THE EFFECT OF NILE PERCH BAIT FISHERY ON THE REPRODUCTIVE AND BIOMETRIC PARAMETERS OF *Mormyrus kannume* ALONG THE UPPER VICTORIA NILE

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A DISSERTATION SUBMITTED TO THE DIRECTORATE OF RESEARCH AND GRADUATE TRAINING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE IN CONSERVATION AND NATURAL RESOURCES MANAGEMENT OF KYAMBOGO UNIVERSITY.

SEPTEMBER, 2025

DECLARATION

I, **MBAHO EUNITH** hereby declare that this dissertation titled **"*THE EFFECT OF NILE PERCH BAIT FISHERY ON THE REPRODUCTIVE AND BIOMETRIC PARAMETERS OF Mormyrus kannume ALONG THE UPPER VICTORIA NILE*"** is my original work. It has never been submitted to this, or any other institution for any degree award.

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Signature   Date

MBAHO EUNITH

APPROVAL

We certify that this dissertation titled **"*THE EFFECT OF NILE PERCH BAIT FISHERY ON THE REPRODUCTIVE AND BIOMETRIC PARAMETERS OF Mormyrus kannume ALONG THE UPPER VICTORIA NILE*"** was conducted under our guidance and supervision.

Dr Asiyo Ssanyu Grace

Signature………………………………………………….

Date ……………………………………………………….

Dr Aruho Cassius

Signature …………………………………………………….

Date ………………………...

DEDICATION

This dissertation is dedicated to my dear family for all their love, support and prayers during this journey. In a special way to my parents Mr and Mrs. Kaawa Wilson, my three sisters; Bonus, Beneth and Bonitah and brothers Saviour and Napoleon, my best friend Kabeeho Ndatsi and my best friend in class Kaganzi Seith for all the extraordinary support they have accorded me towards accomplishing this journey.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
ARDC	Aquaculture Research and Development Centre
CM	Centimeters
COVAB	College of Veterinary Medicine, Animal Resources and Bio-security
IUCN	International Union for Conservation of Nature
LWRs	Length-weight relationships
L_{50}	Length at fifty percent maturity
NaFIRRI	National Fisheries Resources Research Institute
SL	Standard Length
SPSS	Statistical Package for the Social Sciences
TL	Total Length

ABSTRACT

The increased exploitation of *Mormyrus kannume* using illegal fishing gear, used as bait to capture Nile perch, poses a threat to its population and could ultimately lead to its extinction. Monitoring of fish reproductive metrics is crucial for assessing population health, informing sustainable management practices, and ensuring the ecological balance of aquatic ecosystems. This study was carried out to; identify the socio-economic factors promoting the use of *M. kannume* as a bait in the Nile perch fishery, determine its size at sexual maturity (L_{50}) and sex ratios, and examine its biometric parameters (body length and body weight relationship) along the Upper Victoria Nile. The study was both qualitative and descriptive, where questionnaires were administered to respondents in person along selected landing sites on the Upper Victoria Nile and Lake Victoria. The sex ratio was calculated after identifying the sex of each sample following dissection. The L_{50} was determined by the maturity logistic ogive curve. The Total Length and body weight were measured using a measuring board and a calibrated weighing scale respectively. The results generated showed that the key socio-economic factors that influence the use of this bait were fishing experience, bait cost, selling price of Nile perch, bait type, and size of the bait. The chi-square test on sex ratio (females: males) showed no significant deviations from the normal indicating a healthy population structure. Size at sexual maturity L_{50}, for males and females was 23 cm and 21 cm respectively indicating that the fish are maturing at a small length probably due to increased fishing pressure. The TL of the fish caught ranged from 10.5 cm to 67.5 cm (mean of 17.62 ± 0.11 cm), and the body weight ranged from 10.84 g to 2548.8 g (mean of 57.54 ± 2.52 g). The b value (LWR exponent) was 2.9 (Male) and 2.8 (female) indicating a negative allometric growth, implying that the fish are in a healthy condition but slightly underweight probably due to stress from fishing pressure. These results demonstrate that *M. kannume* is facing reduced size at sexual maturity, and slight decline in the relationship between body length and body weight. These changes are probably due to fishing pressure and use of inappropriate fishing gear which may catch fish before they reach maturity. Captive breeding of *M. kannume* is recommended to ease pressure on wild populations and ensure sustainable bait supply. Therefore, this study has highlighted the socio-economic driving factors in the use of *M. kannume* as bait. Understanding *M. kannume's* biological data is important in the development of management strategies to address the already caused effects and preserve *M. kannume* from extinction in the long run.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Nile perch accounts for close to 90% of all fish exported from Uganda, both in terms of volume and value. This has resulted in increased fish export revenues from less than US $30m in 1995 to approximately US $145 m in 2011 (Aloo *et al.*, 2017). Despite its economic value, the decline of native fish species in Lake Victoria, including the mormyrid *Mormyrus kannume* Forsskl, 1775, locally known as 'Kasulubana', is usually blamed on the increasing Nile perch predation, habitat degradation, and fishing pressure (Witte *et al.,* 2013). The introduction of Nile Perch also altered the lake's ecology, causing competition, hybridization, and adaptive radiation, with native fish species occupying new trophic levels (Mboya *et al.,* 2005).

However, the effect of the baited hook fishing has been entirely underestimated (Mkumbo & Mlaponi, 2007). Before 1994, the hook fishery had minimal economic significance and only targeted the tilapia species. However, there has been a major change in the Lake Victoria fishery with the use of longlines to target Nile perch. This has resulted in an exponential surge in the longline fishing with over 12 million hooks being used lake-wide (Njiru *et al.,* 2014). As a result, *Mormyrus kannume* wild stock has been heavily fished for bait. Lately, some fishermen in the Napoleon Gulf are using *Mormyrus kannume* alongside other types of bait; in particular, those that use larger hooks, such as sizes 7 and beyond. Bassa, (2018) reported that hooks of sizes 7 and 8 captured larger fish in terms of total length compared to other sizes, although size 7 caught bigger fish than size 8. Hooks of sizes 7 and 8 harvested fish that weighed more than 2.5 kilograms and measured 50 cm in Total Length, which is the desired slot size that is in compliance with the requirements of fisheries management (Muhoozi & Kamanyi, 2004).

Hooks of sizes 8, 9, 10, 11 and 12 are below the minimum sizes permitted in accordance with Lake Victoria Fisheries Organization regulations (Bassa, 2011).

Inland fisheries across Africa, such as Congo Basin and Lake Tanganyika face significant management challenges including fishing pressures, limited gear regulation and threats to native biodiversity (FAO, 2016). In comparison, European fisheries particularly those targeting hake in the North Atlantic, tend to employ more controlled baiting methods, often relying on frozen or synthetic alternatives to minimize ecological disruption (Sistiaga *et al.* 2018). According to Sistiaga *et al.* (2018), the size and type of bait used were significant factors affecting the effectiveness of catching different sizes of European hake. As a result, the bait selection may impact the distribution of catch sizes. Currently, in Uganda, fishermen and local merchants prefer utilizing *M. kannume* bait to catch Nile perch. This is because the species lacks sharp spines present on the juvenile catfish that frequently can be avoided by mature Nile perch if recognized earlier. It is presumed that *M. kannume* also swings more quickly and stays active on the hook for a much longer period (up to three days alive) than catfish bait, luring curious Nile perch looking for food (Bassa, 2011). The increased use of Juvenile *Mormyrus kannume* as bait in Lake Victoria and the Upper Victoria Nile has led to higher Nile perch catches for fishermen (Nduwayesu *et al.,* 2023). Furthermore, given that *M. kannume* is a deep-water species (Kramer, 2013), it is employed by fishermen to capture large, mature Nile Perch in the lake's deeper areas.

The odour, shape, and consistency of the various baits vary. According to Løkkeborg *et al.* (2014), the most crucial factor in drawing fish to the gear is the odour of the bait. Other factors; such as size and form, become more crucial for luring the fish to attack the bait once it is within striking distance. The firmness of the bait and how well it holds to the hook are additional elements that influence the overall success of each type of bait because they affect how long the bait remains on the hook (Kumar *et al.,* 2016). Hooks are preferentially baited with live bait as it is the most effective type of bait for Nile perch. This has led to increasing importance of the baited hook fishery resulting in increased demand and unsustainable exploitation of baits. This has therefore presented a latent threat to the stocks of the endemic species by hindering their recovery (Mkumbo & Mlaponi, 2003) and the recovery of these native stocks (Clarias, haplochromines, dagaa, synodontis, Labeo and Mormyrus). In fishery assessment studies, length-weight relationships (LWRs) and relative condition factor are crucial because they reveal information on fish growth, general health, and fitness in aquatic ecosystem (Jisr *et al.,* 2018). In order to evaluate reproductive potential and determine stock size populations, basic information like the sex ratio and size structure is necessary (Oliveira et al., 2012).

Therefore, studying the effect of Nile perch bait fishery on the reproductive and biometric parameters of *Mormyrus kannume* along the upper Victoria Nile has provided information on the extent of the impact on the conservation of *M. kannume*. The information helps to devise strategies for regulating the fishing of *M. kannume* from the upper Victoria Nile where most of its remaining populations are confined (Bassa, 2018). This will guide the conservation of the dwindling fish species in the lake, help bridge the gap between the declining bait availability and rising demand, and enhance catch efficiency in the Nile perch fishery.

1.2 Statement of the problem

The use of elephant snout fish (*M. kannume*) as a bait in the Nile perch fishery is phenomenon that has improved the catchability of deep mature Nile perch fish. This has salvaged the Nile perch industry as claimed by the fishermen. Much of the populations of *M. kannume* around

Lake Victoria have now been confined towards the Upper Victoria Nile and no substantial catches are being recorded in Lake Victoria as before (Natugonza *et al.,* 2022). Worse still, the fishing communities are intensively using illegal fishing gear such as basket traps and hooks to capture immature *M. kannume* for use as bait in the Nile Perch fishery (Bassa, 2018). Fishing is being done at unprecedented levels and may consequently lead to unsustainable exploitation, reduced economic contribution and eventual extinction of the populations of *M. kannume* populations. Currently, there is paucity of information on the level of exploitation of this fish, the level of its demand by fishermen, their length at sexual maturity, sex distribution, size structure and the appropriate size selected as bait for catching *Lates niloticus*. Therefore, it was imperative to study the effect of Nile Perch bait fishery on the conservation of *Mormyrus kannume* along the Upper Victoria Nile. This aimed at devising strategies for its sustainable use, both for economic benefits, such as food and for long-term conservation.

