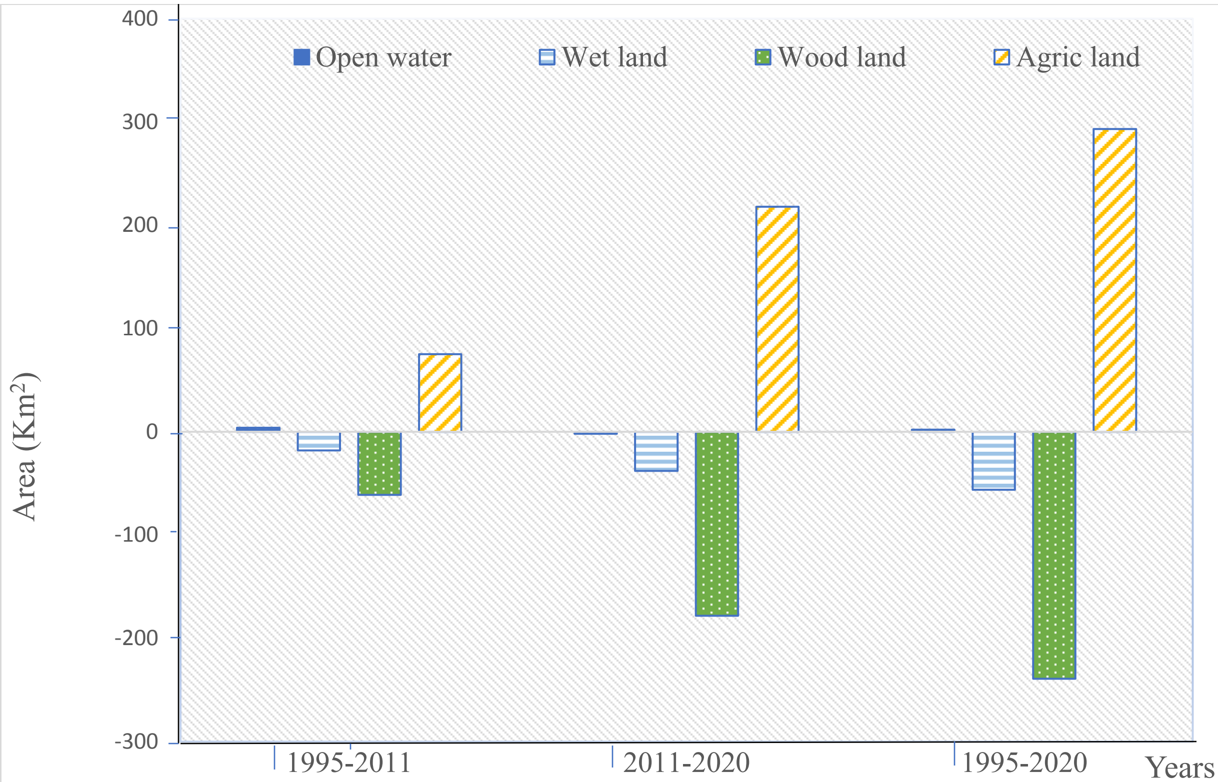


Figure 4.8: Land cover change for 1995-2011 and 2011-2020 in Albert Nile catchment

According to the analysis, 144.72 Km^2 and 81.27 Km^2 of Agricultural land was converted to wood land from 1995 to 2011 and 2011-2020 respectively against 217.43 Km^2 and 292.93 Km^2 of wood land converted to agricultural land from 1995-2011 and 2011-2020 respectively (Figure 4.8). Further analysis showed that area under wood land and wetland registered net loss while, land cover type under agricultural land registered net gain during study period 1995--2020.



	1995-2011	2011-2020	1995-2020
Open water	4	-2	2
Wet land	-18	-38	-56
Wood land	-61	-178	-239
Agric land	75	218	293

Figure 4.9: Gains and losses in land cover types in Albert Nile catchment

From 1995-2020, areas under wetland and woodland registered net loss of (56 and 239) Km^2 respectively, while agricultural land registered net gain of 293 Km^2 (Figure 4.9).

4.2.6 Community perceptions regarding drivers and challenges of the observed LULCC

About 68% of the respondents attributed the observed LULCC to human activity such as charcoal burning, clearing wetland and woodland for agricultural purposes and using soft wood tree species for making artefacts. Other drivers of LULCC were increased demand for human settlements, over grazing by the *Balaro* (herds men) and break down of cultural norms and institutional responsibilities regarding conservation. According to the respondents, serious change in land use land cover for Albert Nile catchment started in 2000.


(a)


(b)


(c)

Plate 4.4: Human induced activities in Albert Nile catchment (a) Charcoal burning, (b) Over grazing and (c) Artefacts making (Survey, 2021)

Much of the charcoal is transported (Plate 4.4a) to major towns and cities such as Kampala. The Balaro move with large herds of their cattle causing heavy grazing and devegetation (Plate 4.4b) while making of artefacts (Plate 4.4 c) was equally reportedly leading to cutting down of soft wood species of tree.


(a)

(b)

(c)

(d)

Plate 4.5: Some tree species being destroyed by human activities in Albert Nile catchment (Survey, 2021)

The pattern of LULCC has put several plant species under immense pressure especially indigenous tree species and medicinal herbs used for treating host of viral and bacterial infections. These species include, *Tamarindus indica* (Cwaa) (Plate 4.5a), *Ficus sycomorus*

(Olam) (Plate 4.5b), *Acacia seyal* (Okudu opiet) (Plate 4.5c), *Butyrospermum paradoxum* (yao) (Plate 4.5d), *Combretum mole* (Oduk) and others.

4.3 The status of water quality in Albert Nile

4.3.1 General observation on activities in the river bank of Albert Nile

Albert Nile river bank was dominated with papyrus vegetation (*Cyperus papyrus*) being actively exploited alongside artisanal fishing, farming especially vegetable gardening adjacent to the river bank and livestock grazing. The slope around the river bank is generally gentle slopping. Effects of floods such as destruction to gardens, homesteads and landing sites facilities were visible. Moving suds and invasive species such as Water hyacinth (*Eichhornia crassipes)* were present.

4.3.2 Water quality

After careful analysis of water quality parameters using data obtained from Ministry of Water and Environment (MWE) and National water and Sewerage Cooperation (NWSC), the results for the different water quality parameters and water quality indexes (WQI) for Albert Nile from 2005 to 2020 are presented below. All water quality parameters were compared against set standards to gauge the water quality status of Albert Nile.

4.3.3 Physical parameters of water

The finding showed a general increasing trend in the values for all the physical parameters.

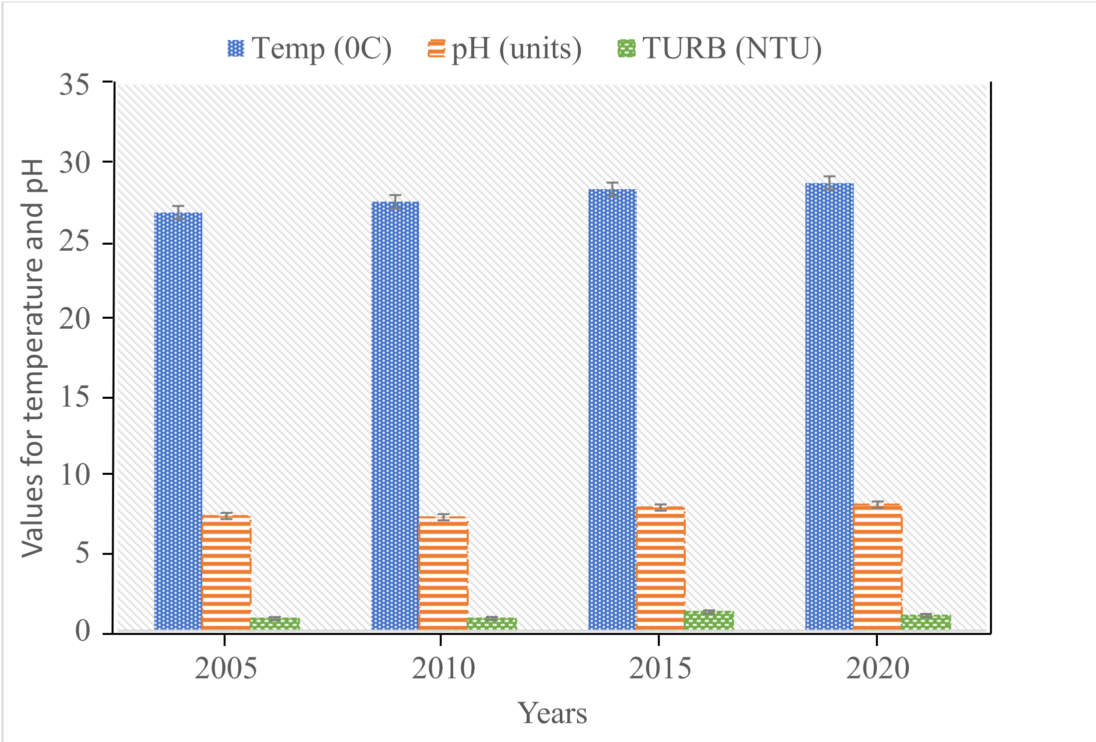


Figure 4.10: Physical parameters in Albert Nile water, 2005-2020 (MWE, 2005-2020)

From Figure 4.10; temperature ranged from (26.8-28.7) °C with a net increase of 1.9°C; pH ranged from (7.4-8.08) and Turbidity equally registered increasing trend (0.77-1.2) NTU over the study period 2005 to 2020 (MWE, 2005-2020). However, the increase in the values of all physical parameters were not significant; temperature [F (7,7) = 1.417, p=0.329]; pH [F (6,8) = 1.469, p=0.300] and turbidity [F (12,2) = 3.056, p=0.273] at $p<0.05$.

4.3.2 Chemical parameters (nutrients) of water

Finding further showed that nutrient species were generally on increasing trend over the study period 2005-2020.

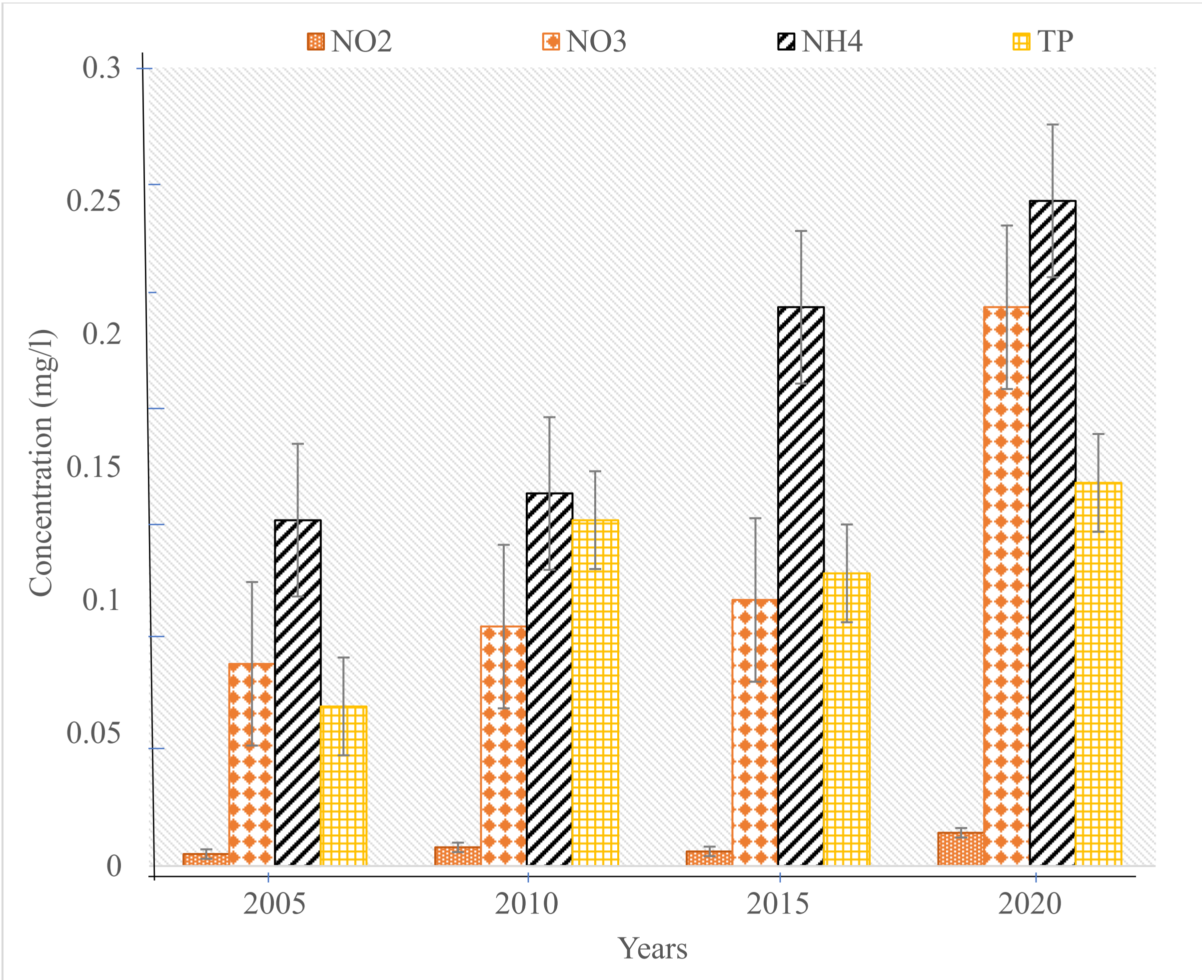


Figure 4.11: Concentrations of nutrients species in Albert Nile, 2005-2020 (MWE)

As indicated in Figure 4.11, the values for Nitrogen species; Nitrite, Ammonia and Nitrate were in the range of (0.0045-0.0125) mg/l, (0.13-0.25) mg/l and (0.076-0.21) mg/l respectively while total Phosphorous ranged between (0.06-0.144) mg/l from 2005 to 2020 (MWE, 2005-2020). However, the increase in the values of all nutrient species were not significant; [F (8,6) = 2.056, p=0.198], [F (12,2) = 3.056, p=0.273], [F (12,2) = 3.056, p=0.273] and [F (11,3) = 1.485, p=0.414] for Nitrite, Nitrate, Ammonium and total Phosphate respectively at $p<0.05$. By 2020, the concentration of both total Phosphorus (0.144±0.091) mg/l (Figure 4.11) and total Nitrogen (2.26±0.44) mg/l (MWE, 2005-2020) depicted a hypereutrophic state for Albert Nile much the concentration of Chlorophyll-a (7.85±0.44) mg/l puts Albert Nile water in eutrophic state.

4.3.3 Indicators of organic matter of water

The values of DO was declining throughout the study period, while, BOD and COD took the oppositely increasing trend over the study period from 2005 to 2020 (MWE, 2005-2020).

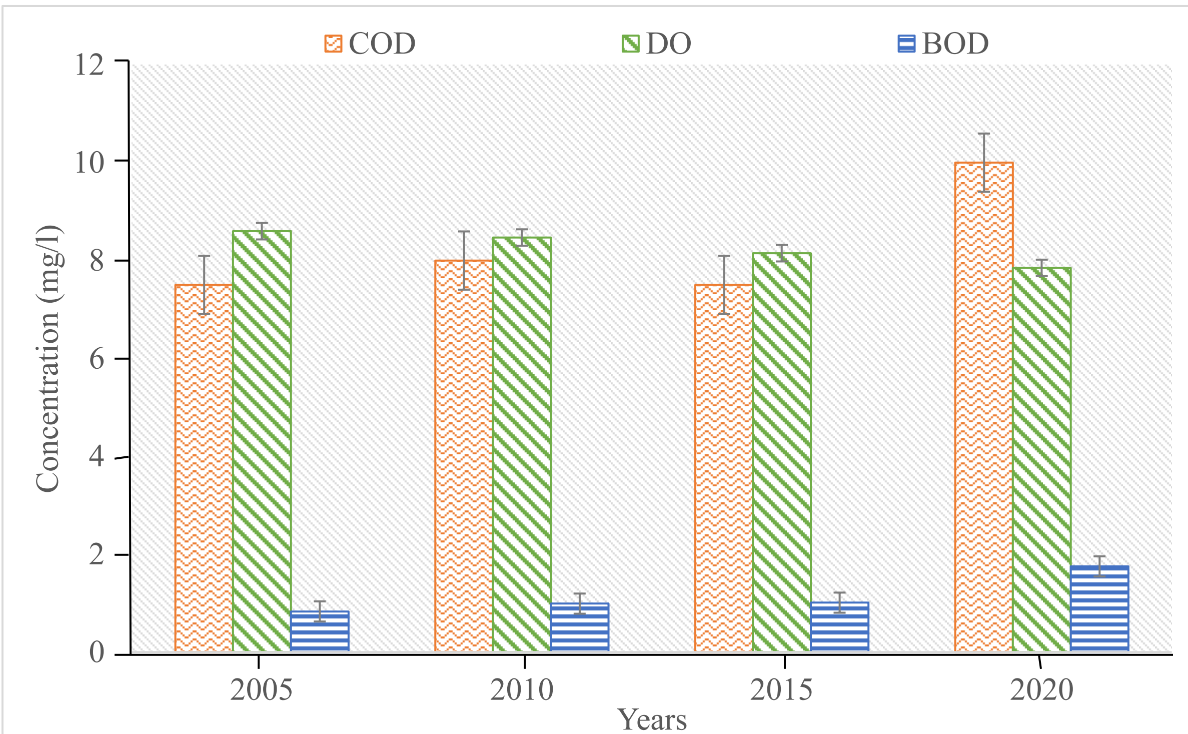


Figure 4.12: Concentrations of organic matter indicators in Albert Nile, 2005-2020 (MWE)

DO ranged from (8.6-7.85) mg/l, BOD ranged from (0.83-1.75) mg/l and COD ranged between (7.5-10) mg/l from 2005 to 2020 (Figure 4.12). To qualify the findings on organic matter indicators, negative correlation was found to exist between DO and BOD and DO and COD i.e., DO and BOD (r=-0.813, n=15, p=0.005) and DO and COD (r=-0.695, n=15, p=0.001 over the study period 2005-2020. However, decrease in DO or decrease in BOD and

COD were not significant; [F (12,2) = 3.056, p=0.273], [F (5,9) = 2.215, p=0.142] and [F (12,2) = 3.056, p=0.273] for BOD, COD and DO respectively at p<0.05.

4.3.4 Water quality index (WQI)

The water quality index (WQI) for Albert Nile registered a decreasing trend over the study period 2005 to 2020.

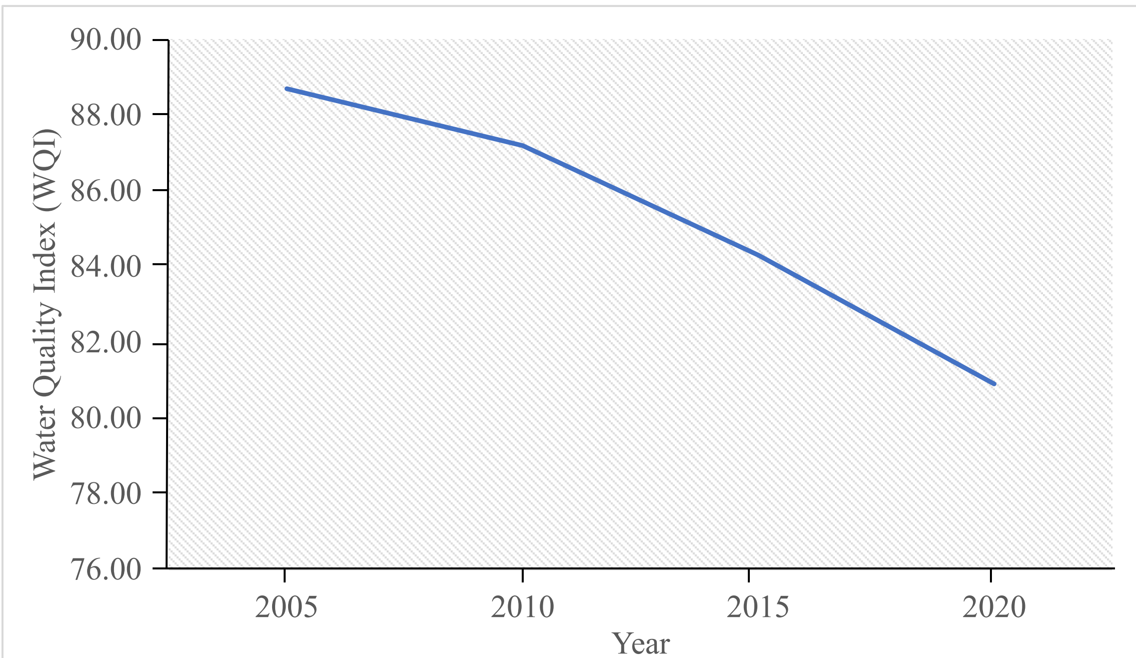


Figure 4.13: Values of water quality index (WQI) in Albert Nile water, 2005-2020.

Between 2005 and 2020, the WQI decreased from 88.7 to 80.9 (Figure 4.13). According to the classification of Sanchez *et al*. (2007) and Pesce and Wunderlin (2000) the water quality of Albert Nile was still in a good state.

4.4 The level of fishing pressure in Albert Nile fisheries

Albert Nile fishery was dominated by prohibited fishing gears especially gears of un recommended sizes. The multifilament nets (MU) and monofilament nets (MO) are of 2-3 panels and at least 500 yards which are all un recommended. There are many illegal landing sites encouraging illegal fishing. The findings on fishing pressure are presented below.

4.4.1 Comparison of fishing effort and fish catch over the past 10 years

According to the findings, fishing effort in terms of input generally increased from 2012 to 2021. However, there was a mismatch between input efforts and output efforts because efforts in terms of output was instead on the decline over the study period.

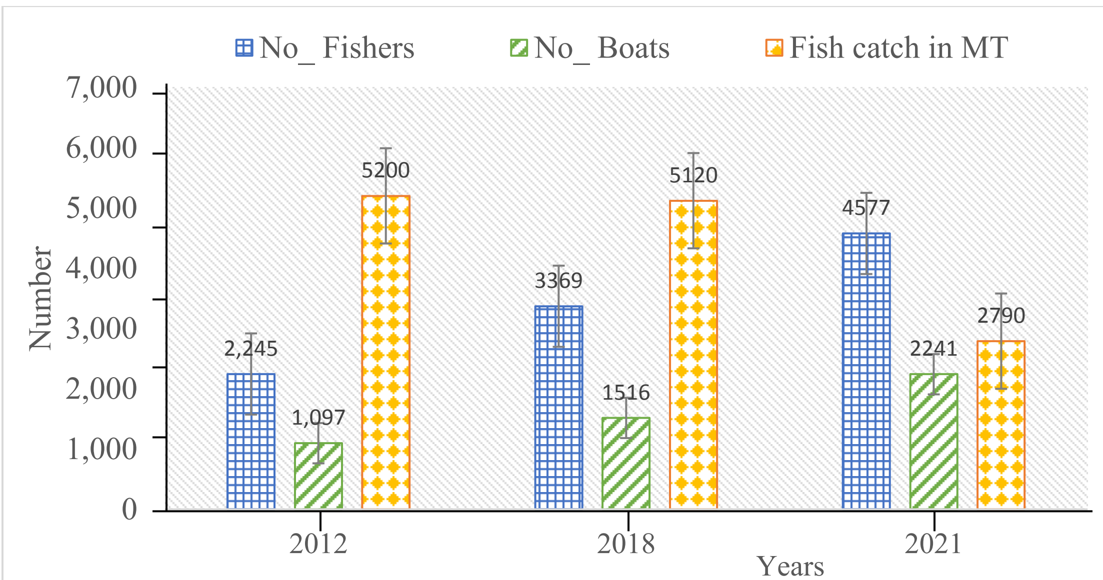


Figure 4.14: Change in number of boats and fishers compared to fish catch over the years for Albert Nile (NAFIRRI, 2012 and 2018; Survey 2021).

In comparative term, input effort increased over the years while output declined. Fish catch declined from about 5000 MT to less than 3000 MT between 2012 and 2021 (Figure 4.14).

Further analysis indicated a general increase in the number of fishing gears, whether illegal or legal used for catching fish in Albert Nile fishery.

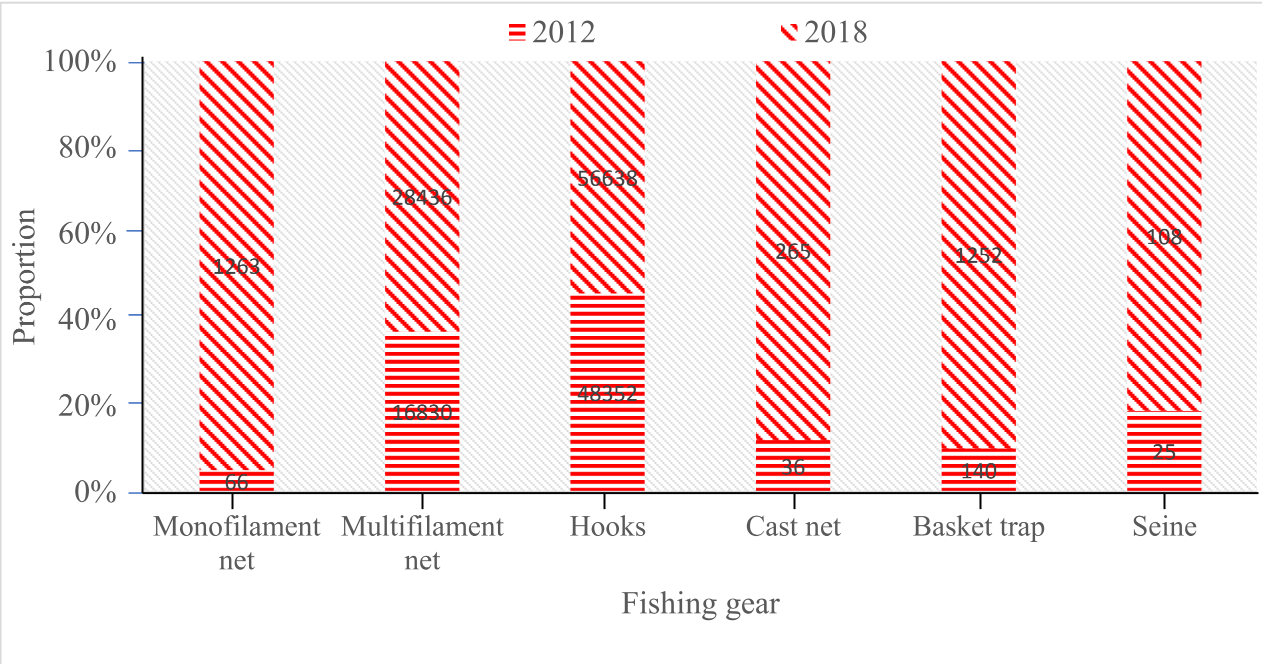


Figure 4.15: Trend in number of all fishing gears in Albert Nile fishery, 2012-2018 (NaFIRRI, 2012 and 2018)

Fishing gears such as monofilament and cast nets registered drastic increase over the year, 2012 to 2018 (

Figure 4.15). The general increase in the fishing gears also meant drastic increase in the number of un-recommended fishing gears as revealed by the findings from documentary review shown in (

Figure **4.16**).

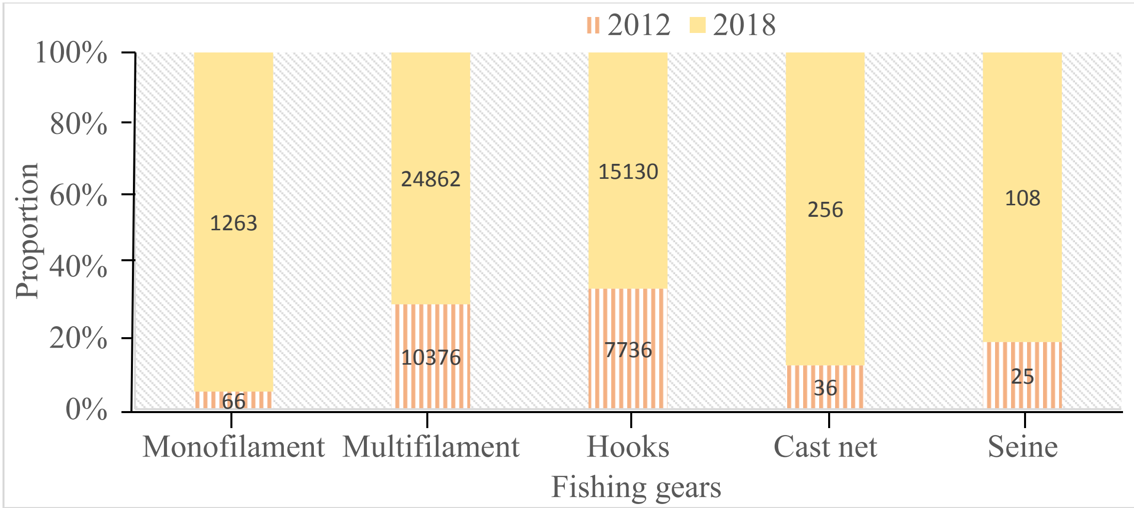


Figure 4.16: Trend of un-recommended gears in Albert Nile fishery 2012-2018 (NaFIRRI, 2012 and 2018)

There was drastic increase in the usage of prohibited fishing gears such as cast nets and seine, monofilament nets and hooks for catching fish over the year 2012 to 2018 (

Figure *4.16*) and (Plate 4.6).


(a)

(b)

Plate 4.6: Some of the Illegal fishing gears in Albert Nile fishery (a) seine net, (b) monofilament net (Survey, 2021)

During the survey there was clear evidence of illegal fishing gears especially the destructive seine nets (Plate 4.6a) monofilament nets (Plate 4.6b) and other un recommended gears that flooded most of the landing sites.


(a)


(b)

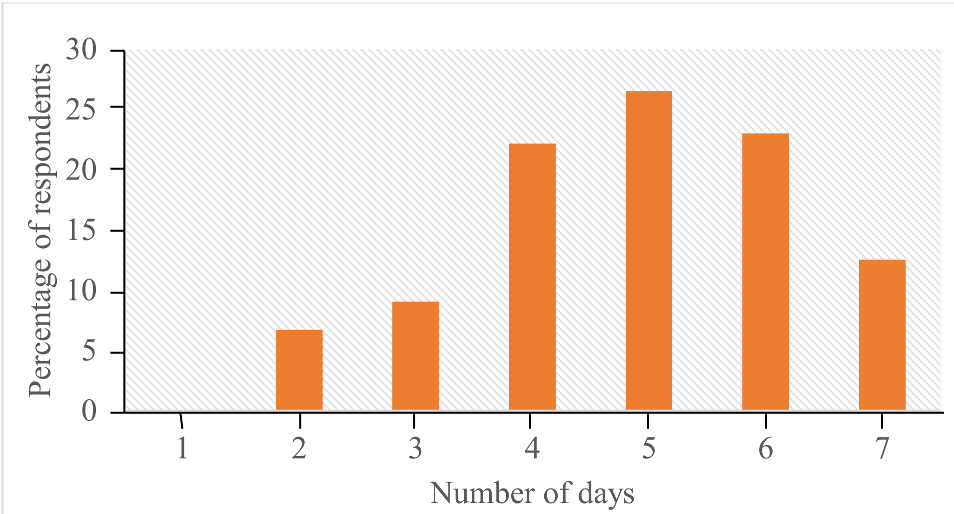
Plate 4.7: Some of the recommended fishing gears in Albert Nile fishery (a) woven basket, (b) multifilament net (Survey, 2021)

It was quite rare to sight recommended fishing gears especially the multifilament net (Plate 4.7) in most landing sites during the survey.