1.3 Objectives of the study

1.3.1 General objective

To assess the effect of Nile Perch bait fishery on the reproductive and biometric parameters of *Mormyrus kannume* along the Upper Victoria Nile.

1.3.2 Specific objectives

1. To identify the socio-economic factors that promote the use of *Mormyrus kannume* as bait in the Nile Perch fishery.
2. To determine the size at sexual maturity and sex ratios of *Mormyrus kannume* in the Upper Victoria Nile.

3. To determine the body length and weight relationship of *M. kannume* in the Upper Victoria Nile.

1.3.3 Research Questions

1. What socio-economic factors promote the use of *Mormyrus kannume* bait in the Nile Perch fishery?
2. What is the size at sexual maturity and the sex ratios of *M. kannume* in the Upper Victoria Nile?
3. What is the relationship between body length and weight of *M. kannume*?

1.4 Significance of the study

This study has provided information regarding the effects of excessive harvesting of *Mormyrus Kannume* captured for use as bait in the Nile perch fishery, suggested ways of sustainable exploitation and conservation of the fish. Understanding the socio-economic factors influencing the exploitation of this bait helps conservationists and other stakeholders identify suitable approaches of engaging the fishing communities. These interventions support the sustainable exploitation of not only the *M. kannume* but also finding alternative strategies for the sustainable exploitation of the Nile Perch. Information on exploitable bait sizes, size at maturity and sexual ratios that was scanty has now been enhanced. These aspects also provide the basis upon which decisions for domestication of *M. kannume* can now be made. For instance, successful domestication of the fish could provide a continuous supply of fish fingerlings to use as bait all year long. This is crucial for developing a thriving bait sector that can consistently produce high-quality baits for the Nile perch fishery (in terms of size, liveness, reasonable costs, and accessibility). This will boost the nation's earnings in foreign exchange, local incomes and job creation for young people (fishers, traders, and fish growers), as well as the availability of animal protein in homes. Additionally, it will support the preservation of Nile perch and elephant snout fish and revive the Nile perch business through dependable fishing with the right fishing equipment and effective baits.

1.5 Scope of the study

The study concentrated on the effect of Nile Perch bait fishery on the reproductive and biometric parameters of *Mormyrus Kannume* with a case study of the upper Victoria Nile. This study focused on identifying the socio-economic factors influencing the use of *M. kannume* bait in the Nile Perch fishing. It also determined the size at sexual maturity, sex ratios and biometric parameters (size in terms of body length and weight) of *M. kannume* bait used in the Nile Perch fishery. The information gathered has helped to establish the damage already done to *M. kannume* as a result of its use as bait in the Nile Perch fishery and this is helpful in informing conservation plans for the species.

1.6 Limitations of the study

Table 1. 1: Limitations of the study

S/N	Limitation	Solutions to the limitations
1.	Some fishermen did not give the right information regarding their socio-economic status based on *M. kannume* bait due to cultural beliefs	There was integration of questionnaires and, individual interviews with their leaders at the landing sites to verify some of the information revealed by fishermen.
2.	Getting fish with reduced sexual maturity due to season effects.	Sampling was done in two seasons to avoid bias resulting from one season.
3.	The effect of the breeding season on sex ratio determination.	The number of sampling points was increased. Sampling in a breeding season and a non-breeding season to avoid this bias/skewed sex ratios.
4.	The size of *M. kannume* in relation to the Nile perch size caught and bait selected	The information was obtained based on the Nile perch caught to the size of *M. kannume* used.
5.	Language of instruction in administering the questionnaire, as some respondents did not speak English.	The questionnaire was translated into local languages, such as Luganda.

1.7 Conceptual framework

The survival of *M. kannume* in the Upper Victoria Nile is threatened by excessive harvesting for use as Nile perch bait, and is influenced by both dependent and independent variables. Socio-economic factors such as the demand, fisher's preference, source and size of *M. kannume*, size of Nile perch caught and fishing gear type, directly and indirectly influence the exploitation and the use of *Mormyrus kannume*, thereby impacting its conservation.

Sex ratios and size at maturity are key aspects of reproductive strategy of *M. kannume* for its survival and population growth. Size at maturity (L_{50}) provides the size at which 50% of the individuals of a population are mature to breed and this may shift depending on the anthropogenic and natural pressure exerted on the fish. If the size of *M. kannume* continues reducing, its maturation size could also reduce/decline. This exposes most of the small sized/juvenile fish to being harvested for catching Nile perch, potentially compromising the species' sustainable exploitation, conservation and its social benefits for the communities. Skewed sex ratios could also make the population not to reproduce optimally. It could be imperative to understand the seasons when there are skewed sex ratios so as to inform when it is appropriate for its conservation for sustainable use in the Nile perch industry. Both parameters can also inform aquaculturalists/researchers on when, where and which size to pick for induced spawning (breeding) procedures. This is important because it will increase fish availability to fish farmers to compliment or support the bait industry and therefore reduced pressure on the wild stocks (Figure 1:1).

As a result, this study focused on the socio-economic factors, size at sexual maturity and sex ratios, and biometric parameters (length-weight relationship) of *M. kannume*. The results obtained will contribute to the conservation and sustainable use of *M. kannume*, ensuring continuous supply of high-quality fingerlings (bait) for the Nile perch fishery and ultimately boosting Uganda's economy.

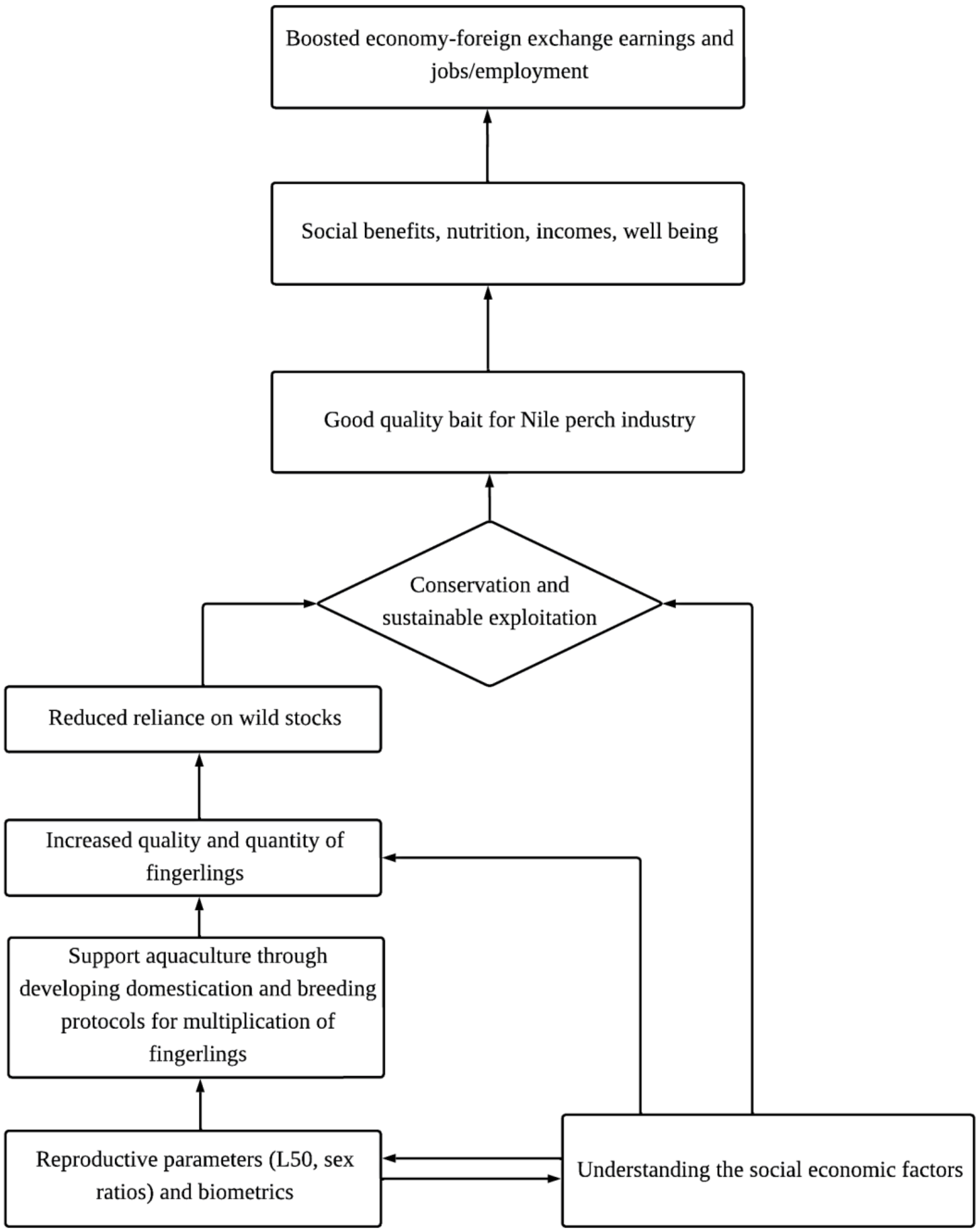

Figure 1. 1: The Conceptual framework

CHAPTER TWO: LITERATURE REVIEW

2.1 The Evolution of the Nile Perch fish industry

Locally known as Mputa and scientifically known as *Lates niloticus* (Linnaeus, 1758), Nile perch is a voracious fish with significant recreational and marketable importance (Aloo *et al.,* 2017). This voracious predator was transferred from Lake Albert to Uganda's lakes Kyoga, Nabugabo, and Victoria between the 1950s and the early 1960s (Goudswaard *et al.,* 2008). Nile Perch was covertly transferred to Lake Victoria's shoreline in Uganda in 1954 (Goudswaard *et al.,* 2008). However, it wasn't until almost ten years later, in 1963, when Ugandan and Kenyan authorities made official introductions. The species required more than 20 years to establish and grow, eventually replacing the majority of native species caught in the lake (Downing *et al.,* 2013). Advocates claimed that Nile perch would introduce a significant new fishery to Lake Victoria by consuming the plentiful and underutilized haplochromine cichlids (Bassa, 2011).

According to Aloo & Njiru, (2017), Nile Perch is among the top 100 worst invasive species in the world listed by the IUCN's Invasive Species Specialist Group. Its introduction into Lake Victoria has had disastrous impacts on the lake's fish ecology but huge positive effects on Lake Victoria's fisheries. Lake Victoria's pre-Nile perch invasion food web was diverse, with the top predators being *Clarias species, Bagrus docmak,* and *Protopterus aethiopicus* (Njiru *et al.,* 2005). Piscivores, zooplantivores, molluscivores, and detritivores/phytoplanktivores were among the existing five food levels prevalent in the waters of the lake from 1970s to the middle of the 1980s. When *Lates niloticus* populations peaked in the late 1980s and early 1990s, the food levels were monopolized by zooplantivores and phytoplanktivores. The trophic groups grew more varied as a result of the decrease of *Lates niloticus* in the early- and late-1990s (Aloo *et al.,* 2017).

Until the 1970s, the Lake Victoria fishery was mostly fuelled by livelihood purposes and a small neighbourhood market (Aloo *et al.,* 2017). Nile perch make almost 90 percent of all fish exported today both in terms of quantity and value, as a result of increased catches, transforming this fishery into a multimillion-dollar commercial fishery industry (Aloo *et al.,* 2017). Fish became Uganda's second-largest source of foreign exchange after coffee, with fish export revenues rising from less than $30 million US dollars in 1995 to approximately $145 million US dollars in 2011 (Aloo *et al.,* 2017).

The Nile perch fishery has attracted a significant number of fishermen to the lake, rising from 12,000 in the 1980s to 205,249 in 2012 (Turyaheebwa, 2014). The surge in Nile perch catches encouraged the construction of fish processing facilities around Lake Victoria's shoreline that produced chilled and frozen fisheries products for export (Njiru *et al.,* 2014). About 17 fish processing facilities in Uganda prepare Nile perch for export while adhering to high-quality standards (Kamanyi *et al.,* 2006). Nile perch has produced impressive financial gains within the East African region, including the creation of a lucrative market for frozen and preserved fillet exports, the growth of the local fishing business, and the readily available supply of Nile perch to consumers in nearby regions (Aloo & Njiru, 2017; Bassa, 2011).

2.2 Ecological Impact of Nile perch on the loss of fish species

A unique number of species centred around tilapias (*Oreochromis esculentus and O. variabilis*), and more than 500 species of haplochromine cichlids were once thought to inhabit Lake Victoria (Witte *et al.,* 2013). Based on more than 20 genera of fishes other than cichlids, there was a significant auxiliary fishery, of *Protopterus aethiopicus*, *Bagrus docmak*, *Clarias gariepinus, Schilbe intermedius*, *Mormyrus kannume*, *Labeo victorianus, Labeobarbus altianalis, Synodontis victoriae* and *Synodontis afrofischeri* (Aloo *et al.,* 2017).

At least 200 haplochromine species have gone extinct due to Nile perch predation, and other endemic fish species have practically disappeared (Wakwabi *et al.,* 2006). After the early 1980s, there was a drop in the number of haplochromines and other species. This decline is attributed to the Nile perch's increased predation, habitat degradation, pollution, Nile tilapia competition, and overfishing. Recent years have seen a rise in native species, which is partly attributed to the decline in the population of Nile perch (Aloo *et al.,* 2017).

2.3 The Nile Perch and bait industry

The effectiveness of longline fishing operations is affected by bait type and quality, which influence species selectivity and gear performance (Aneesh *et al.,* 2015; Løkkeborg *et al.,* 2014b; Foster *et al.,* 2012). According to Coelho *et al.,* (2015), the synergistic effect of hook-bait combinations increases catch crates among different species. *Mormyrus kannume* has emerged as a preferred bait among Nile perch fishers in the Lake Victoria region.

Recent reports from fishermen suggest that though *M. kannume* is commercially valuable species, it is increasingly being targeted in the bait industry due to its unique morphological and behavioral traits while. Fishermen and local merchants favor it over juvenile catfish, citing its smooth and thin body which reduces the likelihood of bait rejection by the mature Nile perch (Bassa, 2018). In addition, its ability to remain actively swinging on the hook, remaining alive on the hook for a period of up to three days are believed to enhance its effectiveness as bait (Witte *et al.,* 2012).

As a deep-water species (Kramer, 2013), *M. kannume* is strategically employed by fishermen in deeper lake zones to target larger and mature Nile Perch. Fishermen have noticed that using this species as bait' particularly pairing them with larger hook sizes such as 7 and above helps them catch larger Nile perch than they would with other bait (Bassa, 2011; Communication with NaFIRRI scientists, 2022).

However, these claims are not documented and therefore, there is need to study the scientific basis for *M. kannume's* apparent effectiveness in the Nile Perch fishing bait industry. Moreover, concerns have been raised about ecological implications of bait harvesting, particularly from habitats of rare and threatened species, as this further threatens the already threatened different species of fish in the aquatic environment (Kamanyi, 2005). Intensive bait collection driven by expanding longline fisheries could worsen the pressure on understudied fish populations and contribute to biodiversity loss.

2.4 Description, feeding and distribution of *Mormyrus kannume*

Mormyrus kannume, known as elephant-snout fish is a fresh water species that belongs to the family of Mormyridae (Figure 2:1). Mormyrids are endemic to African Rivers and are represented by about 208 species, which belong to 18 genera (Chapman & Hulen, 2001). This fish can grow up to 100 cm TL. The depth of the body (20.71-23.41% in SL) is smaller than the length of the head, and the upper profile of the head descends in a straight line. It has a tiny eye (HL: 14.46 -19.67%). All of the fins are paired and vertical, and the caudal peduncle is shallow (6.82–93.39% SL) and deeply forked. The meristic traits of *Mormyrus kannume* are 22 - 23 rays in the anal fin and 51-59 rays in the dorsal fin. The dorsal and anal fins are located on either side of the body's posterior region. The fish is a reddish or olive tint on top and white underneath (Mengesha & Akalie, 2015).

Figure 2. 1: A picture of *Mormyrus Kannume*

Mormyrus kannume spends the day at the bottom of waterbodies, but at night it becomes quite active while looking for food, making it nocturnal and connected with rocks. It feeds on insects, especially chironomid larvae, shrimp, earthworms, annelid worms, and other bottom dwellers. It has a peculiar habit of swimming backwards. Well-grown fish may deliver a significant electric shock because they have electric organs on either side of the tail's terminal part. This fish emerges from the mud in deep water to breed over rocks (Khallaf & Authman, 2010). *Mormyrus kannume* is widely dispersed throughout Africa, and in Uganda in particular, it is found throughout the Lake Victoria basin, including Lake Victoria, Kyoga, Albert, Edward, and George as well as the Upper Victoria Nile (Farrag *et al.,* 2022).

2.5 Effect of fishing on biometric fish parameters

During development, organisms become larger (in length and weight). In addition to the fish's size, age, and sexual maturity, other water quality variables, such as temperature and oxygen levels, as well as the amount of food readily available and the total number of fish relying on a specific food supply, are important growth-influencing factors for fish. A key factor in fishery evaluations is the length-weight relationship, which is one of the accepted techniques for producing reliable biological information (Kuriakose, 2017). Length-weight relationships of fishes are also among the most important biological parameters in combination with population and environmental parameters. They provide key information for conservation of natural populations and fishery management (Hossain *et al.,* 2013), and also plays a vital role in comparing morphological traits across different fish populations (Flura *et al.,* 2022).

The size spectrum remains stable within an exploited community despite changes in species composition, but it differs across systems, with these fluctuations potentially attributed to over fishing. It makes sense that most fisheries will selectively remove huge fish through exploitation, thus there will be fewer giant fish than there are little fish (Benoît & Rochet, 2003). The sustainability of the population is significantly influenced by the size structure of the fish stock. Size-selective fishing and/or warming are projected to create a shift in the size distribution of an exploited population toward tiny individuals (Tu *et al.,* 2018). A fish population's size structure may change as a result of several external factors. The most well-known examples are temperature and fishing. Fishing selectively removes larger fish, truncating a fish population's size structure, disrupting population structure and potentially reducing reproduction, recruitment success, and overall stability (Barnett *et al.,* 2017).

Research shows that agriculturally dominated streams, with increased sedimentation, higher water temperatures, and nutrient enrichment, shift fish assemblages towards more tolerant species (Neachell, 2014). There is a connection between fish assemblage and habitat structure, according to several research. In addition, habitat spatial variations brought on by changes in physical gradients may have an impact on fish population biometrics. These density-independent factors include food availability, structural elements like refuge areas, and organism interactions like competition and predation within the system (Ssanyu *et al.,* 2014).

2.6 Effect of fishing on sex ratios of fish species

Sex ratio is a key demographic factor with significant consequences for the dynamics, management, and conservation of animal populations (Alonso-Fernández *et al.,* 2017). The fishers Principle suggests that the male to female ratio may not be exactly 1:1. This discrepancy could be attributed to a variety of dynamic characteristics, including processes that are density dependent, resource-limited, or even processes that interact with the environment (Manning *et al.*, 2015). There seems to be a significant decrease in the larger sex members of sex-changing species that are subject to size-selective fishing, particularly those species that form enormous spawning aggregations, such as *Microlepidoptera Mycteroperca* species (Smith *et al.,* 2018). The common hogfish *Lachnolaimus maximus* is an example of a species that does not form spawning aggregations but nevertheless experiences losses in the bigger sex due to the nature of the spawning behavior and fishery (Cooper *et al.,* 2013). Fishing has an effect on population vital rates and demography depending on the sizes and sexes used (Chong-Montenegro & Kindsvater, 2022). Also, domesticating fish necessitates studying its reproductive biology, which resolves issues for spawning season, fecundity, mode of spawning, size at sexual maturity, and sex ratios (Aruho *et al.,* 2013). If one sex is more likely to be recorded than the other at a given site, assessments of the sex ratio there may be biased. Different physical intimacy catchabilities can also result in skewed sex ratios since male and female fish are removed from fisheries at different rates (Jury *et al.,* 2019).