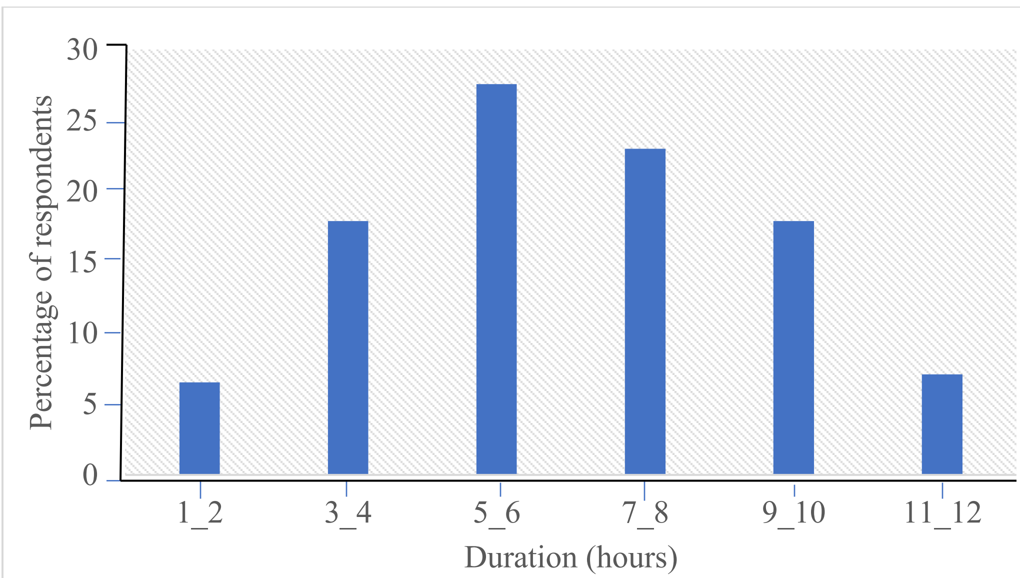
4.4.2 Fishing frequency and Catch Per Unit Effort (CPUE)

Fishing frequencies

Finding of CAS survey (2021) indicated that the fishers are spending much of their time on fishing activities.



(a)



(b)

Figure 4.17: Fishing duration in Albert Nile fishery (a) Number of days fished in a week, (b) Number of hours fished in a day (Survey, 2021)

Most fishers spent much of their time in fishing (Figure 4.17a and b). On average, the fishermen were spending 5±1.3 days per week and 6.5±2.7 hours per day on fishing trips. The modal number of days spent on fishing per week was 5 while the modal hours spent on fishing per day was 6.4.

Catch Per Unit Effort (CPUE)

The average CPUE was 6.95±4.06 kg/boat/trip with a range of (2.20 to 12.30) kg/boat/trip.

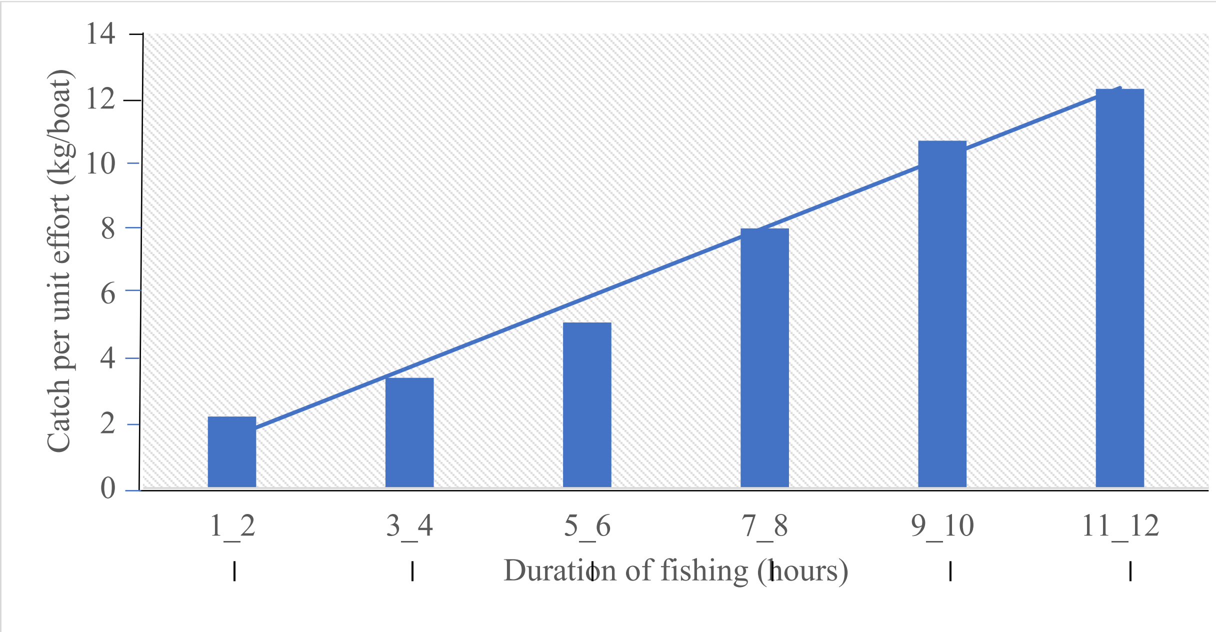
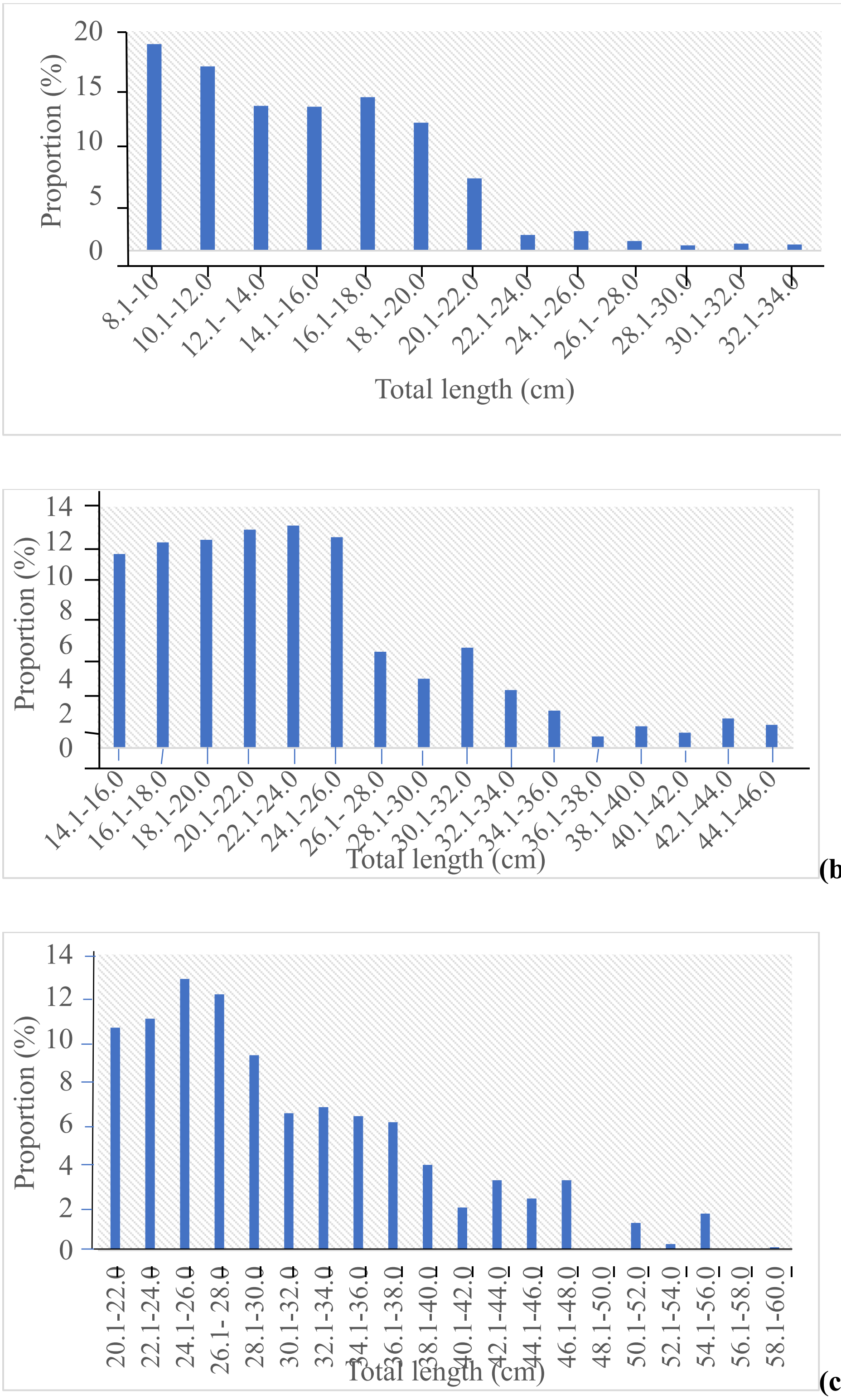


Figure 4.18: Comparing duration of fishing and catch per unit effort in Albert Nile fishery (Survey, 2021)

CPUE was found to be directly proportional to the duration of fishing (Figure 4.18). The result of Pearson product-moment correlation test showed a strong, positive significant correlation between fishing duration and CPUE (r = .992, n = 6, p = .001). The linear regression analysis also showed high degree of correlation R=0.992, R^2=0.983, p =0.0005.

4.4.3 Length of fish caught in Albert Nile

More than 90% of the *Alestes baremose* and *Lates niloticus* sampled were of un recommended length size of 20 cm and 50 cm respectively and at least 70% of the *Oreochromis niloticus* were of un recommended size of less than 28 cm.



(a)

(b)

(c)

Figure 4.19: Length frequency for (a) *A. baremose*, (b) *O. niloticus*, (c) *L. niloticus* in Albert Nile fishery

The length ranges were; *A. baremose* (8.3-33.5 Cm), *O. niloticus* (14.6-45.7 Cm) and *L. niloticus* (20.5-59.0 Cm) (Figure 4.19a, b and c). Under sized and immature species were found to have low beach values, mature *A. baremose* could fetch 18,300= Ugx equivalent of 4.1$ while undersized ones could hardly fetch 3,000= Ugx (0.8$) per Kg.

4.4.4 Fish Biodiversity

4.4.4.1 Species composition

A total of 53792 fish samples were collected belonging 16 different species encountered between October 2021 and January 2022. Averagely, 5379±1058.1 per sampling points, with a range of 3861.00 - 6921.00.

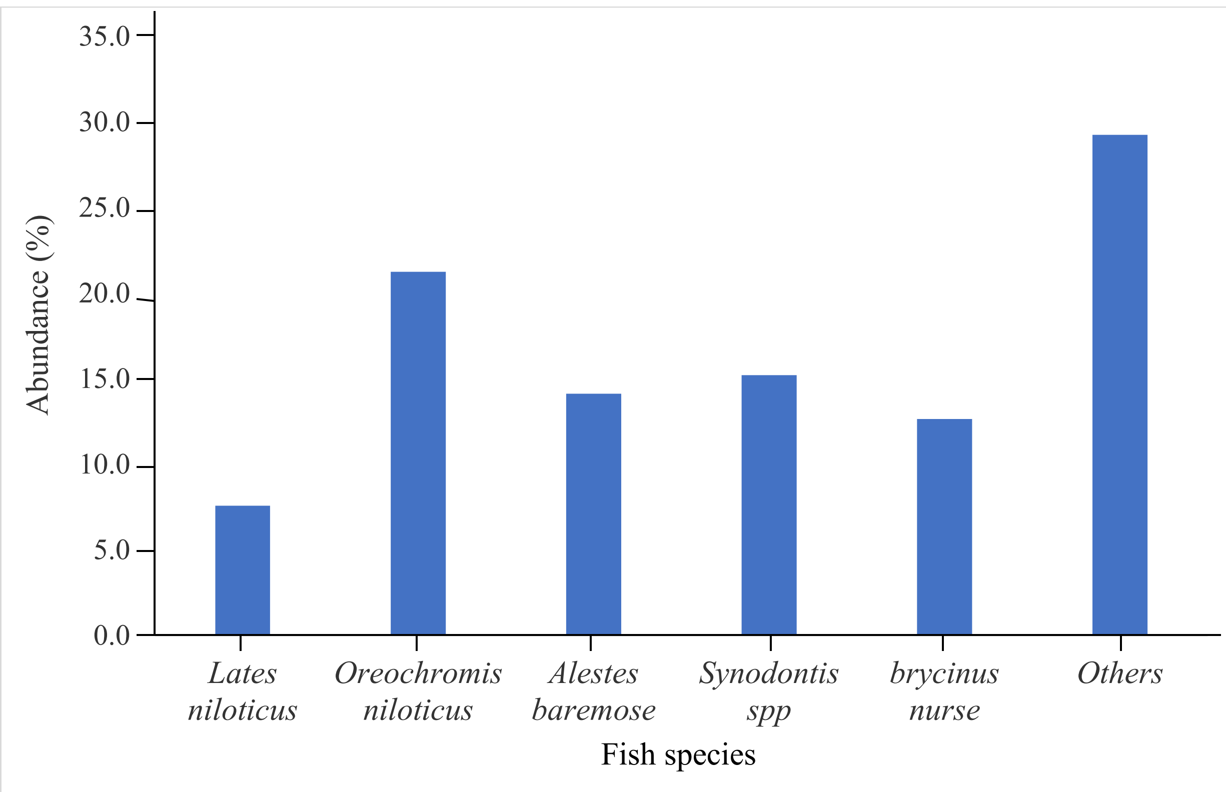


Figure 4.20: Dominant species contributing to the catch composition in Albert Nile fishery (Survey, 2021)

Only three large species; *O. niloticus, A. baremose and L. niloticus* were dominant species in the catch, with *O. niloticus* the most dominant species (Figure 4.20). The contribution from the small pelagic species of low beach value is quite considerable with *Synodontis ssp and B. nurse* combined contributed close to 30% of the total catch composition. Some species were reportedly appearing once in a blue moon especially *haplochromines* s*sp*.


(a)

(b)

Plate 4.8: Some of the dominant fish species (Survey, 2021)

Some of the dominant fish species observed during the survey, *O. niloticus*, (Plate 4.8a) and *L. niloticus* (Plate 4.8b).

4.4.4.2 Spatial species abundance

In terms of spatial abundance, the sampling sites contributed species composition differently to the abundance during the study period. Most noticeable was that *H. forskali and P. senegalus* were not uniformly distributed among the sampling sites. More than 70% of *H. forskali* was contributed by only the first two sampling sites downstream (Ogal and Wangkado) that are nearer to Lake Albert. Meanwhile, only the last four sampling sites upstream (Padhoch, Jacan, Akello and Mutir) contributed 70% of the *P. senegalus* (Figure 4.21). However, there was no significant difference among sampling sites in terms of the species composition as determined by one-way ANOVA test (F (9,150) = 0.505, p = 0.869).

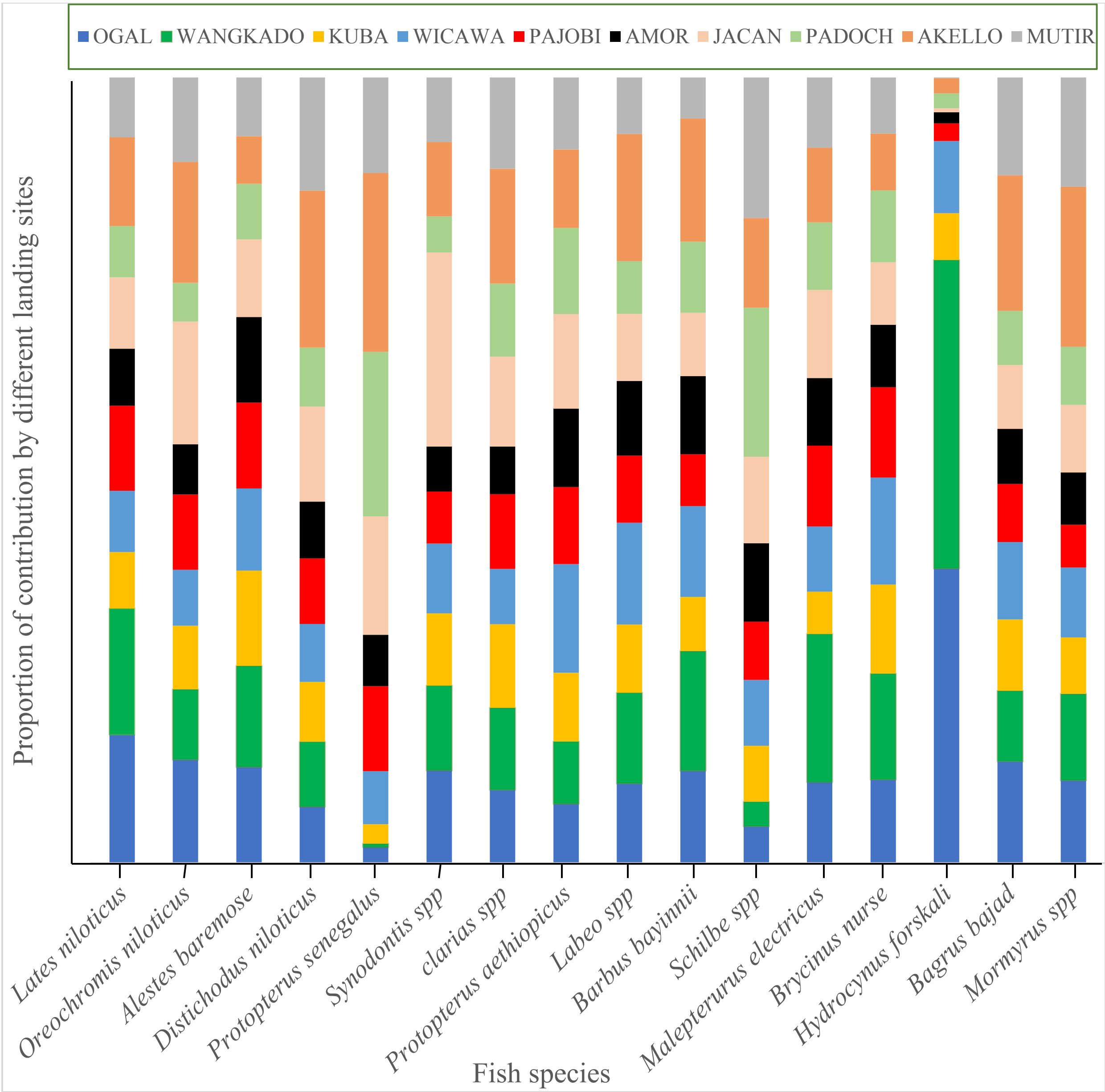
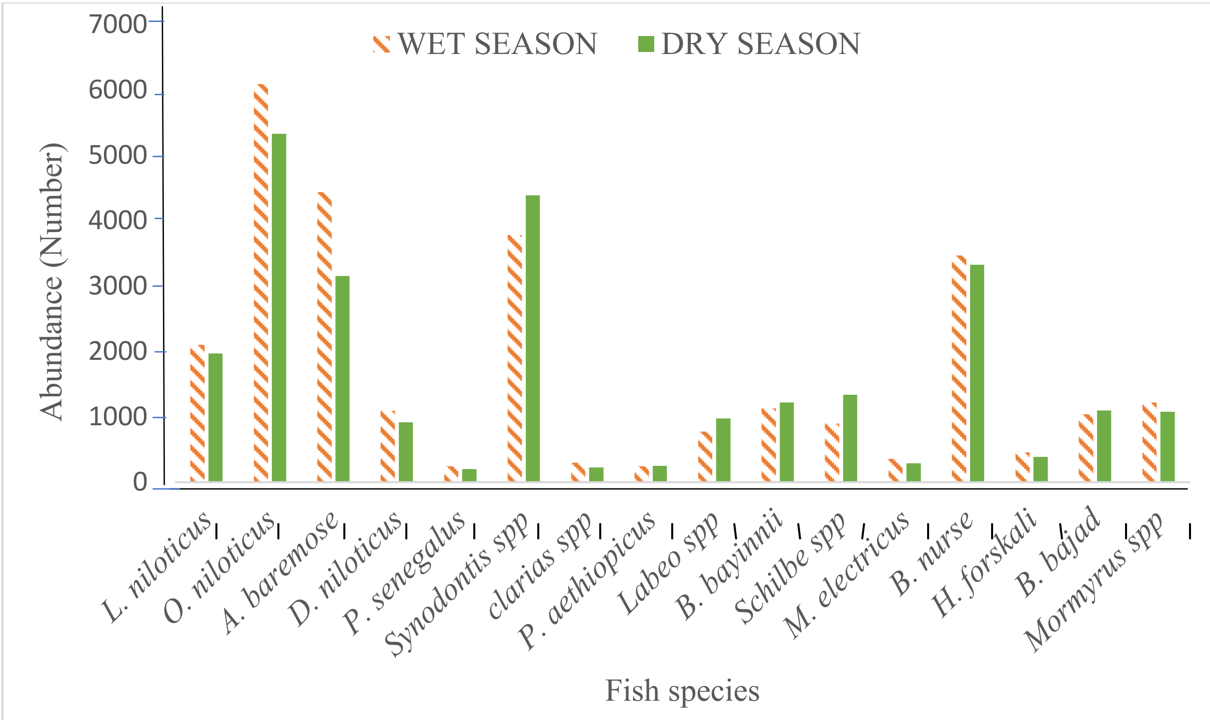


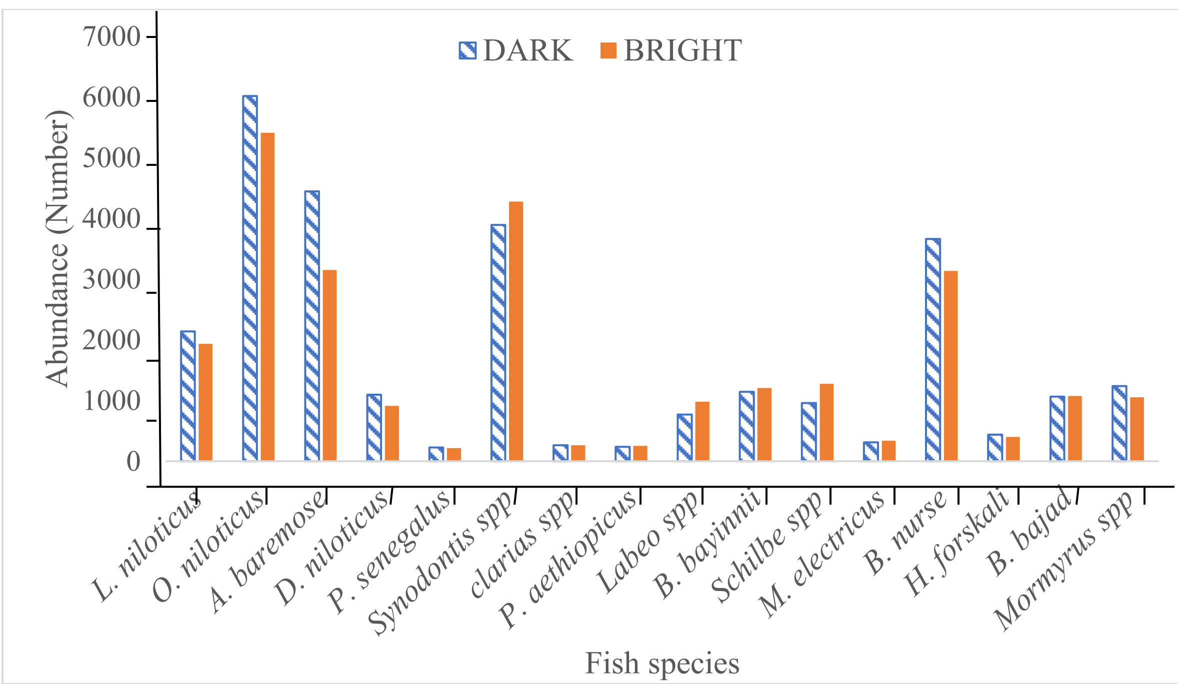
Figure 4.21: spatial species abundance in Albert Nile fishery (Survey, 2021)

4.4.4.3 Temporal species abundance

Species abundance for wet season months (October and November), dry season months (December and January), dark phase of the moon and bright phase of the moon between October and January 2022 were analysed and presented below.



(a)



(b)

Figure 4.22: Temporal species abundance in Albert Nile fishery (a) Dry and wet season (b) Dark and bright moon phase

The abundances of species were affected differently by wet season, dry season, dark moon phase and bright moon phase (Figure 4.22a and b). However, the result of independent t- test showed no significant difference in the means for species composition; for dark and bright moon phase, $t(30)=0.214$, $p=0.832$; for wet and dry season, $t(30)=0.158$, $p=0.876$.

Further analysis was done to ascertain the effect of the interaction between moon phases and rain factor whose finding is presented below.

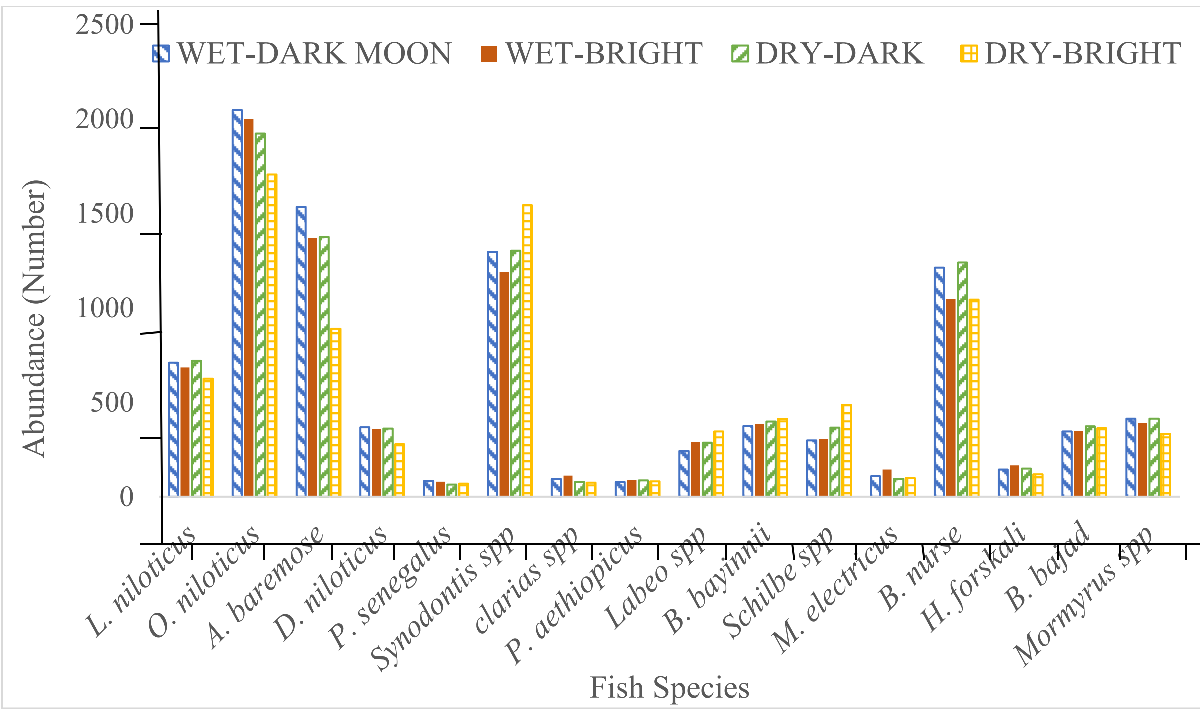


Figure 4.23: Interaction between rain and moon factor as determinants of fish catch in Albert Nile fishery (Survey, 2021)

The interaction between rain factor and moon phase appeared to have affected species abundance (Figure 4.23), however, two-way ANOVA test showed no significant interaction between the independent variables, rain factor and moon phase on fish catch $F(1, 60) = 0.007$, $p = 0.935$.

4.4.4.3 Spatial and temporal diversity index

The species richness was equivalent to a total of 16 species recorded.

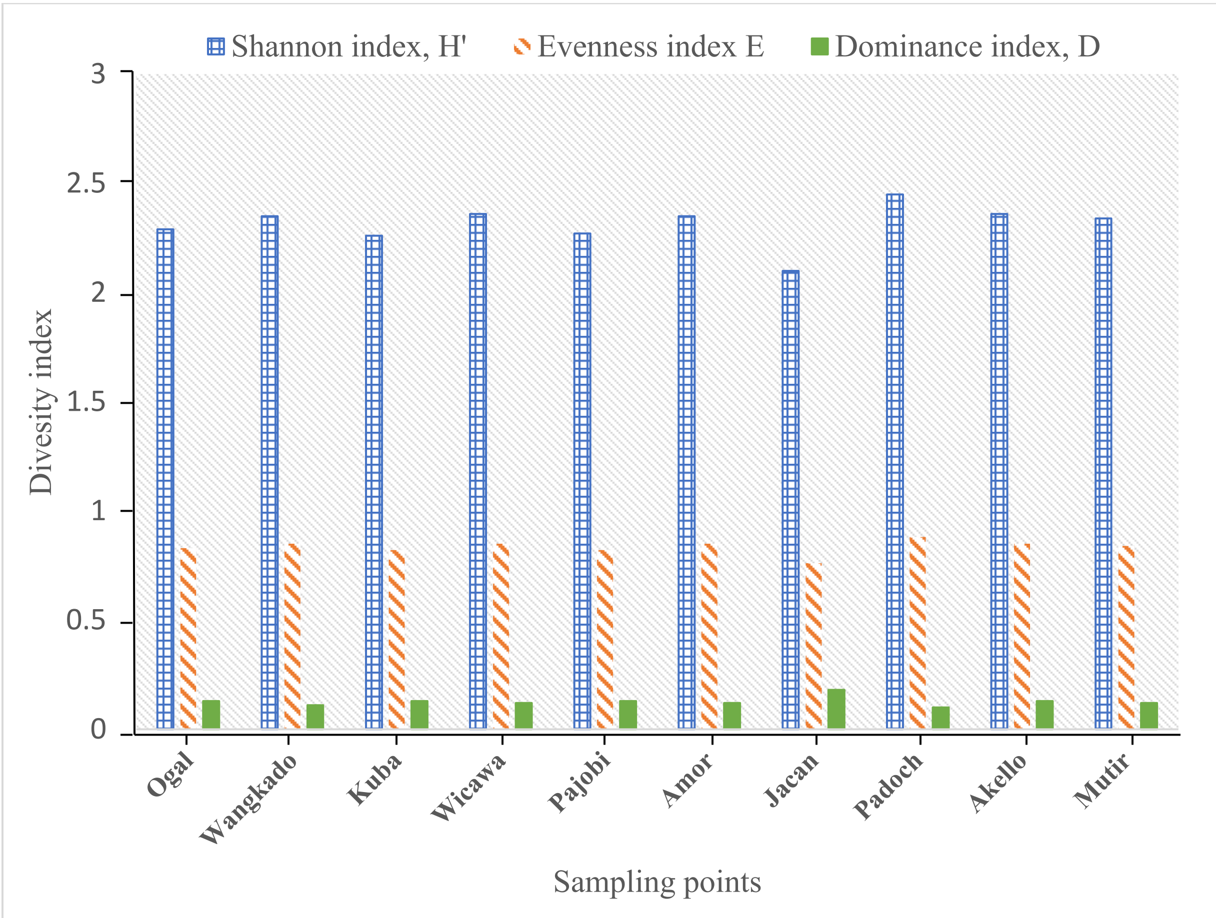


Figure 4.24: Spatial diversity index for Albert Nile fishery (Survey, 2021)

Mean diversity indexes from the different sampling points were; H'= 2.31±0.09, E= 0.83±0.03 and D=0.13±0.02. (Figure 4.24). Padoch landing sites had the highest diversity with H'=2.38, E=0.18 and D=0.1. Generally, upstream landing sites registered high diversity. The result of Pearson correlation test showed a strong, positive correlation (r = .997, n = 10, p < .01) between H' and E and a strong, negative correlation (r = -.998, n = 10, p = .000) between H' and D.