2.7 Effect of excessive fishing on fish size at sexual maturity

The term "size at maturity" describes a fish population when 50% of a particular class size is sexually mature (Aruho *et al.,* 2018). The most common mean indices used to determine the stage at which half of fish in the same classification reach sexual maturity are length and weight (Hossain *et al.,* 2012). For effective management of fisheries resources, it is essential to have objective information about fish demographics, such as frequency patterns for length, length-weight correlations, sexual maturity sizes, and stages of gonadal maturity (Magqina *et al.,* 2021). Size at maturity (L_{50}) is a fundamental population indicator that is significant in managing fisheries for overfished stocks (Karna *et al.,* 2011). Information on the size at first maturity is often required by the governing systems to guarantee that an adequate number of juveniles attain sexual maturity. Size at maturity is closely connected to a fish species' growth, maximum size, and lifespan (Magqina *et al.,* 2021).

According to Magqina *et al.,* (2021), increased fishing pressure lowers the proportion of large or targeted size individuals in the adult population, which in turn alters the size distribution of the stock. While a high frequency of large, sexually mature individuals is usually considered indicative of a healthy fish stock structure, this change in size structure is widely recognized as detrimental for fish communities. The same study further highlights that overexploitation directly influences sex ratios and the size at sexual maturity. In order for fish to secure their survival, they must start reproduction at smaller sizes because it is anticipated that a decline in size at sexual maturity will be counterbalanced by a rise in death among adults (Jørgensen *et al.,* 2007). The maturity ogive, which is the term for the percentage of mature individuals at a given age or length, is a crucial population characteristic since it has a direct bearing on the population's capacity for reproduction and therefore its recruitment. For exploited fish populations, understanding the maturity ogive is crucial since it establishes the spawning biomass that conservation efforts are based on (Vitale *et al.,* 2006).

There are various methods for determining size at maturity, but the most frequently used one is to track the seasonal variations in fish gonad growth (Magqina *et al.,* 2021). Histology or macroscopic studies are used to reveal the various stages of gonadal development or maturity, and they are used to establish the phase that most clearly demonstrates the reproductive potential/maturity staging (percentage of mature fish at a specific age or length). Macroscopic analysis to determine different stages of sexual maturity (Table 2:1) is quite cheap, however it typically introduces a lot of inaccuracy. Histology is the most accurate procedure for maturity staging, but it is also the most expensive and time-consuming. Histology helps to identify the sexes of individuals before they are appropriately staged (Brown-Peterson *et al.,* 2011).

Gerber *et al.,* (2009) used microscopic and histological approaches in gonad grading of male and female Tigerfish, aiming to identify when sexual maturity is reached. It was concluded that it was the most appropriate method for estimating size at sexual maturity. The study focused on the Tigerfish *Hydrocynus vittatus* Castelnau, 1861 from the Okavango Delta.

Table 0:1 Histological features of female and male gonadal stages defined: adapted from (Brown-Peterson *et al.,* 2011)

Phase/stage of sexual maturity	Macroscopic and histological features (female)	Macroscopic and histological features (male)
Immature (never spawned)	Small, often clear ovaries, with indistinct blood vessels. Contains only oogonia and primary growth oocytes. No atresia or muscle bundles. Thin ovarian wall and little space between oocytes	At this stage, undifferentiated germ cells necessary for sex identification (via histology) are absent, similar to what is observed in females.
Developing (ovaries beginning to develop, but not ready to spawn)	Enlarging ovaries with increasingly distinct blood vessels. Contains primary growth, cortical alveoli, vitellogenic stages 1 and 2 oocytes. No post- ovulatory follicles or vitellogenic stage 3 oocytes. Some atresia may be present. Early developing subphase: primary growth and cortical alveoli oocytes	Characterized by the prevalence of germinal areas where spermatogonia and spermatocytes are developing. Occasionally, small clusters of maturing spermatids and early-stage spermatophores can be seen.
Mature/ripe/ Spawning capable (fish are ready to spawn in this cycle)	Large ovaries with prominent blood vessels. Individual oocytes visible to the naked eye. Presence of vitellogenic stage 3 oocytes or post ovulatory follicles in batch spawners. Possible atresia of vitellogenic and/or hydrated oocytes. Early stages of oocyte maturation may be present. Actively spawning subphase: oocytes undergoing late germinal vesicle migration, germinal vesicle breakdown, hydration, or ovulation	Numerous seminiferous tubules filled with spermatids are evident, surrounded by two secretions that facilitate agglutination for spermatophore formation. One secretion appears blue to purple when stained with hematoxylin-eosin, while the other is an intense pink. Occasionally, fully formed spermatophores may be observed within the pink-stained substance, though significant spacing is present between them.
Spent/ Regressing (cessation of spawning)	Flaccid ovaries with prominent blood vessels. Presence of atresia at any stage and post ovulatory follicles. Some cortical alveoli and/or vitellogenic (stage 1 and stage 2) oocytes may be present.	This stage is marked by a high concentration of mature spermatophores encased in a pink-stained substance, with minimal spacing between them (average diameter of 263.7 microns). There is

		also a noticeable decline in the secretion of the blue-purple substance. Small developing areas may still be visible.
Regenerating (sexually mature but reproductively inactive)	Small ovaries with reduced but present blood vessels. Contains only oogonia and primary growth oocytes. Muscle bundles, enlarged blood vessels, thick ovarian wall and/or gamma/delta atresia or old, degenerating post ovulatory follicles may be present	Similar to the process observed in females, this stage involves extensive cellular degradation, with remnants of advanced-stage male gametes and phagocytes actively participating in resorption.

2.8 Socio-economic importance of *M. kannume*

Recent years have seen a need for greater research into the breeding capacity of the commercially important species because of the need for the sustainable use of the Lake Victoria Basin's fish stocks. *Mormyrus kannume* is an indigenous and dominant fish species widely distributed across East Africa, extending up to Egyptian waters. On the Upper Victoria Nile, it is heavily exploited as bait and food by riparian communities, where fishing has long played a key socioeconomic role (Bassa, 2018). Additionally, this may be related to the Nile River's traditional gillnet setting being abandoned in favour of the exploitation of the fishery through the use of basket traps. The use of Elephant snout fish as food and a bait for *Lates niloticus* fishing in Lake Victoria has changed, which has also led to changes in the fishery (Hitamwebwa *et al.,* 2009). The use of bait for fishing the Nile perch has modified how fish are caught across the ecosystem, which has resulted in an ecological loss (Bassa, 2011).

2.9 Catch trends and economic importance of *Mormyrus kannume*

The annual catch of the *M. kannume* indicated an increase from 5 tonnes to 28 tonnes and an increase in yearly beach revenue from 1,200 to 8,600 US dollars from 2008 to 2016. This shows how the *M. kannume* has appreciated due to heavy human exploitation as bait for Lake Victoria's Nile perch fishing (Bassa *et al.,* 2018), (Figure 2:2). The small-scale fisheries' information regarding open access, wide dispersal owing to nature, and leadership of fishing areas and landing locations supports the exploitation, which makes the management of fishing related activities challenging (Bassa *et al.,* 2016).

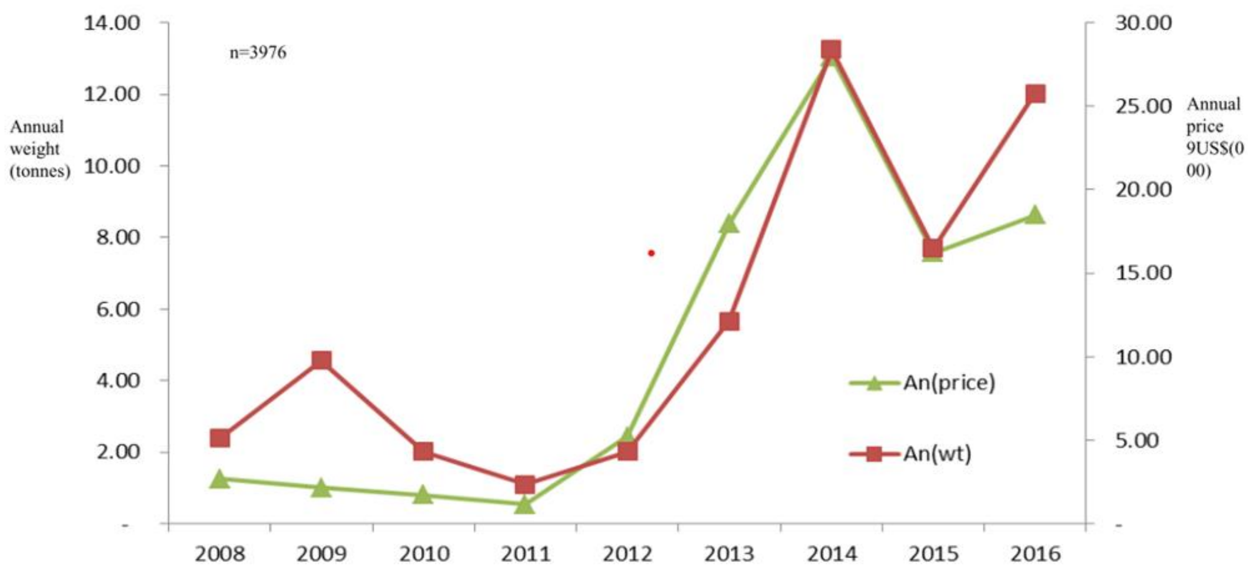

Figure 2. 2: Catch trends and economic importance of *M. kannume:* as adapted from (Bassa *et al*., 2018).

2.10 Summary of gaps in the literature

Bassa (2018) assessed the socio-economic contribution of *M. kannume* based on bait and food for the riparian populations. This study overlooked the key socio-economic factors in the Nile perch fishery. These include bait demand and preference, bait sources, bait sizes and the size of the Nile Perch caught using *M. kannume*. It also did not account for the comparative costs and returns associated with this bait use.

A study by Natugonza *et al.,* (2022), highlights the increasing use of *Mormyrus kannume* as bait in the Nile perch fishery but points to a significant gap in understanding its exploitation and population dynamics. Despite claims by fishermen that this practice has improved Nile perch catchability, there is limited data on the current population structure of *M. kannume*, its size distribution, sex ratio, and length at sexual maturity. The species, once abundant in Lake Victoria, is now largely confined to the Upper Victoria Nile, with declining catches reported. Without comprehensive studies on its reproductive biology and population trends, it remains unclear how intensive fishing is affecting its sustainability. This gap makes it difficult to assess the long-term impact of its exploitation and the potential risks of overfishing, which could lead to population decline or even extinction.