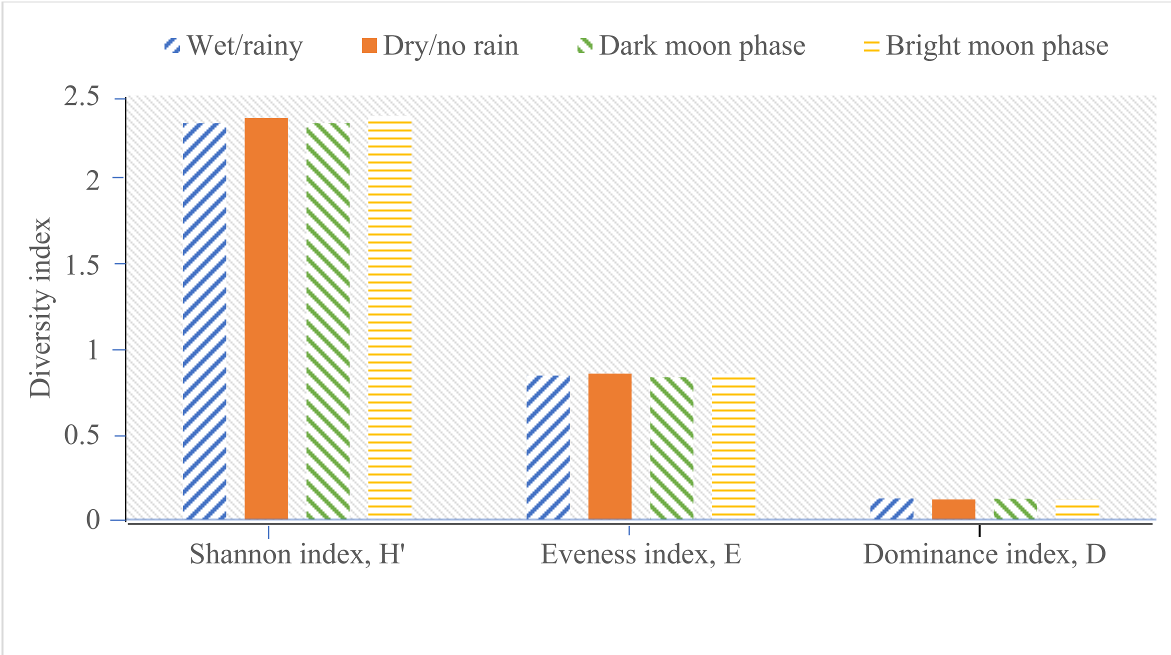


Figure 4.25: Temporal species diversity index for Albert Nile (Survey, 2021)

Mean diversity indexes for the different seasons were, H', 2.36±0.02 with a range of 2.33-2.38, E, 0.85±0.007 with a range of 0.84-0.86 and D, 0.12±0.004 with a range of 0.11-0.12 (Figure 4.25). The result of Pearson correlation showed a perfect, positive correlation (r =1 .000, n = 4, p = .000) between H' and E and a strong, negative correlation (r = -.998, n = 4, p = .000) between H and D.

Rank abundance curve was equally used to visualize both species richness and evenness

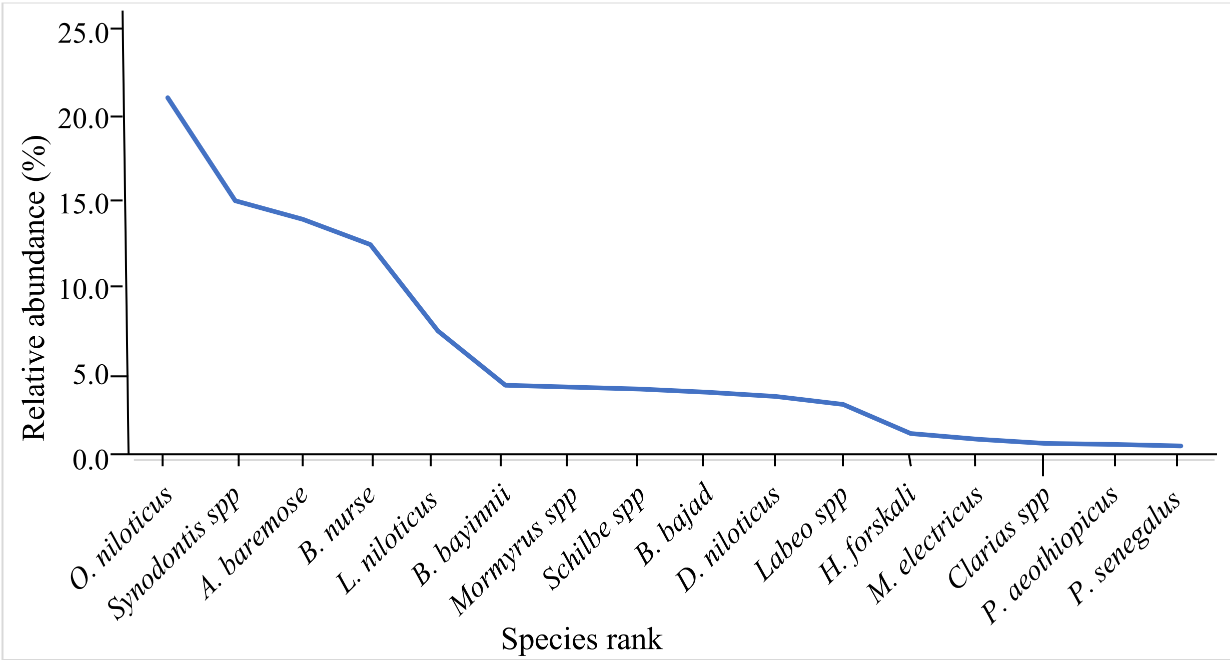


Figure 4.26: Species rank abundance curve for Albert Nile fishery (Survey, 2021)

The generally shallow gradient observed with the species rank abundance curve (Figure 4.26) was an indication of high evenness which is only achieved when no single species dominate in the habitat.

CHAPTER FIVE: DISCUSSION OF RESULTS

5.1 To assess the socio-economic activities and status of the fishers in Albert Nile fishery

5.1.1 Socio-economic activities

Out of the many socio-economic activities, fishing was quite dominant and could be the one affecting the SSF of Albert Nile to a larger extent. Over 90% of respondents depend on fishery as main source of livelihood. This finding is related to Uganda National Household Survey (UNHS) which reported that agricultural sector, fisheries inclusive employed more than 60% of Ugandan, more than any other sector of the economy (UBOS, 2020).

According to Failler *et al.* (2016), the lack of alternative livelihood options such as trading can easily drive many people into agricultural activities such as farming and fishing. To worsen the matter further, some youths engaged in extraction of snail from beneath the water could not continue with the activity due to flooding and Bilharzia (*Schistosoma ssp*) infestation. Such lucrative activities would relieve some pressure on Albert Nile fishery. This means most of these youths have to find their ways into the Albert Nile fisheries for their livelihood. The implication of such over dependence on natural resources is obvious as it will lead to degradation of the resource base in Albert Nile fishery (Failler *et al.*, 2016).

5.1.2 Sex and age aggregation of the fishers

Women dominated in the post-harvest handling of fish while men dominated as crew possibly due to the cultural perception that active fishing is a preserve for male. This observation is similar to findings by Luomba & Salehe (2013) who reported most women in Uganda fisheries as involved in post-harvest handling of fish. Frangoudes & Gerrard (2018) however argued that the numerical disadvantage of women in the activities that occur on the water sideline and make them voiceless on pertinent issues regarding fisheries. SSF guidelines equally recorgnises full participation of women along all the value chains and advocates for their inclusion in decision making processes regarding fisheries. According to the UN SDG 5, women are entitled to equal rights and access to economic resources. (Kleiber *et al*., 2017; Frangoudes *et al*., 2013b; Gallardo & Sauders, 2018) point out that where women are involved in fish harvesting, they show high capacity to manage the resources and formulate rules than men, who only give more attention to fishing operations.

The recent population explosion should be responsible for changes in the population structure majorly composed of younger people especially in sub–Saharan Africa and in rural areas where jobs may be difficult to find (FAO, 2017). NPA (2020) reported 78% of Ugandan population being youthful, aged 30 years and below with unemployment rate of 13.3%. According to UBOS (2020), only 27% of Ugandan youths transited to stable jobs meaning inadequate stable employment opportunities for the youth. The current finding of high proportion of the youth is expected to intensify competition and increase fishing pressure. This makes it difficult to achieve sustainable exploitation of natural resources supportive to the economy of Uganda, enshrined in NDP III (NPA, 2020)

5.1.3 Household characteristics of the fishers

The current finding of higher proportions, more than 60% of fishers who fail to complete primary education is a clear sign that the fishing communities are preferring fishing activity to education. UNHS (2018) similarly reported low completion rate at about 60% and 34% for primary and secondary schools in Uganda respectively. This is contrary to UN SDG 4 of inclusive and equitable education for all citizens of the world. Such trend is dangerous and implies flooding of Albert Nile fishery with resultant consequence of unsustainable exploitation of Albert Nile characterized with over fishing.

The current finding of household size equivalent to averagely 9.8 ±3.33 and a mode of 8.3 is much higher than the national average of 4.5 and 4.8 persons per household in rural setting (UDHS, 2016). Such large household sizes coupled with Uganda's high dependency ratio of more than 90% (World bank, 2022) may compel fishers to increase fishing efforts to meet house hold demands. The large household sizes observed in the current study could be attributed the high level of illiteracy among the fishers hence low uptake of family planning measures to regulate birth rate. No wonder, more than 60% of the fishers could not afford to provide adequate meals in their families. This is similar to FAO (2010) report of billion people suffering from hunger and malnutrition worldwide especially in developing countries. Panyango community development project final baseline study report (2021) equally found 56% of the households in Panyango sub county, part of the study area failing to afford 3 meals daily. Whereas UN SDG 2 aims to end hunger by 2030 (UN, 2017), 6 out of 10 households in Northern Ugandans were food insecure as UBOS (2020) reported.

The incidents of food insecurity can be attributed to the fact that most youth and adult men are taken up by fishing activities whose economic viability has unfortunately declined. Only women and children are left to cultivate which cannot meet the food demand of the household coupled with the large house hold size.

The current finding of 70% mud and wattle house types can be attributed to the high rate of poverty. Northern Uganda is one of the most chronically poor regions at 21.6%, while in Pakwach district, poverty rate stands at 31% well above the national average of 8.5% (UBOS, 2018). However, the fact that at least 50% of the fishers could afford mattresses to sleep on is a sign that the fishers are working hard to improve their socio-economic status. Therefore, the large household sizes, incidence of food insecurity, chronic poverty coupled with Uganda's high dependency ratio of more than 90% (World Bank, 2022) may compel fishers to increase fishing efforts to meet house hold demands.

5.1.4 Asset ownership

The low level of assets accumulation of more than 70% of the fishers without fishing assets may be attributed to the fact that the fishery is dominated by the youths who are transiting into to the work force group and have not had time and opportunity to accumulate wealth. Fishers reported reduced economic viability of the fisheries and low level of financial literacy as the reasons for low level of assets accumulation. However, fisherfolk's dissolute lifestyles of drunkenness and belief of daily earning; highly capitalistic mode of sharing proceeds from fishing activities with gear and vessels owners should not be ignored regarding low level of assets accumulation among the fishers.

The low level of asset accumulation is as well supported by the current study findings of; low level of financial literacy of just 18%; low level of saving with less than 50% fishers affording to save in their village savings and less than 5% owning commercial bank accounts. This implies the fishers are not saving enough to accumulate assets. Panyango community development project final baseline study report (2021) found that only 3.9% of the house hold in part of the study area had bank account and 43% individuals were saving averagely UGX 5,500 (1.5 USD) a month.

The current findings of very low rate of saving among the fishers implies the fishers of Albert Nile are far from achieving increased household incomes and improved quality of life as envisioned in NDP III (NPA, 2020). However, some fishers reported that the money they get from fishing is being consumed up by domestic, school fees and health services expenses. The implication of being assetless is that fishers will have to engage in fishing activities continuously sometimes using destructive means to meet their livelihood demand.

The survey finding of high level of land fragmentation is supported by Annual Agricultural Survey (AAS) conducted by UBOS (2018) which reported more than 95% of land ownership in northern Uganda as characterized by high level of fragmentation and low level of fertility and productivity. Land right decisions are highly influenced by older men, UBOS (2018) reported 31.1% of female and youths with rights to land. This leaves women and youth not only voiceless but with very limited access to land for farming. Land fragmentation may be attributed to population pressure. The implication of land fragmentation, exhaustion and limited access right will be massive entry into Albert Nile fisheries by the youths in search of alternative livelihood.

5.1.5 Management and governance of the fishery

The observed low level of fishers registering with landing site management committee (LMC), less than 20% and inadequate access to extension service may stem from the weak relationship that exist between the fishers and the authorities. According to Allison and Edward (2003) fisheries officials describe fisherman as excessively greedy, myopic, and unpatriotic while fishermen on the other hand feel that the officials behave like policemen. Hence the fisherfolk learn to avoid officials and continue breaking the law.

Much as many literatures focus on the lack of good governance regarding fisheries policies in Uganda, Kjaer *et al*. (2012) concluded that implementing policies regarding sustainable fisheries comes with short-term political costs of failing to attract votes for the political elite to remain in power. According to Pinello *et al.* (2017), the traditional top-down approach of regulating fisheries in which fish is placed before fishers is un sustainable as it does not address the root cause of livelihood related fishing pressure hence undermining the principle of sustainable livelihood. Membership to the LMC body is therefore, left to boats owners, fishers are hesitant to enforcement. Many ungazetted landing sites have been opened to carry out illegal fishing under the open access manner which in the long run puts the future of Albert Nile fishery in jeopardy contrary with the expectation of UN SDG 14 of sustainable use of the fisheries resources (UN, 2017).

The fact that most facilities were flooded and no contingence measures taken by authorities may be regarded as a sign of neglect of SSF by authorities despite of the substantial contribution of the sector to the local livelihood. Amenities such as fish slab and good road networks are necessary to reduce post harvest losses which is a common problem in most SSF (Gallardo & Sauders, 2018). Women may be affected disproportionately since majority are in post-harvest value chain.

In summary, the high proportion of youth in an ever-growing population coupled with occupational and geographical immobility as a result of limited education, employment opportunities, access to land, productivity of the land and fishing assets has resulted into flooding of Albert Nile fishery. The implication is intensified competition, overexploitation and a destructive loop in which degradation leads to further competition, triggering further resource degradation. This makes the fishers vulnerable to shock, stress and trend; they continue fishing with the perception of open access right hence vicious cycle of unsustainable utilization of Albert Nile fishery. Un like men, the livelihood of women can be affected disproportionately by the collapse of this fishery due to high chance of geographical immobility compared to men.

5.2 Land use and land cover change in catchment of Albert Nile, 1995-2020.

Over the study period 1995-2020, wetland and wood land registered net loss while agricultural land registered net gain. This phenomenon could have resulted from the increase in both subsistence and commercial agricultural activities in the catchment of Albert Nile. The current finding is similar to finding by UBOS (2019) in which woodlands, grasslands, bushlands and wetland were converted to small-scale farmland in the catchment of Albert Nile by 2015 such that about 60% of the total land cover was attributed to small scale farm land and 40% shared by the rest of the other land use and cover types in the catchment of Albert Nile (UBOS, 2019).

The state of environment reports by Pakwach district local government (2018) indicated that incidents of reclaiming wetland and the general encroachment on the wetland of river Ora and Albert Nile in Wadelai Sub- County have resulted into deadly floods annually. Wetland and wood land provide both direct and indirect benefits to the communities (NEMA, 2018). The direct benefits include the activities like crop production, papyrus, reeds, herbs, foods and fruits harvest for income generation and food for the riparian communities. The indirect benefits include climate modification due to ground water recharge and surface water retention, flood control that reduce spread of water borne diseases, landscape and aesthetic values that attract the tourism industry and reduction of greenhouse effect.

Flooding disrupts farming activities with the likely consequence of driving people into Albert Nile fishery for their livelihood. Degrading wetland especially those near the river banks means loss of breeding ground for some of the fish species (Obbubu *et al*., 2021) which is expected to have negative impact on the productivity and sustainability of the Albert Nile fishery in the long run. According to Johannsen and Armitage (2010), rapid expansion of cultivated lands greatly contributes to changing turbidity levels for water within the catchment. Degrading wetland with their filtering abilities will lead to pollution load as animal waste and agricultural chemicals are eroded into the Albert Nile water with negative affect on the fishery productivity.

According to NFA (2016), destroying natural land covers such as wetland and wood lands is equally associated with knock-on effects of climate change, especially increased greenhouse gas (GHG) emissions as the number of trees available to absorb carbon dioxide through photosynthesis is greatly reduced. This means achieving the global agenda of United Nation Frame Work Convention on Climate Change (UNFCCC) and the Kyoto Protocol of reducing emission of GHGs may be futile. Continued buildup of GHGs will lead to negative consequences of global warming associated with un predictable climate pattern such as drought and flooding. Un predictable climate pattern will work negatively on other livelihood activities such as farming forcing people to flood and mount pressure on Albert Nile fishery.

The fact that many wetland's and wood land's indigenous species of trees such as *T. indicus* and herbs have been subjected to immense pressure should be of great concern because some of these species have medicinal values. According to Jayakumara *et al*. (2018) Feeding on varieties of natural fruits and herbs is understood to boost immunity and provide natural remedy against host of viral, bacterial and other parasitic infections in livestock. Livestock is a very important alternative livelihood option to the riparian communities of Albert Nile with potential to relieve Albert Nile from fishing pressure.

The community members around Albert Nile reported population pressure as the lead causes of the observed LULCC. According to Julian *et al*. (2016) and Pullanikkatil *et al*. (2015), rapid population growth and the increasing human dominated activities can drive land use pattern to skew towards agricultural and built-up areas at the expense of natural land cover types such as wood land and wetland. Therefore, much of the wood land and wetland areas have been cleared for wood fuel, charcoal and setting up agricultural ventures.

The current finding of increased demand for charcoal is consistent with UBOS (2019) that equally reported increase in nominal value of household consumption of firewood and charcoal from $17,000 in 2014 to $19,000 in 2018. The state of environment reports by Nebbi district local government (2011) equally revealed that about 100% of the population in Albert Nile catchment rely on charcoal or wood fuel for cooking hence leading to more destruction of woody vegetation cover. Kkatt consult (2021) reported massive charcoal related pressure on tree species such as *Acassia hokii* (Oriang), *C. molle* (oduk), *Mangifera indica* (Mango) *Butyrospermum paradoxum* (yao), *T. indica* (chwaa) *Balanites aegypticum* (too), *Albizia coriria* (Uber), *Persea americana* (Avocado), *Kigelia africana* (yago) and *Lannea schweinfurthii* (kwogo) in West Nile.

Okurut Emmanuel (2020) reported estimate of 6 million tonnes of wood being transformed into just 1.8 million tonnes of charcoal annually in Uganda which reflects low energy efficiency thus increasing wood fuel consumption and demand. This low energy efficiency has been compounded by; increased wood fuel demand by ever growing number of schools and upcoming small-scale manufacturing factories moreover with low energy technology such as use of outdated and in-efficient cooking stove, further worsening devegetation in

Albert Nile catchment. The continued increasing demand for wood and charcoal fuel may be attributed to high cost of electricity and low access to electricity.

According to World Bank (2017), electricity access in Uganda stands at 20.4% nationally and 10% in rural areas making Uganda as one of those countries with the lowest per capita electricity consumption in the world at just 215 KWh per capita per year. Coupled with high cost of electricity, the implication is that the current trend of increased demand for wood and charcoal fuel and the associated devegetation is not likely to cease contrary to the aim of Uganda's Energy Policy (2002) and Renewable Energy Policy (2006) of meeting energy needs of the population in environmentally sustainable manner. Having exhausted the trees due to charcoal burning, many of the charcoal dealers will most likely find their way back to Albert Nile fishery for their livelihood thus pilling more pressure on Albert Nile fishery.

Therefore, to summurise the foregoing discussion, the observed trend of rapidly changing LULCC characterized by loss of ground covers and wetland is going to have far reaching effect of negatively impacting the water quality of Albert Nile making it unsuitable for fishery productivity. Low productivity in Albert Nile fisheries will trigger competition and further fishing pressure. On the other hand, flooding and other associated weather vagaries such as drought may equally result from the current observed LULCC, this will have negative consequences on other livelihoods with the likely implication of driving people to pile more pressure on Albert Nile fisheries. People who use natural resources unsustainably find it rational to keep shifting from one type of natural resource to another. Therefore, after degrading the vegetation cover in the catchment of Albert Nile, these people are likely going to find their way into Albert Nile fishery in search of alternative livelihood options further increasing fishing pressure in Albert Nile.

5.3 Status of water quality in Albert Nile, Pakwach district.

5.3.1 Physical parameters

Most values for physical parameters were all within accepted limits for aquatic life (Figure 4.10). According to WHO (2011); FAO (1988), the recommended temperature range for stable aquatic life is (26.5-31) °C. Meanwhile, Hansda *et al*. (2017); Stone *et al*. (2013); Pradeep *et al*. (2012) and Chapman (1996) recommend a p^H range of (7.0-8.5) as suitable for aquatic life. Turbidity range of ≤3NTU is equally recommended (NEMA, 2020).

Temperature range of (26.8-28.7) °C with a net 1.9°C increase registered over the study period may not only be attributed to the general global warming (Obubu *et al.,* 2022), the increased heat capacity of the water as a result of suspended matter cannot be ignored (Sayed Rashad *et al*., 2019). According to Piccolotti & Lovatelli (2013), temperature has effect on many processes in the aquatic system such as rate of metabolism of aquatic plants, solubility of gases, as well as fish growth. Whereas, the change in temperature from 2005-2020 was not significant [F (7,7) = 1.417, p=0.329], altering of the temperature in Albert Nile system as per the current study finding will in the long run have devastating effect of disrupting this aquatic system required for fish productivity.

The water in Albert Nile River was alkaline throughout the study period with p^H range of (7.95-8.08) units. According to Uttah *et al*. (2010), the pH of a river is determined by its age and geology, however, the composition of waste water discharged equally has effect of altering the p^H of a water body as pointed by Guzha *et al*. (2018) and Obubu *et al*. (2021). The observed increasing trend in pH. should be resulting from unfiltered waste finding their ways into the Albert Nile water system. The P^H of water body is a very important quality indicator for aquatic life such that a slight change may be enough to cause harm to aquatic life (Uttah *et al*., 2010). Much as, the change in pH from 2005-2020 was not significant [F (6,8) = 1.469, p=0.300], if the current increase continues, it is likely that the p^H of Albert Nile will not be suitable for fishery productivity in the long run.

Whereas turbidity values for fresh water system can be affected by factors such as geology, farming and urban development that come with negative effect on vegetation cover may change turbidity faster than expected (APHA, 1992). The increasing turbidity over the study period (0.77-0.97) NTU should be attributed to increased flooding of waste into Albert Nile water. Though the change in turbidity from 2005-2020 was not significant [F (12,2) = 3.056, p=0.273], deterioration of water system due to enhanced turbidity comes with negative implication of increasing particulate matter loading and sedimentation that reduces light penetration (Perera *et al*., 2015). This is likely to destroy considerable fish habitat and disrupt primary production in Albert Nile system that are pertinent to fishery productivity.

5.3.2 Chemical parameters (nutrient species)

As observed, the concentration of nitrite and nitrate were below the recommended limit of 2.0 and 20 mg/l respectively while for ammonium and Total phosphate, they were above the recommended levels of 0.2 and 0.025 mg/l respectively (Pesce *et al*., 2000; Mishra *et al*., 2001; Obubu *et al.,* 2022). The change in values of the nutrient species over the study period were not significant, [F (8,6) = 2.056, p=0.198], [F (12,2) = 3.056, p=0.273], [F (12,2) = 3.056, p=0.273] and [F (11,3) = 1.485, p=0.414] for nitrite, nitrate, ammonium and total phosphate. However, the generally increasing trend in the values for nitrite, (0.0045-0.0125) mg/l, ammonia (0.13-0.31) mg/l, nitrate (0.076-0.21) mg/l and total phosphorous (0.06-0.144) mg/l over the study period points to increasing trend in pollution of the Albert Nile water system. According to Badr *et al*. (2013), phosphate and nitrogen in water are mostly from anthropogenic sources such as domestic, agriculture and industrial waste. Industrialization in the catchment of Albert Nile is quite minimal, therefore, the observed increasing trend in the concentration of the nutrient species in the current study should be associated with pollution by agricultural waste.

Nitrate in aquatic system results from oxidation of organic matter, ammonium from hydrolysis of ammonia, while nitrite from both oxidation and reduction (redox) reaction such as nitrification of ammonia to nitrate and denitrification of nitrate to nitrogen (Badr *et al*., 2013). The increasing trend in concentration of nitrite points to the fact that redox reactions are in rapid progress consequently consuming considerable oxygen in terms of BOD or COD with likely consequence of reducing DO (Varol and Sen, 2012 and Badr *et al*., 2013).

Whereas nutrients such as phosphorus and nitrogen are required for primary productivity, enrichment far beyond the aquatic system limits can shift the trophic status (Varol and Sen, 2012). The values for phosphorus (0.144±0.091) mg/l (Figure 4.11) and total nitrogen (2.26±0.44) mg/l in 2020 gives Albert Nile water Hypereutrophic status (UN, 1992; Lakewatch, 2004; Obubu *et al.,* 2022). Hypereutrophic status depicts water whose quality is very bad due to highest level of biological productivity (Lakewatch, 2004) associated with suffocation of aquatic life due to algal blooms and consequently reduced light penetration and reduced DO as has been reported in Lake Kyoga by Obubu *et al*. (2022).

The implication of Reduced light penetration in the Albert Nile water system will be halting productivity of the phytoplankton. Halting primary productivity of the phytoplankton that forms the base of food chain in the aquatic ecosystem negatively affect the fish in terms of food availability, the productivity of the fishery can thus be in jeopardy. Therefore, the shift towards hypereutrophic status implies the water of Albert Nile will cease to be suitable for fishery productivity in the long run.

5.3.3 Organic Matter Indicators

Organic matter indicators such as DO, BOD and COD are regarded as the best indicators of pollution load in the water body (APHA, 1992U; sman *et al*., 2018; Obubu *et al*., 2021). Much as DO with the range (8.6-7.85) mg/l (Figure 4.12) was within acceptable limit of >6.0mg/l for fresh water (Tsegaye *et al*., 2006), it however depicted a nonstop decreasing trend over the study period 2005-2020. The observed decrease in DO can be attributed to increased nutrient load into the water associated with increased activity of aerobic microorganisms to decompose such waste thus consuming considerable volume of oxygen required to aerate the water.

The concentration of BOD ranging from (0.83-1.75) mg/l was within recommended limits of <2.0mg/l for fresh water (Hanh *et al*., 2011; Usman *et al*., 2018; Fataei *et al*., 2013) but the generally increasing trend is a sign of deteriorating water quality most likely as a result of pollution by the nutrient species. The fact that the increase is nearly exceeding the recommended limit should be a reason for further concern. The study finding of increasing trend of COD, (7.5-10) mg/l from 2005 to 2020 is an indication that the recommended COD level of ≤10mg/l for aquatic life (Badr *et al,* 2013) may soon be surpassed. Though change in values for the organic matter indicator were not significant; [F (12,2) = 3.056, p=0.273], [F (5,9) = 2.215, p=0.142] and [F (12,2) = 3.056, p=0.273] for BOD, COD and DO respectively, the reducing trend in DO and increasing trend in both BOD and COD from 2005 to 2020 add more strength to finding on the changing trophic status of Albert Nile towards hypereutrophic state.

According to Kasozi *et al*. (2016), DO is a very important parameter regulating metabolic activities of the biological community as a whole. Whereas both Sanchez *et al*. (2007) and Badr *et al*. (2013) attribute reduced DO to oxygen consumption by respiration of biological community, the current finding of decreasing trend in the values of DO seem to emanate from the degradation of organic matter that is exhausting oxygen at a faster rate compared to the processes involved in the re oxygenation of the water. This is equally supported by the increase in the values of BOD and COD which reflects oxygen required for the aerobic decomposition of organic matter by microorganisms and chemical oxidation of organic matter in the water respectively.

The current COD/BOD ratio at 5.71 registered in 2020 is above the recommended 3.5, indicating high organic matter resistant to microbial degradation possibly associated with some agrochemicals as was earlier reported by Priscila *et al*. (2017) and Badr *et al*. (2013). The implication of reduce oxygen concentration in Albert Nile water in the long run will be undesirable as it leads to anoxic condition quite unfavorable for the different stages of fish life cycle negatively affecting productivity of fish in Albert Nile.

5.3.4 Water quality index (WQI)

The WQI range of (88.70-80.90) over the study period 2005 to 2020 showed that the water quality of Albert Nile was in a good state. However, the general decreasing trend could be due to the fact that the water quality is being affected negatively due to pollution load of the nutrient species. Vegetable gardening near the river bank is quite pesticide intensive, waste from cattle, all may increase the pollution load into the water of Albert Nile. Kasozi *et al*. (2016) reported a similar finding that much as most water quality parameters for Albert Nile were within acceptable limits, nutrient species and organic matter indicators were tending towards the upper limits of the recommended range. The increased pollution load may be attributed to the changing LULCC.

Negative effects of LULCC on water quality have equally been reported for Nawuni Catchment of the White Volta Basin, Northern Region, Ghana (Abdulai *et al*., 2020) and Lake Kyoga Basin (Obubu *et al*., 2021). According to Guzha *et al*., (2018) and Obubu *et al*., (2021), the effects of LULCC on water quality is linked to soil erosion associated with usage of nutrient rich agro-chemicals such as fertilizers, herbicides, pesticides and dertergents that are highly concentrated with Phosphorus and Nitrogen. This argument is further supported by MWE (2016) that pollution in Albert Nile catchment related to aquaculture, and industry was negligible compared to pollution from livestock and agriculture. The increased conversion of wetland and wood land areas into crop fields means nutrients and sediments run off un checked into Albert Nile water system which in the long run may negatively impact water quality required for fishery productivity.

In summary, the increased pollution load of nutrient species as a result of various human activities in the catchment of Albert Nile is changing the trophic status of Albert Nile. The increased nutrient load is leading to increased BOD, COD and temperature all at the expense of reducing DO. Increasing nutrient load is equally expected to lead to algal bloom whose consequence is reduced light penetration and further reduction of DO into the water. Reduced light penetration in the water means primary productivity of phytoplankton may be halted, while reduced DO leads to anoxia and fish death. Pollution of Albert Nile water will threaten not only the fisheries but also other ecosystem functions and services provided such as clean water supply to the riparian communities. Generally, the suitability of Albert Nile water to support fishery productivity is likely to be affected negatively in the long run. Reduced productivity in Albert Nile will lead to competition for whatever little the Albert Nile can offer further intensifying fishing pressure.