A study by Bassa (2018), further underscores the lack of established management strategies for the sustainable use of *M. kannume* in the Nile perch fishery. While fishermen rely on this species as bait, illegal fishing practices, such as the use of basket traps and hooks to capture immature fish, are widespread. However, there is no clear guidance on the appropriate size of *M. kannume* selected as bait, which could help balance economic benefits with conservation efforts. The absence of regulations on bait selection and fishing methods raises concerns about unsustainable exploitation, potentially reducing the species' economic contribution and threatening its survival. Without targeted conservation measures and sustainable fishing practices, the continued use of *M. kannume* as bait may lead to severe ecological consequences in the Upper Victoria Nile.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

The research study was conducted along the Upper Victoria Nile in Jinja District Eastern Uganda. The questionnaire was administered to fishermen along 7 selected landing sites on the Upper Victoria Nile and Lake Victoria where most of the *Mormyrus kannume* fish is primarily transported in water-filled jerrycans by motorcycles and taxis and then sold to fishermen for use as bait to catch Nile perch (Figure 3:1). The study area's topography is characterized by a flat to gently sloping landscape with an average elevation of 1,200 meters above sea level, surrounded by hills. The area has a tropical climate with average temperatures between 20°C and 28°C (68°F to 82°F) throughout the year. It experiences a humid subtropical climate with two main rainy seasons; from March to May and from August to November, with an average annual rainfall of 1,200 mm and a dry spell from December to February and June to August. The vegetation in this area is dominated with mainly; shrubs and papyrus grass (*Vossia*) (NaFIRRI, 2017). The catch composition is dominated with Fish species of Nile perch (62.79%), Tilapia (23.51%) and Elephant snout fish (13.64%) (Bassa *et al.,* 2020). According to the 2024 Uganda Population and Housing Census, the area is densely populated with districts along the Upper Victoria Nile (Jinja, Buikwe, and Mayuge) having a combined population exceeding one million residents. The area is predominantly inhabited by the Basoga, with significant communities of Baganda, Iteso, and other local tribes (UBOS, 2024). People in the area engage in various economic activities. These include, fishing, aquaculture, sugarcane cultivation, sale of fish, agricultural products, and other goods, as well as in small-scale industries involved in fish processing.

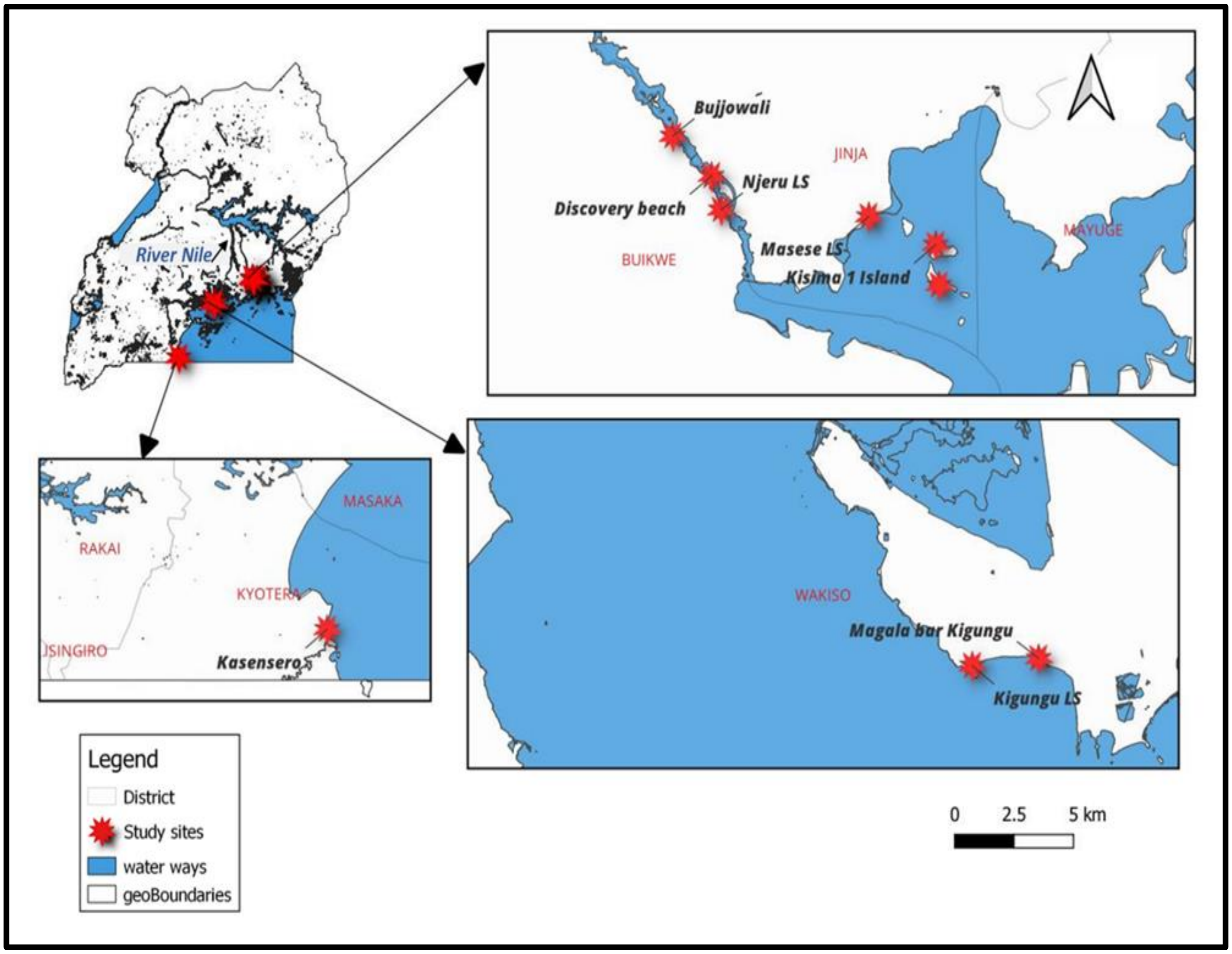

Figure 3. 1: A map of the study area showing study sites

3.2 Research design

The study was both qualitative and descriptive utilizing both qualitative and quantitative data. The descriptive part was on the estimation of gonadal maturity stages using histological procedures in the laboratory, determination of sex ratios and length and weight measurements. The study intended to provide information on the extent of the impact of overfishing of *Mormyrus kannume* bait on its conservation and devise strategies for regulating its fishing along the upper Victoria Nile. Random sampling method was utilized in the selection of respondents in selected landing sites along the upper Victoria Nile and selected landing sites along the Lake

Victoria. The sample specimens of *M. kannume* from the river were collected from the upper Victoria Nile using basket traps and fishing nets with the help of the fishermen. The collection was done using random sampling method. The specimens were collected for a period of 12 months from March 2023 to February 2024.

A consent form was designed and taken to the appropriate authorities for study approval and data collection from respondents. The fish samples for the study were collected, packaged and transported safely to NaFIRRI Jinja laboratory where the length and weight parameters were measured and sex visually identified and all recorded on a data sheet and gonads extracted. The extracted undifferentiated gonads were preserved in 10% formalin, transported to Makerere University's COVAB histology laboratory for histological processing, examination and staging. The size at sexual maturity was determined through microscopic examination of histological slides from histological processing. This revealed key gonadal development stages, such as oocyte maturation in females and spermatogenesis in males, providing detailed insights into the specimens' reproductive status/stage of sexual maturity. Data was analysed using IBM SPSS Statistics 20 and Microsoft Excel 2016 software. The socio-economic aspects, size at sexual maturity, sex ratios, and biometric parameters (length and weight) were determined for further analysis.

3.3 Data collection tools and methods

3.3.1 Identification of the socio-economic factors that promote the use of *Mormyrus kannume* as bait in Nile perch fishery.

From a population of 290 fishermen, 166 respondents were selected. According to the sample determination table by Krejcie & Morgan, (1970), this sample size is appropriate for a target of

165 respondents, at 5% margin of error and 95% confidence interval. A total of 166 questionnaires were designed targeting 166 respondents from 8 selected fish landing sites along the upper Victoria Nile and Lake Victoria. The selected landing sites were Bujjowali, Lower Naava (Discovery beach), Njeru, Kisima 1 and Kisima 2 Islands on the Upper Victoria Nile and Masese in Jinja, and Kigungu in Entebbe and Kasensero in Kyotera at the Lake Victoria. These are some of the landing sites where most of the bait is primarily transported and subsequently sold to fishermen for use as bait in catching Nile perch. The face-to-face interviews with fishermen/respondents were conducted personally with the support of chairpersons of the landing sites. However, the fishermen encountered at Masese landing site during the survey were only using gillnets and did not require the bait, making them unsuitable respondents for the study. Therefore, no interviews were conducted at Masese landing site. The questionnaires were administered during the month of March 2023. Face to face interviews (Figure 3:2) were used to administer the questionnaires to the respondents. Non probability sampling method in particular purposive/judgement sampling method was used to select participant respondents. This method helped in selecting individuals on the landing sites based on their fishing experience in reference to the research subject (Makwana & Hardik, 2023). The respondents largely included the fishermen, boat owners and fisheries managers. These respondents had knowledge and experience on the Nile perch fishing using baits.

The questionnaire was in English language and was comprised of both open-ended and closed-ended questions (semi-structured questionnaire). It composed of questions regarding prior Nile perch captures with various bait species, demand, preference, source, and size of *M. kannume* bait used, and Nile Perch size being captured with the bait, the gear used with the bait, the locations of the preferred *M. kannume,* the cost of the preferred bait, and the comparative cost versus the returns on the Nile Perch captured. A major challenge encountered was the language of instruction in the questionnaire, as some respondents did not speak English. To address this issue, the questionnaire was translated into local languages, such as Luganda.

Figure 3. 2: The researcher (Eunith Mbaho) interviewing fishermen along; (A) the Kisima 1 island on Lake Victoria and (B) along the upper Victoria Nile

3.3.2 Collection of fish samples

To determine the size at sexual maturity, sex ratios and biometric parameters (size in terms of body length & weight) of *M. kannume*, a total of 1689 fish samples were collected; that is approximately 140 fish samples of *M. kannume* over a period of twelve months (March 2023 to February 2024) (Ahmad & Halim, 2017). The fish samples were collected at the end of every month; (March 2023 to February 2024) by the help of fishermen using passive collection methods particularly entrapment gear; basket traps (**Error! Reference source not found.**) (Environmental Protection Agency *et al.,* 2023). The basket trap method is the most popular technique employed by fishermen to capture *M. kannume* in this region (Bassa, 2018). These basket traps were set up for three consecutive nights each month, for a duration of twelve hours per night. They were positioned near rocky areas in the river, which is the preferred habitat for *Mormyrus kannume* (Khallaf & Authman, 2010). This placement eased the fish's movement into the traps, which were designed to prevent escape due to their small, portable, and rigid structure with an opening that allows entry but hinders exit. The collected fish were then transported live with a live fish transporting vehicle to NaFIRRI laboratory Jinja.

Figure 3. 3: Basket traps used to catch *Mormyrus kannume*

1.7.1 Determination of sex ratios of *Mormyrus kannume*

In the NaFIRRI laboratory the fish samples were anaesthetised with overdose of clove oil to kill them. For each fish, its length and weight were recorded. They were then dissected to expose the reproductive organs so as to visually identify the males and females in the samples collected. Sex for each fish sample was recorded in a data sheet alongside an Identification Number (appendix 2).

3.3.3 Determination of size at sexual maturity of *M. kannume*

The collected and transported live fish were anaesthetised with overdose clove oil to kill them

at NaFIRRI laboratory. Fish length and weight were first recorded before dissecting the fish to expose the gonads. Each of the fish samples was dissected to expose the gonads so as to identify sex of the fish and its stage of sexual maturity. To confirm the different maturity stages, tiny gonad fragments from each fish were immediately stored in 10% Formalin solutions in small plastic sample bottles (Figure 3:4) for additional histological examination. The preserved specimens were transported to Makerere University's Faculty of Veterinary Medicine, Animal Resources and Biosecurity (COVAB) histology laboratory where they were histologically processed in accordance with accepted histological methods (Torres-Martínez *et al.,* 2017). The histological procedure done in the laboratory is clearly described on page 30-31 of this thesis. The classification into maturity stages was based on the revisions to the classification from (Brown-Peterson *et al.,* 2011).

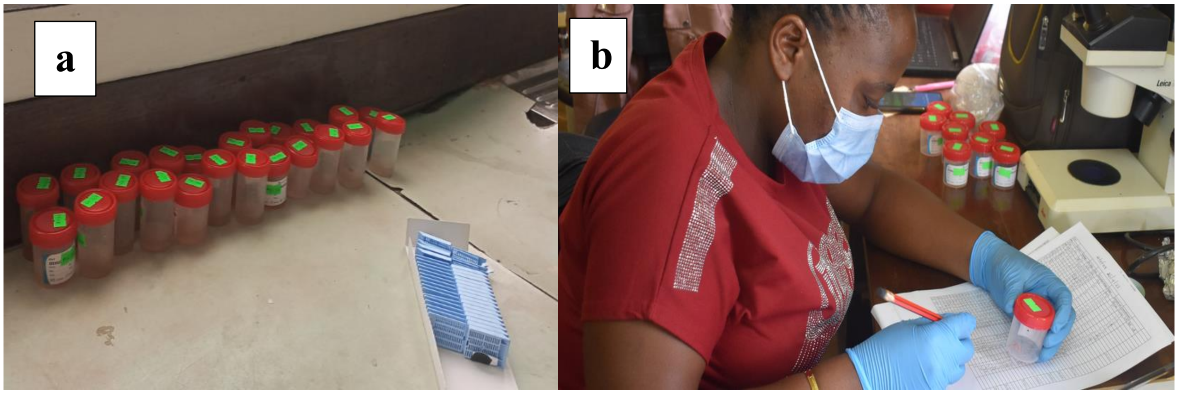

Figure 3. 4: (a) Preserved samples at COVAB lab Makerere, (b) Recording the identified sex of the fish on the fish sample data collection sheet and marking of sample bottle containing the preserved gonad sample with the corresponding fish ID

3.3.4 Examination of the biometric parameters (length-weight relationship)

The length and weight parameters were first measured before dissecting the fish to expose the gonads (Figure 3:5). Body weight was measured to the nearest 0.01gram using a calibrated electronic weighing scale (AEX 9552), and the individual fish weight in grams was recorded on a fish sample data collection sheet (appendix 2). The standard and Total Lengths of the individual male and female samples were measured to the nearest 0.1 centimeter using a measuring board (R590.24 WESTCOTT® Stainless steel ruler) and recorded separately. The standard length of the fish was obtained by measuring the length of the fish from the snout to the bend of its caudal fin, and the total length by measuring the fish from the base of the snout to the most posterior part of the caudal fin. Total Length was used because fishery regulations, including size limits, are often based on total length (TL), making it a practical choice for enforcement and field data collection (Carlander & Smith, 2016). Additionally, TL considers caudal fin growth, offering a more comprehensive representation of fish size, which is valuable for growth and population studies (Draper, 2020). The obtained length and weight values of the fish samples was further used to estimate/calculate the length weight relationship of *M.*

kannume. Also, the Total Length measured was used in the calculation of the Length at sexual maturity (L_{50}).

3.3.5 Tissue processing

The fish samples were processed for histological examination as described by Torres-Martínez *et al.,* (2017) for fish maturity stage determination. Fish gonads fixed at 10% formalin were grossed or cut to a thickness of 3-4 mm and loaded into standard sized tissue cassettes and then loaded on the automatic tissue processor (Histo Kinette model Leica TP1020-Germany). During processing, tissue samples were first dehydrated through a series of increasing concentrations of Ethanol starting with 70%, 80%, 90% and 95% for an hour in each bath then continued to three changes of 100% ethanol for one and a half hours to completely remove the water content from the tissues.

After complete dehydration, the tissues were cleared of ethanol by using two changes of xylene. In xylene one, samples stayed for one hour and in xylene two, samples were cleared for one and a half hours. Then, the samples were taken to the last stage of tissue processing called infiltration using two changes of molten paraffin wax for two hours in each bath. The aim of that stage was to provide internal support to the tissues. After tissue processing, the samples were sectioned at a thickness of 4 μ using a rotary microtome (model Leica RM2235, Germany).

The cut sections were floated on water bath (model Leica, H11210, Germany) at a temperature of 44°c to remove the wrinkles. Wrinkle free sections were mounted on microscope slides and then dried in the hot air oven (model Esco Isotherm, Forced Convection Lab. Oven) at a temperature of 53°c overnight. They were; then stained with Haematoxylin and Eosin standard protocol and finally mounted using D.P.X and allowed to air dry. The slides were then examined using a light microscope (model BM-120) to facilitate identification of sexes and developmental stages.

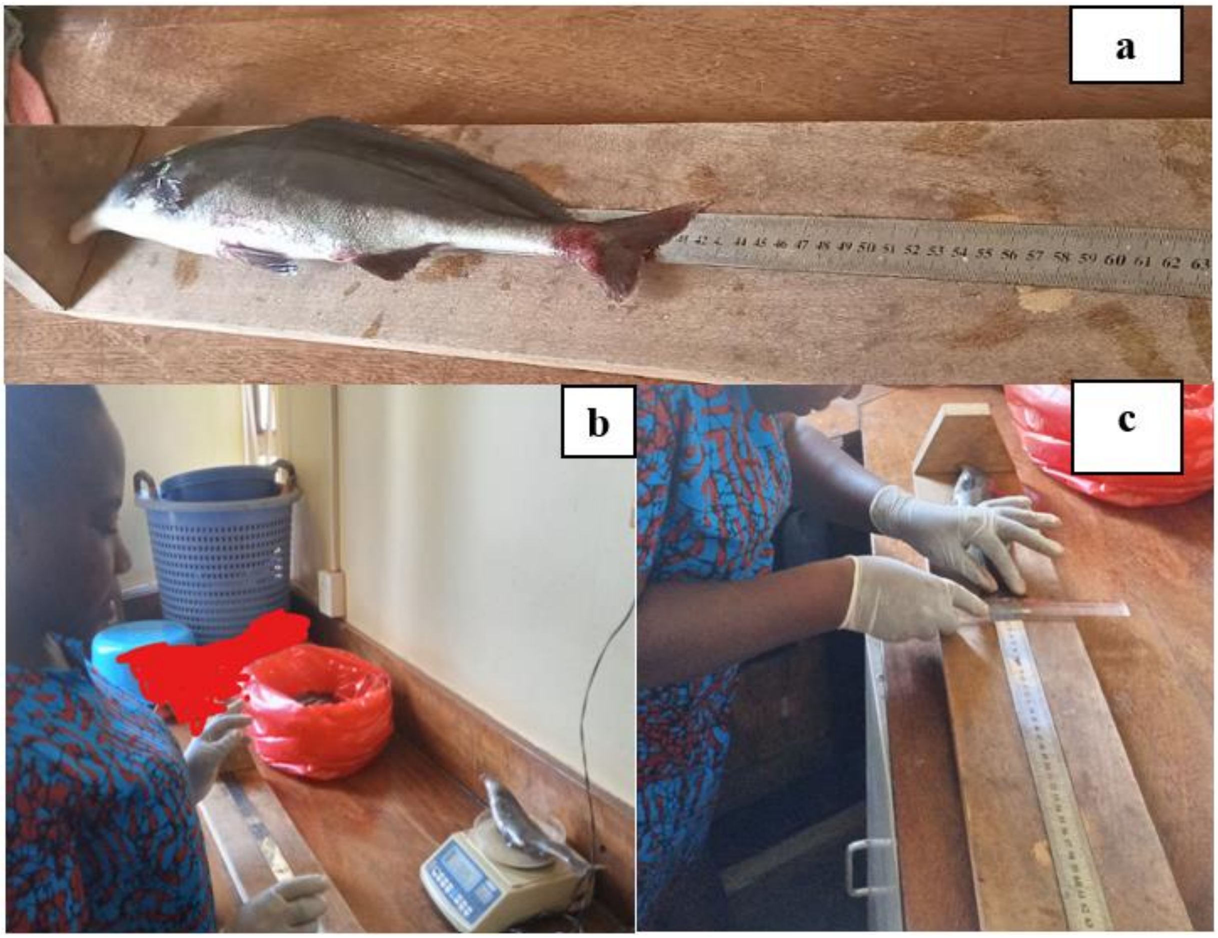

Figure 3. 5: (a) Fish sample on a measuring board, (b) measurement of fish weight on an electronic balance; (c) measuring of fish Total and standard length on a measuring board

3.4 Ethical considerations

The following ethical guidelines were considered during the study period:

1. Participation in the research survey was totally voluntary and the selected respondents had the right to or not to answer every question asked to them, as well as decline to respond to any that they felt uncomfortable responding to.