5.4 The level of fishing pressure in Albert Nile fishery, Pakwach district.

To determine fishing pressure, both output and input efforts were considered and compared. In fisheries, input efforts refer to all the effort taken in regards to exploiting the fish stock such as the human labour, time investment, gears and fishing vessels. On the other hand, output effort refers to what can be realized by the fisher such as amount of catch of different species and sizes in relation to the input utilized.

5.4.1 Comparison of fishing effort and total fish catch over the years

The fact that input effort in terms of number of gears, landing sites, boats, fishers was increasing while output in terms of total fish catch (t) declined from 2012 to 2021 could be attributed to depleted stocks' biomass as a result of use of destructive un-recommended fishing gears. From 2012-2021, Albert Nile fishery was mainly dominated by prohibited destructive gears, most of the multifilament and Monofilament nets commonly used by fishers were under sized, 2-3 panels and ≥ 500 yards. The reason for the persistent use of un recommended gears could be due to the fact that the large size species in Albert Nile fishery has been overfished such that the fishers are only left with the option of using undersized gears if they are to land any catch.

The survey finding of un recommended gears dominating Albert Nile fishery is similar to findings by other authors. Mbabazi *et al.* (2012) reported undersized gears as most dominant in Albert Nile fishery used for capturing large quantities of immature species. Fishing rule (2010) prohibits; monofilament nets and cast nets; all multifilament nets less than 4-inch, more than 100 yards wide and more than 33 meshes and hooks of size > 9. The effect of undersized and unrecommended gears is depleted stocks' biomass characterized by reduced CPUE and capture of immature low beach valued species. This may hamper the aspiration of Uganda's National Development Plan (NDP) III of promoting sustainable exploitation of the natural resources required for socio-economic transformation of attaining middle income status (NPA, 2020). Whereas NEMA (2021) attributed the negative resource rent in many water bodies in Uganda to reduced CPUE, it seems the meager economic return from the low beach valued under sized and immature species cannot be ruled out. Under sized and immature species have low beach values compared to matured grown up species.

5.4.2 Fishing frequency and Catch Per Unit Effort (CPUE)

The current findings of CPUE as low as 6.95±4.06 kg/boat/trip with a range of (2.20 to 12.30) kg/boat/trip could be due to too many fishers compared to the fish stock which has resulted in over fishing with the likelihood of disrupting stock replenishment. Because of low CPUE, fishers are expected to spend much time in the water in the hope of better catch, no wonder, it was discovered during the survey that fishers were increasing fishing frequency with over 80% of the fishers spending at least four days weekly while over 70% of the fishers spending at least five hours on each fishing trip. Mbabazi *et al.* (2012) equally reported decline in CPUE for some species in Albert Nile with CPUE for *L. niloticus* and *H. forskali* as low as <10 and 5.0 kg/boat/trip respectively.

Low CPUE poses threat to food security, disease prevention and cultural norms since much of the catch will end up being sold for cash (Feiller *et al*., 2016). The fact that CPUE correlated positively with fishing duration ($r = .992$, $n = 6$, $p = .001$), is a clear sign that the resource base of Albert Nile has dwindled. According to Cooper (2018), fishermen respond to fish scarcity by deploying more canoes, devoting a lot of their time to fishing and using destructive fishing gears, a true example of tragedy of commons.

Hardin vision of 'tragedy of the commons' (1968) has it that people find it rational to individually overexploit open access resources, hence the motivation for the fishers to continue fishing despite earning far less than the opportunity costs. According to Kjaer *et al.* (2012), due to over fishing, the CPUE in most water bodies in Uganda have seriously dwindled, fishers have to spend much longer time in order to get whatever meager catch. The increasing efforts to improve CPUE is likely to compound the effect of gear selectivity, true positive feedback likely to cause further degradation of fish biomass further reducing CPUE. Reduced CPUE implies meager earning for fishers which is contrary to NDP III vision of increasing household incomes and improving quality of life (NPA, 2020).

5.4.3 Fish length

The current finding of over 90% of *A. baremose* ,70% of *O. niloticus* and 90% of the *L. niloticus* caught below the recommended length is attributed to the high level of illegality in Albert Nile fishery associated with use of destructive under sized fishing gears. NAFIRRI (2012) similarly reported a worrying bimodal distribution of length frequency for *H. forskali* on Albert Nile mainly consisting of immature species. Fishing rules (2010) set minimum length of 28cm and 50 cm for *O. niloticus* and L. niloticus respectively. Mbabazi *et al* (2013) discovered 20cm as the length at maturity for *A. baremose* in Lake Albert and Albert Nile.

Whereas Welcomme (1970); Kolding (1993) and Natugonza (2015) asserts that changes in mean total length are largely driven by lake water levels as opposed to fishing pressure, the current finding of capture of under sized species should be attributed to gear selectivity.

According to Brian Marshall (2010) and Kjaer *et al.* (2012), the consequence of overfishing associated with destructive gears is decline in fish stocks characterized by decrease in biomass. The catch of under sized and immature species is a true characteristic of fisheries with decreased biomass (Kjaer *et al.,* 2012).

Mass exclusion of immature fish from the population can impose various forms of selection pressure including miniaturization i.e., body length and weight of a fish species at specific age decreasing consistently over time in response to stress (Liang *et al*., 2012; Raza *et al*., 2022). According to Safina (2012), miniaturization results from environmental stresses such as habitat destruction, interference with migration, decreases in spawning sites, food shortages and climate change. However, Sun (2013) contends that enough evidences have demonstrated that miniaturization is a response to fishing pressures. Miniaturization is associated with decreased reproductive potential since smaller females produce fewer eggs (Nalukenge and Winnie Nkalubo, 2012).

The observed total length of the indicator species, namely, *A. baremose*, *O. niloticus* and *L. niloticus* may imply miniaturization of these species in the long run. The finding on the total length of the above indicator species provides valuable evidence that Albert Nile fishery is overwhelmed with fishing pressure. Whereas UN SDG 2 advocates for ending hunger and improving nutrition, it's achievement should not contradict with UN SDG 14 which calls for the sustainable use of the fisheries resources (UN, 2017).

5.4.4 Spatial and temporal species abundance

During the Catch Assessment Survey (CAS), dominant species in the catch composed of only three large species; *O. niloticus*, *A. baremose* and *L. niloticus*. Previously 5 large species; *O.*

niloticus, *A. baremose*, *L. niloticus, H. forskali and Labeo ssp* were reported by NAFIRRI (2012) as dominant species. However, the contribution from the small pelagic species of low beach value were quite considerable especially *Synodontis spp* and *Brycinus nurse*. The increasing contribution to the catch composition by pelagic species should be the result of over fishing that has taken place on the stock of the large economically valuable species.

NAFIRRI (2012) equally regarded large proportion of the Albert Nile catch in the group termed 'other species. Sharpe *et al. (*2012) reported increasing contribution by the small pelagic species to the overall catch composition in other water bodies in Uganda such as Lake Victoria, Edward and Albert.

There was no significant difference among sampling sites in terms of the species composition ($F (9,150) = 0.505$, $p = 0.869$), no significant difference in species composition; for dark and bright moon phase, $t(30)=0.214$, $p=0.832$; for wet and dry season, $t(30)=0.158$, $p=0.876$. However, about 70% of the catch for *H. forskali* was contributed by only the first two sampling sites downstream which could be due to the overlapping catch from Lake Albert or Murchison Park protected area implying that the Albert Nile *H. forskali* may have been severely overfished. Furthermore, throughout the Catch Assessment Survey (CAS), H*aplochromines species* was not sighted.

According to Mbabazi *et al.* (2012), species such as *P. senegalus* and *Haplocromines spp* had reduced on Lake Albert and were mostly surviving in Albert Nile, no wonder, with the current fishing pressure the abundance of such species has equally declined in their hide out, Albert Nile. Similarly, Owiunji (2013) and NEMA (2007;2017 and 2018) reported over 40 threatened species of fish in Uganda. The loss of any species whether important now or in the future implies loss to the gene pool hence loss of genetic diversity in the population.

Fisheries officers attributed variation in catch to feed abundance, but most importantly to illegal gears used with their ability to catch under size fish of any species. The likely extinction of species such as *Haplochromines spp* may be linked to destructive fishing of the stock to a point at which recovery is difficult.

5.4.5 Spatial and temporal fish species diversity index

Due to immense fishing pressure in Albert Nile, the species composition has changed considerably, however, the change in species composition has not affected species richness. A total of 16 species were recorded during the CAS and as was previously reported by Mbabazi *et al*. (2012). Generally, the observed diversity index at the different sampling points and the different seasons were high as supported by high evenness and low dominance.

According to Shannon (1949); Shannon and Weaver (1963) and Ramos *et al*. (2006), diversity is low when single species dominates but as the number of species increases in an assemblage, especially if they are evenly distributed, diversity increases. The positive correlation between Shannon and evenness index ($r = .997, n = 10, p < .01$) and ($r$ =1 .000, $n = 4, p = .000$) and negative correlation between Shannon and Dominance index (r = -.998, $n = 10, p = .000$) and ($r = -.998, n = 4, p = .000$) among the different sampling points and different seasons respectively further give a true picture of diversity index in which Shannon diversity is strong under high evenness and low dominance (Magurran, 2004). The high level of species evenness was further supported by the shallow gradient of rank abundance curve indicating uniform species distribution (Magurran, 2004).

However, difference in diversity in spatial and temporal terms can be attributed to diversity of habitats, the different gears used and also matters of regulatory mechanisms being enforced and adhered to. The generally higher diversity upstream in this current CAS could be attributed to low level of regulations by officials upstream compared to downstream.

In summary, due to increased input effort such as number of fishers, gears, landing sites and fishing duration, Albert Nile fishery is overwhelmed with fishing pressure. This has negatively affected output efforts such as total catch, CPUE, total length and species abundance. Fishers have resorted to capture of under sized immature species, a true evidence of gear selectivity. This gear selectivity is expected to result into body length and body size miniaturization associated with decreased reproductive potential since smaller females produce fewer eggs. The multi species nature and high diversity index of Albert Nile cannot be a reason for smile since the catch is overwhelmingly composed of undersized and immature species. In fact, if the recommended gears were being used, certainly diversity index would have much lower than what was observed. This is likely to be compounded by the increasing efforts to improve CPUE, positive feedback that may further worsen the degradation of fish stock in Albert Nile to a point at which recovery can be difficult.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Based on the study findings, it was concluded as follows;

1. The current socio-economic status of the fishers as characterized by limited livelihood options, large household size and limited assets accumulation has resulted into unregulated entry of fishers into Albert Nile fishery. This is likely leading to increased pressure on fisheries of Albert Nile.
2. The observed LULCC indicate massive devegetation i.e., deforestation and conversion of wetland and wood land into agricultural land. Devegetation is likely to disrupt other livelihoods due to knock on effects of climate change such as drought. Flooding and water pollution in Albert Nile will equally take place thus making Albert Nile water un suitable for fishery productivity.
3. Much as the water quality was in a good state, the changing trophic status as pointed by the increasing concentration of nutrient species may affect the long-term suitability of Albert Nile water for fishery productivity. Reduced fishery productivity is likely to lead to competition among the fisher hence further increase in fishing pressure.
4. The fishing pressure was characterized by increased input effort and overwhelming capture of immature and under sized species using illegal gears is going to be unsustainable in the long run. Stock replenishment is likely to be disrupted with likely extinction threats.

6.2 RECOMMENDATIONS

1. Socio-economic status of the fishers should be regularly analysed and used as input for participatory management of Albert Nile fishery with the aim of adequate livelihood and maintenance of stocks at sustainable level.
2. The capacities of fisheries officers and LMC be enhanced to enable them transform the SSF of albert Nile into a sector that is economically viable by providing financial awareness, ecosystem sustainability awareness and enforcing regulation.
3. The community around Albert Nile Catchment area are bonded together by ethnic groupings, such cultural organizations have voices over their subject thus there is need for NEMA to build capacities of the cultural leaders to conserve the environment.
4. There is urgent need for NEMA to sensitise and build capacities of the masses at grass roots and institutional level to adopt energy saving stoves and efficient charcoal production technology to reduce wood fuel consumption.
5. Subsidizing the cost of electricity by the central government to enable upcoming industries to shift from wood fuel-based energy to hydro power. This should equally target home steads in urban settings to shift from charcoal based fuel to electricity to reduce pressure on wood fuel.
6. Protecting and preserving of Albert Nile banks, prohibition of wetland degradation, restoration of wetland, re-afforestation should be priotised by NEMA to conserve the catchment of Albert Nile.
7. Fisheries of Albert Nile and other minor water bodies in Uganda to take centre stage of policies and dialogue on sustainability to stream line management of policies and compliance.

8. Mitigation of overfishing should be long term strategies as opposed to short term tactics; for instance, creation of land-based alternative employment opportunities for ill-trained young fishers can substantially reduce the pressure on fisheries.
9. All the different initiatives by government of alleviating poverty such as Emyoga, Operation Wealth Creation (OWC), Parish Development Model (PDM) should be implemented with major focus on the fishers as target group.
10. Fishing effort should be regulated to ensure adequate spawning stock of fish to mature and replace the harvested stock, however, negative effects on livelihood of the fishers be mitigated.
11. For species that are under immense pressure, their exploitation should be banned periodically to allow replenishment of their population.

6.2.1 AREAS FOR FURTHER RESEARCH

1. More study be done to evaluate the effect of gear selectivity, especially miniaturization and its negative effects on fish population in Albert Nile fishery.
2. Study be conducted to analyse the constraints to aquaculture and how to overcome these constraints, aquaculture has potential to boost fish productivity while at the same time relieving pressure on Albert Nile fishery.
3. Study be conducted to evaluate the strength and weakness of the current co-management approach of fisheries management especially in small water bodies such as Albert Nile.
4. The impact of LULCC on other aspects of Albert Nile, including biological components such as zooplankton, phytoplankton, macroinvertebrates, macrophytes should be studied.

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APPENDICES

Appendix I: Informed consent form

Dear respondents,

I am KWIYOCWINY EMMANUEL a student of Kyambogo University pursuing MSc. Conservation and Natural Resource Management (MSc. CNRM). I am conducting research on "**The effects of anthropogenic activities on the small-scale fisheries in the albert Nile portion of Pakwach district**" as a partial requirement for the award of the MSc. CNRM. You have been selected to participate in this study voluntarily, your decision to participate, not to participate or withdraw in this study will be respected. The information collected shall be used for the purpose of this study only and handled with a lot of confidentiality without disclosing your identity even in the publication regarding this study.

Please tick Yes in the box bellow if you are willing or No if you are not willing to participate in this study.

☐ Yes

☐ No

Thank you for deciding appropriately.

Appendix II: Data collection tools

Observation quide for description of study site

GPS…………………………………………………………………………………………

a) **Fishing effort**

Number of boats……………………………………………………………………………….

Number of fisher men per boat………………………………………………………………

b) **Socio-economic survey**

Available social facilities at the landing sites

- [ ] Latrines, permanent or semi permanent
- [ ] House shelter, permanent or semi permanent
- [ ] Fish laid on some plat form, permanent or semi permanent
- [ ] Others, specify ……………………………………………………………

Evidence of Beach management unit (BMU), present or absent (how often meetings are held with resource users) ………………………………………………………………………

Evidence of visit by extension service provider ……………………………………………

c) Water quality and fish habitat suitability

Status of other biodiversity that are supportive to the fishery such as wetland, blockage by aquatic weeds etc. Please elaborate with evidences, if any……………………………………

☐ Very good

☐ Good

☐ Not good

☐ Very bad

Thank you for your response.

Questionnaire for respondents

Please tick in one of the boxes or write in the space provided where necessary:

a) Biography

- [ ] Sex Male
- [ ] Female

Age…………………………………………………………………………………………

Education level………………………………………………………………………………….

b) Fishing effort

Number of days in a week spent on fishing…………………………………………………

Number of hours in day spent on fishing ……………………………………………………

Catch per unit effort (all fish species) in Kgs …………………………………………………

The fish catch (catch per unit effort) is:

- [ ] Increasing
- [ ] Decreasing
- [ ] The same/ Has not changed

The sizes (length or weight) of fish caught is:……………………………………………….

- [ ] Increasing
- [ ] Decreasing
- [ ] The same/ Has not changed

c) Socio-economic status of the fishers

What is your Major economic activity?

- [ ] Fishing
- [ ] Cropping
- [ ] Livestock keeping
- [ ] Others, specify ……………………………………………………………

What other economic activities do you do?

- [ ] Fishing
- [ ] Cropping
- [ ] Livestock keeping
- [ ] Others, specify …………………………………………………………….

Assets owned

- [ ] Land, how many acres…………………………………………………………
- [ ] Livestock, specify, how many ………………………………………………
- [ ] Fishing assets, specify how many ……………………………………………
- [ ] Others, specify ……………………………………………………………

Access to other services

- [ ] Financial, specify the source…………………………………………………
- [ ] Health service, specify the adequacy …………………………………………
- [ ] Extension service, specify the adequacy ………………………………………
- [ ] Others, specify ……………………………………………………………

What do you spend the money you obtain from fishing for? …………………………………

What is the most critical challenge facing the fishers and fishery according to you?

…………………………………………………………………………………………

What do you think will be the most serious consequence for you, if this fishery collapses?

……………..…………………………………………………………………………………..

Water quality

Do you think the water quality is good or bad both for human consumption and the fishery?

- [ ] Good
- [ ] Bad

Please give reasons accordingly …………………………………………………

Thank you for your response.

Interview quide for respondents or focus group discussion (FGD) or key informants

1. What changes have you noticed in the catch per unit efforts over the years? …………
2. Are the sizes (length or weight) of fish caught increasing or decreasing?......................
3. Give one reason for your response in 2 above……………………………………….
4. Are there some fish species that have gone extinct in this fishery? if so, please specify and what do you think could have led to the extinction of these species?......................

5. What are the challenges facing the fishers and fishery in this landing site? ……………

6. Identify the most critical challenge facing the fishers and fishery in this landing site?

7. What do you think will be the consequences, if this fishery collapses?.........................
8. What do you think will be the most serious consequence, if this fishery collapses?

………………………………………………………………………………………………

9. Do you think the water in this fishery is polluted or not? ……………………………
10. If you think that the water is polluted, what do you think are the causes of this pollution? …………………………………………………………………

    10. How has climate change impacted on your livelihood?...

11. How have you responded to these impacts of climate change?......................................

Thank you for your response.

CATCH COMPOSITION SHEET

LANDING SITE…..................GPS CORDINATES............…………SUB COUNTY.............

DATE…...............TOTAL BOATS……… BOATS SAMPLED…………………………

S/N	SPECIES & number	Number of Days fished in a Week	Number of Hours fished in a day	CPUE	Gear used
1					
	TOTAL				
2					
	TOTAL				
3					

	TOTAL				
4					
	TOTAL				
5					
	TOTAL				

LENGTH FREQUENCY TABLE

Species…………………… Date ………………………………………………………

S/County											
Length group (Cm)/ Landing site										TOTAL	PROPORTION (%)
0.0 - 2.0											
2.1 - 4.0											
4.1-6.0											
6.1-8.0											
8.1-10											
10.1-12.0											
12.1- 14.0											
14.1-16.0											
16.1-18.0											
18.1-20.0											
20.1-22.0											
22.1-24.0											
24.1-26.0											
26.1- 28.0											
28.1-30.0											
30.1-32.0											
32.1-34.0											
34.1-36.0											
36.1-38.0											
38.1-40.0											

40.1-42.0											
42.1-44.0											
44.1-46.0											
46.1-48.0											
48.1-50.0											
50.1-52.0											
TOTAL											

Appendix III: Disproportionate allocation of the sample size and response rate

Disproportionate allocation of the sample size (Pinello et al., 2017)

Number of boats	Sampling rate
< 50	50%
50 - 500	25%
500 - 2000	10%
>2000	5%

Response rate

Category	Intended	Averagely sampled	% Sampled
Boats	223	219	98.206278
Key informants	11	11	100
Fishers and Mongers	354	347	98.022599
Sampling sites	11	10	90.909091
Overall average			**96.784492**

Appendix IV: Morgan, Krejcie table (1970) for sample size determination.

Population	Sample size	Population	Sample size
10	10	440	205
15	14	460	210
20	19	480	214
25	24	500	217
30	28	550	226
35	32	600	234
40	36	650	242
45	40	700	248
50	44	750	254
55	48	800	260
60	52	850	265
65	56	900	269
70	59	950	274
75	63	1,000	278
80	66	1,100	285
85	70	1,200	291
90	73	1,300	297
95	76	1,400	302
100	80	1,500	306
110	86	1,600	310
120	92	1,700	313

130	97	1,800	317
140	103	1,900	320
150	108	2,000	322
160	113	2,200	327
170	118	2,400	331
180	123	2,600	335
190	127	2,800	338
200	132	3,000	341
210	136	3,500	346
220	140	4,000	351
230	144	4,500	354
240	148	5,000	357
250	152	6,000	361
260	155	7,000	364
270	159	8,000	367
280	162	9,000	368
290	165	10,000	370
300	169	15,000	375
320	175	20,000	377
340	181	30,000	379
360	186	40,000	380
380	191	50,000	381

Appendix V: Data on fisheries for Albert Nile

	ABUNDANCE OF ALL SPECIES FROM DIFFERENT SAMPLING POINTS										
SPECIES	OGAL	WANGKADO	KUBA	WICAWA	PAJOBI	AMOR	JACAN	PADOCH	AKELLO	MUTIR	SUB TOTAL
Lates niloticus	666	654	292	318	440	297	369	266	460	310	4072
Oreochromis niloticus	1505	1022	928	811	1096	730	1782	566	1757	1227	11424
Alestes baremose	928	979	919	795	830	827	750	538	459	568	7593
Distichodus niloticus	144	166	153	148	168	145	243	151	401	289	2008
Protopterus senegalus	9	2	11	30	48	29	67	93	101	54	444
Synodontis spp	963	883	751	727	541	468	2019	377	770	673	8172
clarias spp	49	55	56	37	50	32	60	49	77	61	526
Protopterus aethiopicus	37	39	43	68	48	49	59	54	49	45	491
Labeo spp	177	203	152	227	149	167	149	118	283	126	1751
Barbus bayinnii	277	359	162	272	156	234	190	213	369	123	2355
Schilbe spp	104	71	159	187	166	223	246	424	255	400	2235
Malepterurus electricus	67	123	35	54	67	56	73	56	62	58	651
Brycinus nurse	723	918	770	925	783	540	539	623	492	485	6798
Hydrocynus forskali	315	330	50	77	19	12	4	16	16	1	840
Bagrus bajad	277	192	194	211	158	150	174	147	369	266	2138
Mormyrus spp	241	253	165	204	125	153	197	170	467	319	2294
Sub toatal	6482	6249	4840	5091	4844	4112	6921	3861	6387	5005	53792

ABUNDANCE OF ALL SPECIES FOR DRY/WET AND DARK/BRIGHT MOONSEASON							
Species	WET	DRY	TOTAL		DARK	BRIGHT	TOTAL
L. niloticus	2103	1969	4072		2137	1935	4072
O. niloticus	6092	5332	11424		6015	5409	11424
A. baremose	4440	3153	7593		4445	3148	7593
D. niloticus	1091	917	2008		1095	913	2008
P. senegalus	243	201	444		228	216	444
Synodontis spp	3783	4389	8172		3895	4277	8172
clarias spp	299	227	526		264	262	526
P. aethiopicus	243	248	491		240	251	491
Labeo spp	774	977	1751		771	980	1751
B. bayinnii	1133	1222	2355		1146	1209	2355
Schilbe spp	899	1336	2235		960	1275	2235
M. electricus	360	291	651		311	340	651
B. nurse	3471	3327	6798		3663	3135	6798
H. forskali	455	385	840		438	402	840
B. bajad	1040	1098	2138		1064	1074	2138
Mormyrus spp	1218	1076	2294		*1240*	*1054*	2294
Toatal	**27644**	**26148**	**53792**		**27912**	**25880**	**53792**

Appendix VI: Data on water quality for Albert Nile, 2005-2020

Parameters	2005	2010	2015	2020
Temp (°C)	26.8±1.41	27.5±1.73	28.3±1.41	28.7±2.16
pH (units)	7.35±0.21	7.27.1±0.2	7.89±0.28	8.08±0.17
TURB (NTU)	0.77±0.2	0.78±0.2	1.2±0.14	0.97±0.38
NO2 (mg/l)	0.0045±0.001	0.007±0.003	0.0055±0.001	0.0125±0.003
NO3 (mg/l)	0.076±0.005	0.09±0.01	0.1±0.003	0.21±0.072
NH4 (mg/l)	0.13±0.004	0.14±0.05	0.21±0.015	0.25±0.172
TP (mg/l)	0.06±0.006	0.13±0.06	0.11±0.05	0.144±0.091
BOD (mg/l)	0.83±0.03	0.99±0.14	1.01±0.16	1.75±0.13
COD (mg/l)	7.5±0.71	8±1	7.5±0.71	10±1.41
DO (mg/l)	8.6±0.42	8.47±0.4	8.15±0.07	7.85±0.13

Appendix VII: Institutional Introductory and authorization letters

KYAMBOGO UNIVERSITY
FACULTY OF SCIENCE
P. O. BOX 1, KYAMBOGO – KAMPALA, UGANDA
TEL +256-41-287347, 285001/2 Fax 041-220464/222643
Website www. Kyu.ac.ug
BIOLOGICAL SCIENCES DEPARTMENT

29th September 2021

The Chief Administrative Officer
Pakwach District Local Government
P. O Box 1
Pakwach

Dear Sir/Madam,

RE: INTRODUCTORY LETTER FOR CONDUCTING A FINAL YEAR RESEARCH

This is to introduce to you **MR. KWIYOCWINY EMMANUEL** of Registration Number 19/U/GMSM/18965/PE a second-year student of Kyambogo University pursuing a Master's of Science in Conservation and Natural Resource Management in the Department of Biological Sciences, Kyambogo University.

As part of the requirements for the award of the Master's he's required to conduct a research project. The title of the research is **"The effects of anthropogenic activities on the small-scale fisheries in the Albert Nile portion of Pakwach District".**

Please accord him the necessary assistance to enable him carry out the research.

Thanks

Sincerely,

KYAMBOGO UNIVERSITY
BIOLOGICAL SCIENCE DEPT.
29 SEP 2021
P. O. BOX 1, KYAMBOGO

Asio Santa Maria (PhD)
Ag. HEAD OF DEPARTMENT
BIOLOGICAL SCIENCES, KYAMBOGO UNIVERSITY

CHIEF ADMINISTRATIVE OFFICER
PAKWACH DISTRICT LOCAL GOVERNMENT
RECEIVED
06 OCT 2021
REGISTRY
P. O. BOX 64, PAKWACH

ACUTOGENO VILLAGE

OWOI PARISH

POKWERO SUB COUNTY

PAKWACH DISTRICT

06/10/2021

THE CHIEF ADMINISTRATIVE OFFICER,

PAKWACH DISTRICT LOCAL GOVERNMENT.

Dear sir,

RE: **AUTHORITY TO COLLECT DATA ON FISHERIES ACTIVITIES IN PAKWACH DISTRICT**

I am Kwiyocwiny Emmanuel a resident of Acutogeno Village, Owoi Parish, Pokwero Sub County, Pakwach district. I am currently conducting research titled. The effects of anthropogenic activities on the small-scale fisheries in the Albert Nile portion of Pakwach District. This research is part of the requirements for the award ofMaster of science in conservation and natural resource management Degree that I am currently pursuing from Kyambogo University

I therefore, humbly request your office to grant me authority to collect data on fisheries activities. I intend to obtain these data from the fisheries and production department of Pakwach district localgovernment at the district headquarters, sub county headquarters and Beach Management units (BMU) or landing sites.

Yours Hopefully,

KWIYOCWINY EMMANUEL

0773995696/0757178386

Kwiyocwinyemmanuel2017@gmail.com

No objection

6/10/21

DIRECTORATE OF WATER RESOURCES MANAGEMENT
06 APR 2022
RECEIVED

4/5/22

AKWORO SECONDARY SCHOOL

P.O BOX 216, NEBBI.

16/03/2022

CENTRAL REGISTRY
MINISTRY OF WATER AND ENVIRONMENT
RECEIVED
04 APR 2022
SIGN:
DIRECTORATE OF WATER RESOURCE MANAGEMENT

THE DIRECTOR

WATER RESOURCES MANAGEMENT

MINISTRY OF WATER AND ENVIRONMENT

P.O BOX 200026 KAMPALA, UGANDA.

Dear Sir/Madam,

RE: AUTHORITY TO OBTAIN ARCHIVED DATA ON WATER QUALITY PARAMETERS FOR ALBERT NILE

I am Kwiyocwiny Emmanuel a student of Kyambogo University currently conducting research titled "*The effects of anthropogenic activities on the small-scale fisheries in the Albert Nile portion of Pakwach District*". This is part of the requirements for the award of Degree of MSc conservation and natural resource management that I am pursuing at Kyambogo University.

I kindly request your office to grant me authority to access five (5) data sets on water quality parameters from 2000 to 2021 as shown below:

Year range	Number of data set(s)	Water quality parameter
2000-2005	1	Temperature, p^H, Turbidity, Dissolved Oxygen (DO)Biological oxygen demand (BOD), Chemical oxygen demand(COD), Ammonium, Nitrite, Nitrate and Total/Phosphorus
2006-2010	1	
2011-2015	1	
2016-2021	2	

I pray for your consideration.

Yours Hopefully,

KWIYOCWINY EMMANUEL

0773995696/0757178386

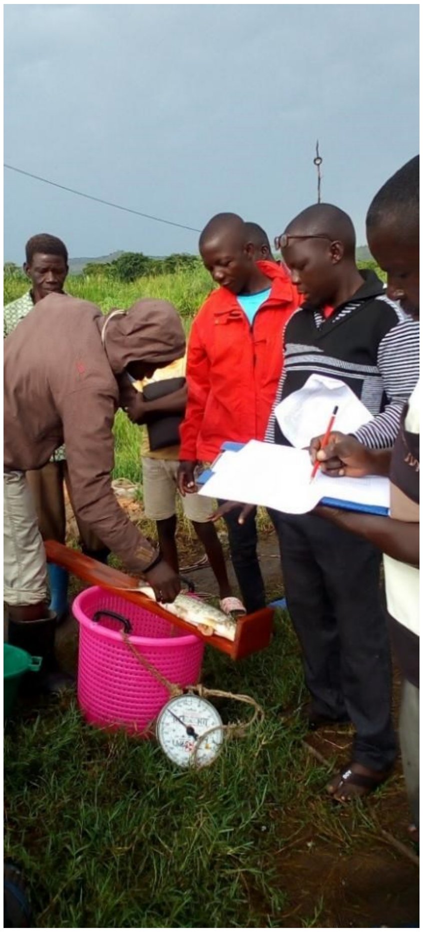
Kwiyocwinyemmanuel2017@gmail.com

Com, WRM

Handle

6/4

Appendix VIII: Photo gallery



Measuring fish length

Signing visitors' book at one of the landing sites

Administering questionnaire and interview to respondents at one of the landing sites

Appendix IX: Some of the common fish species in Albert Nile

Malepterurus electricus *Distichodus niloticus*

Mormyrus ssp *labeo ssp*

Clarias ssp *Bagrus bajad* *Barbus bayinni*

Appendix X: GPS points for the sampling units

Study_site	X_Longitude	Y_Latitude
Ogal	31.33	2.26
Wangkadu	31.36	2.31
Kuba	31.47	2.39
Wicawa	31.41	2.33
Pajobi	31.49	2.45
Amor jukal	31.51	2.47
Jacan	31.42	2.61
Padhoch	31.47	2.51
Akello	31.41	2.67
Mutir	31.42	2.76