2. Informed consent was used to allow survey participants to participate (Appendix 5). Before consenting to participate in the study, respondents were given sufficient information about the study and its intended objectives. Individuals were allowed to freely make a choice on whether to take part in the study or not without putting them under any pressures.
3. The research data was kept confidential throughout the study, ensuring that participants' dignity and wellbeing were consistently protected. Care was taken to avoid using disrespectful, biased, or otherwise inappropriate language in formulating the questionnaire.

3.5 Data analysis

To determine the socio-economic aspects relating to the use of *Mormyrus kannume* as bait, questionnaire data was entered in Microsoft Excel and then imported into SPSS for analysis. Descriptive statistics with means, frequency distribution, percentages, identification of patterns, trends, and outliers were done in SPSS. Chi-Square tests of independence and Fisher's Exact test, were run in SPSS to show if there is a significant relationship between the socio-economic factors promoting the use of *M. kannume*. All the results were presented in form of tables and graphs.

The sex ratio that is females: males (F:M) was calculated monthly by dividing the total number of females by the total number of males. A chi-square (X^2) test was run using Microsoft Excel to assess whether there were significant differences between the observed sex ratio and the normally expected 1:1 (Oliveira *et al.,* 2012).

Size at sexual maturity; the length at which 50% (L_{50}) of *M. kannume* in class size are sexually mature was estimated from the ratio of the coefficients of a binary logistic regression of Total Length and gonadal maturity level that is mature to immature *M. kannume*. By using Excel-solver, a statistical application in Microsoft Excel version 2016, the binary regression's coefficients (α and β) were computed. The length L_{50} = Alpha (α)/Beta (β), where α and β are the coefficients of a two-parameter non-linear model (Aruho *et al.*, 2018) obtained by stabilizing the coefficients and fitting the logistic ogive curve using Excel-solver. The two-parameter logistic ogive were described by the non-linear equation:

$PL = (1+\exp(L-L_{50}))^{-1}$;

Where: PL was the predicted proportion of mature fish at the length of the fish L,

$L_{50}=\alpha/\beta$,

α and β were coefficients of the parameter model.

A regression analysis was run relating length and weight to determine an equivalent weight at L_{50}. Different fish sizes were clustered into ranges of eight classes or divisions with an Excel pivot table so as to generate the size frequency distributions (number of collected fish in each size class) for each size class for the data collected. A graph was plotted with individual sizes against these class intervals, and a line was drawn from the X-axis at length to intersect with the weight at 50%, from which the L_{50} value was determined as adapted from (Longenecker *et al*., 2020).

The biometric parameters (length-weight relationship) of *Mormyrus kannume* fishes is defined by the typical equation;

$W=aL^b$,

where w, (weight in grams) and L (length in cm) are variables

a and b are parameters (Le cren, 1951).

The estimation procedure for length - weight relationship was through linear regression. Prior to regression analysis of logW on logL, length weight relationship was expressed graphically by plotting the observed lengths and weights and log transformed length and weight on a scatter chart diagram for visual inspection of the data (Froese, 2006).

Since the aforementioned length to weight relationship model was not linear, it was transformed into linear type by applying logarithmic transformation (using base-10 logarithms) to transform the above model into linear for regression as;

$\text{Log } W = \log10\ a + b\ \log10L$;

Where: ln(a) is the intercept and (b) the slope or regression coefficient.

Regression analysis was run using Microsoft excel version 2016 (regression analysis tool) to estimate the length weight parameters (a and b) (Kuriakose, 2017). The calculated value of b was then compared to the p-value of an independent T-test to determine the relationship or correlation between length and weight of *Mormyrus kannume* fishes.

CHAPTER FOUR: RESULTS

4.1 Socio-economic aspects relating to the use of *Mormyrus kannume* as bait in the Nile Perch fishery

This section presents results from the survey conducted on the selected landing sites along the Upper Victoria Nile and Lake Victoria; Bujjowali, Lower Naava, Njeru landing site, Kisima 1 and Kisima 2 Islands on the Upper Victoria Nile and Kigungu landing site in Entebbe and Kasensero landing site in Kyotera along Lake Victoria.

4.1.1 Characteristics of the respondents

Table 4:1 presents the fishing activity attributes of the respondents surveyed in the study area in frequency and percentage. The majority of fishermen (43.4%) had between 11–20 years of fishing experience with a mean of 15.9 ± 9.5 years. The majority of the fishermen were relatively experienced, while only a small percentage (4.2%) had over 30 years of experience. All respondents (100%) were male, reflecting a male-dominated profession. The Nile perch was the predominant species targeted by 90.4% of fishermen. Other species, such as tilapia (5.4%), lungfish (0.6%), and other species that is *M. kannume* (2.4%), were less targeted by fishermen using baits. The majority of the respondents (37.0%) used a combination of *Mormyrus kannume* and other baits (Haplochromines, Spiny eel, Mudfish, Catfish, Synodontis), followed by *M. kannume* used exclusively (19.8%) and Haplochromines (16.0%). Less common bait types included Spiny eel and Haplochromines (11.7%), Mudfish (5.6%), and Catfish (1.9%). Less than 1% of fishermen used Synodontis, showing its limited use as bait.

The respondents were relatively evenly distributed across major landing sites. Kisima I and Kasensero had the highest number of respondents, each having 20.5% of fishermen, followed by Kisima II (19.3%) and Kigungu (11.4%). Smaller numbers of respondents were found at Discovery Beach (10.8%), Bujjowali LS (9.6%), and Njeru LS (7.8%).

Table 4. 1: Fishing activity characteristics of the respondents (n =166)

Variables	Frequency	Percentage (%)
Fishing experience (Years)		
1-10	58	34.9
11-20	72	43.4
21-30	29	17.5
31-40	5	3.0
41-50	1	0.6
51-60	1	0.6
Mean $\pm$ std	15.9 $\pm$ 9.5	
Sex		
Male	166	100
Target species		
Nile perch	150	90.4
Lung fish	1	0.6
Tilapia	9	5.4
Others (*M. kannume*)	4	2.4
All (Nile perch, Lungfish, Tilapia)	2	1.2
Preferred bait types used		
M. kannume and any other	60	37.0
M. kannume	32	19.8
Haplochromines	26	16.0
Spiny eel and Haplochromines	19	11.7
Mudfish	9	5.6
Catfish	3	1.9
Synodontis	1	0.6
All (*M. kannume*, haplochromines, Spiny eel, mudfish, catfish, synodontis)	12	7.4
Landing Sites (LS)		
Kisima I	34	20.5
Kisima II	32	19.3

Kasensero	34	20.5
Kigungu	19	11.4
Discovery beach/Lower Naava	18	10.8
Njeru LS	13	7.8
Bujjowali LS	16	9.6

4.1.2 Proportion of fishermen (anglers) using *M. kannume* as bait

From the Figure 4:1 below, (131) 78.9% of the respondents were using *Mormyrus kannume* as bait to catch Nile perch while (35) 21.1% respondents had not used *Mormyrus kannume* as bait to catch Nile perch.

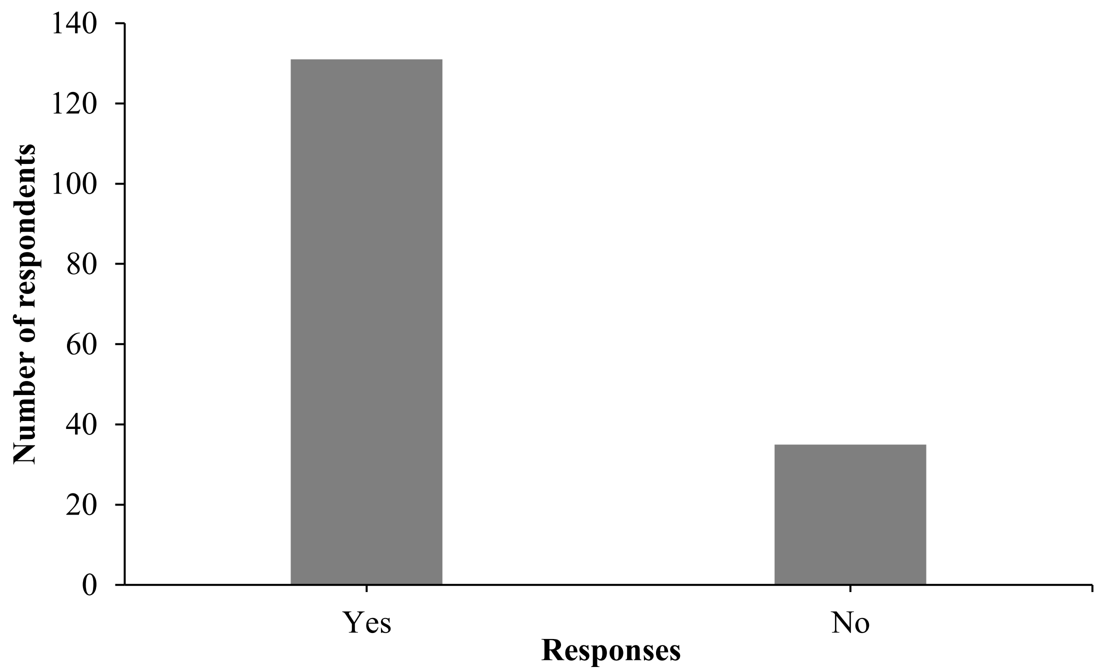

Figure 4. 1: The number of respondents who have ever used *M. kannume* to catch Nile Perch

4.1.3 Preferred size of *M. kannume* for catching Nie perch

Based on the data presented in the Figure 4:2 below, majority of respondents, 42 (40.4%), preferred using *Mormyrus kannume* baits with a girth measurement of 2.1-3.0 inches. The least preferred girth size by respondents was 2.0-3.0 inches, mentioned by only 1 respondent (1.0%) as their preferred size.

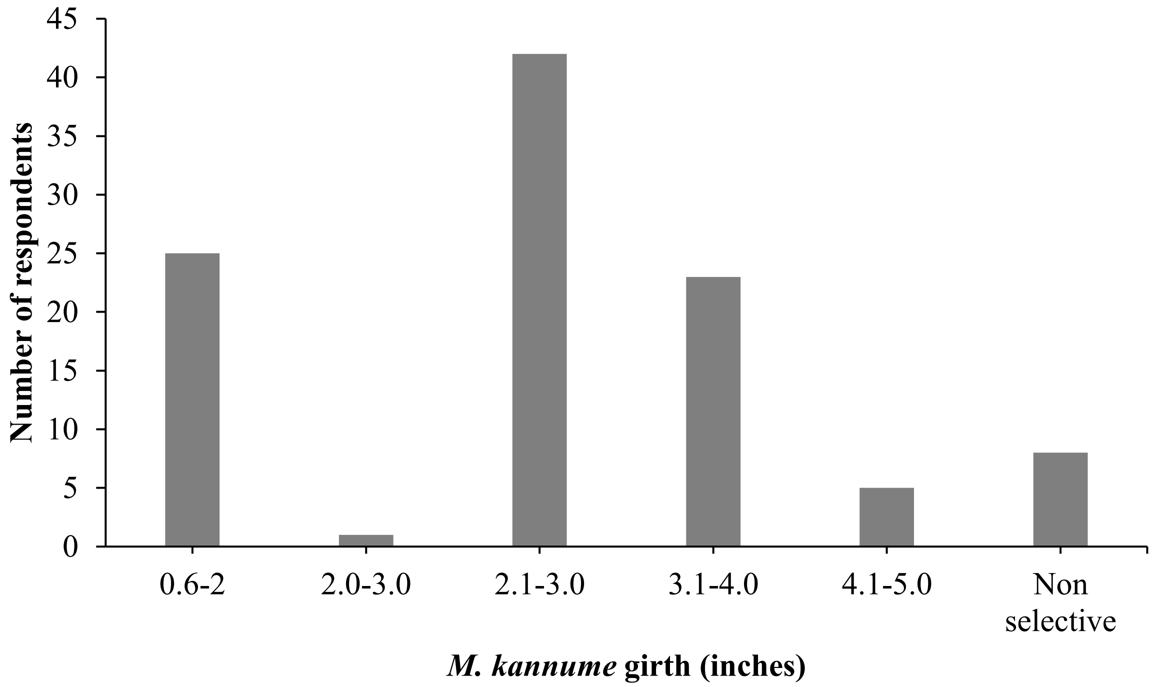

Figure 4. 2: Estimated fish girth of *M. kannume* preferred for use by fishermen

4.1.4 Number of *M. kannume* baits used per fishing trip

The majority of respondents, 36 (34.6%), reported using 31-100 baits of *M. kannume* per fishing session, while the least group, consisting of only 1 respondent (1.0%), used just a single bait per fishing as presented in the Figure 4:3 below.

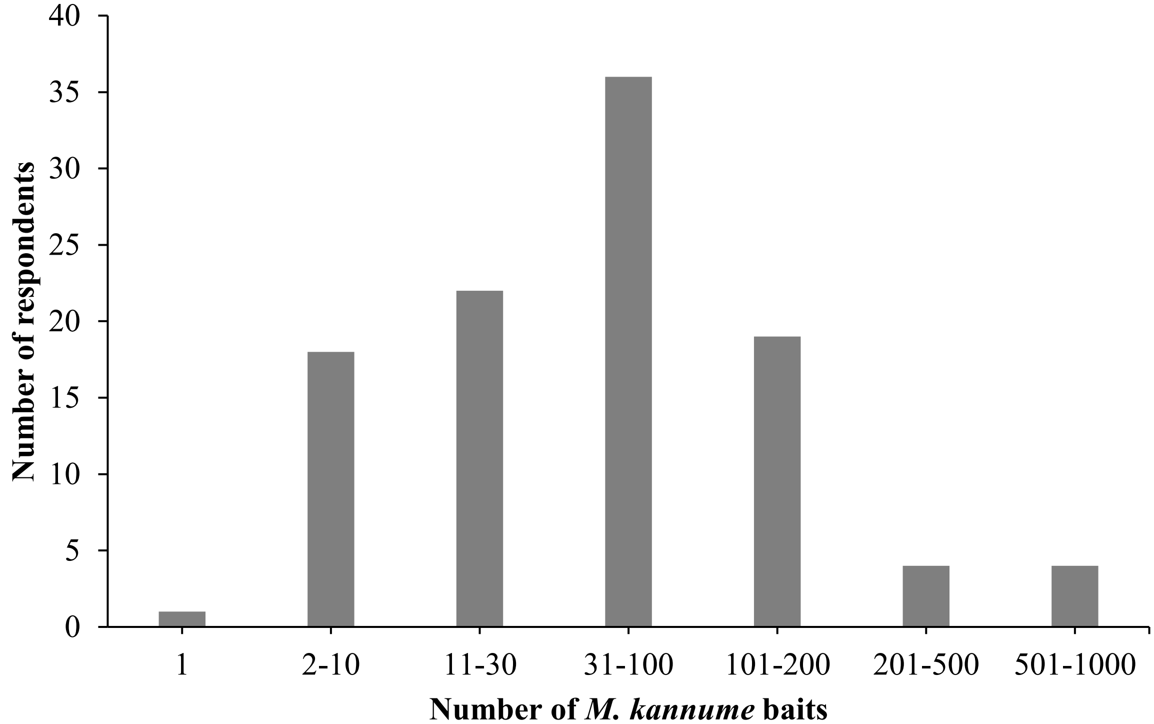

Figure 4. 3: Number of *Mormyrus kannume* baits used per fishing by respondents

4.1.5 Number of hooks used with *Mormyrus kannume* to catch Nile perch

There was a wide range in the number of hooks used by fishermen, reflecting diverse scales of fishing operations among those using *M. kannume* bait for Nile perch. The majority of respondents, 40 (38.5%), operated using a moderate to large number of hooks (51–200). However, some fishermen operated using either very few hooks (as low as two) or an exceptionally high number of hooks (>1001) as shown in Figure 4:4 below.

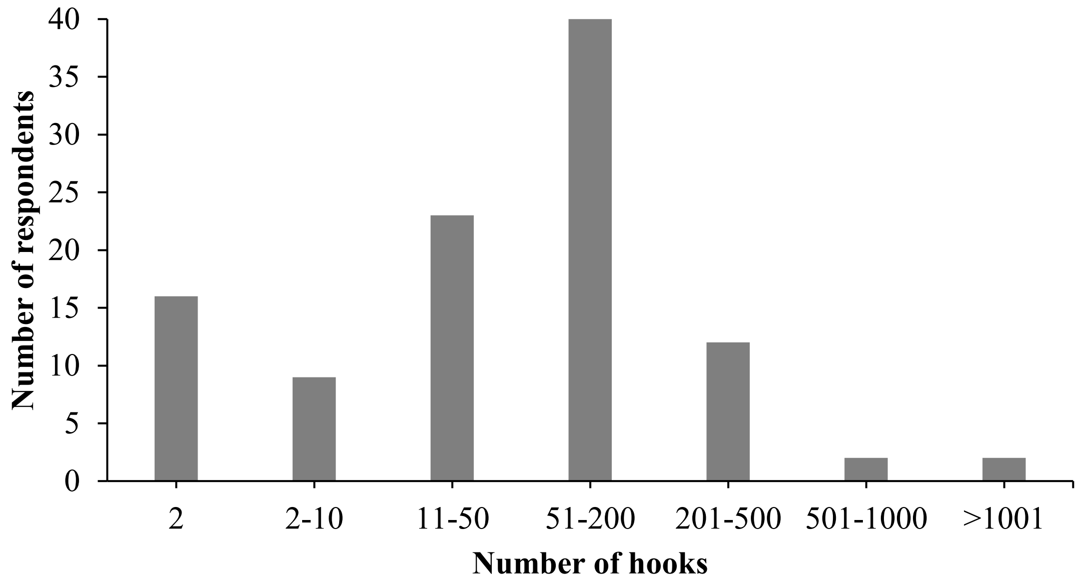

Figure 4. 4: Number of hooks used by respondents to catch Nile perch using *M. kannume* baits.

4.1.6 Frequency of setting of hooks when using *Mormyrus kannume* to catch Nile perch

From Figure 4:5, majority of the respondents 57 (54.8%) set their hooks daily, 26 respondents (25.0%) set their hooks three to five times a week, and 19 respondents (18.3%) set their hooks once or twice a week. The smallest group, 2 respondents (1.9%), set hooks once or twice a month citing seasonality of *Mormyrus kannume* and engagement in other businesses.

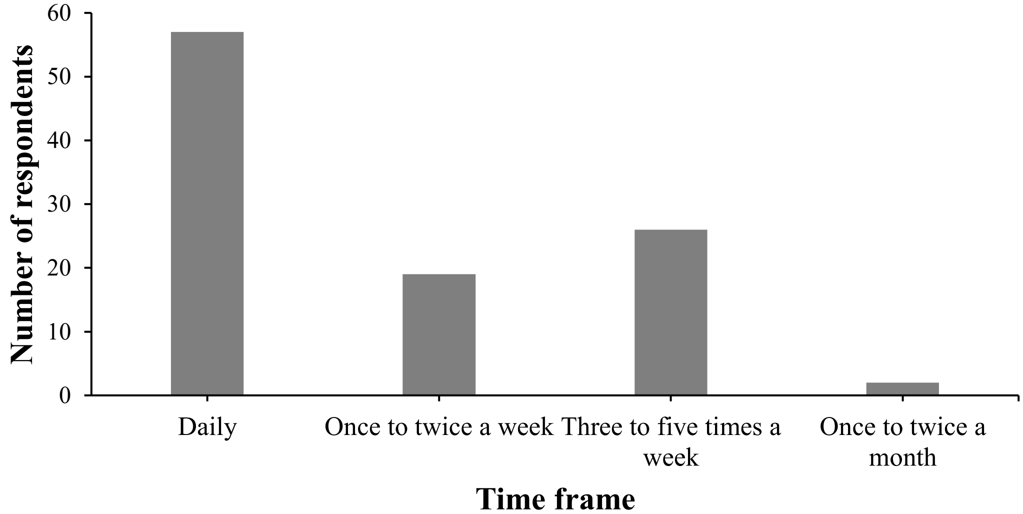

Figure 4. 5: The frequency at which respondents set hooks to catch Nile perch

4.1.7 Hook sizes used with *Mormyrus kannume* for Nile perch fishing

Majority of the respondents 96 (55.8%) used hook size 9 to catch Nile perch as presented in the Figure 4:6 below.

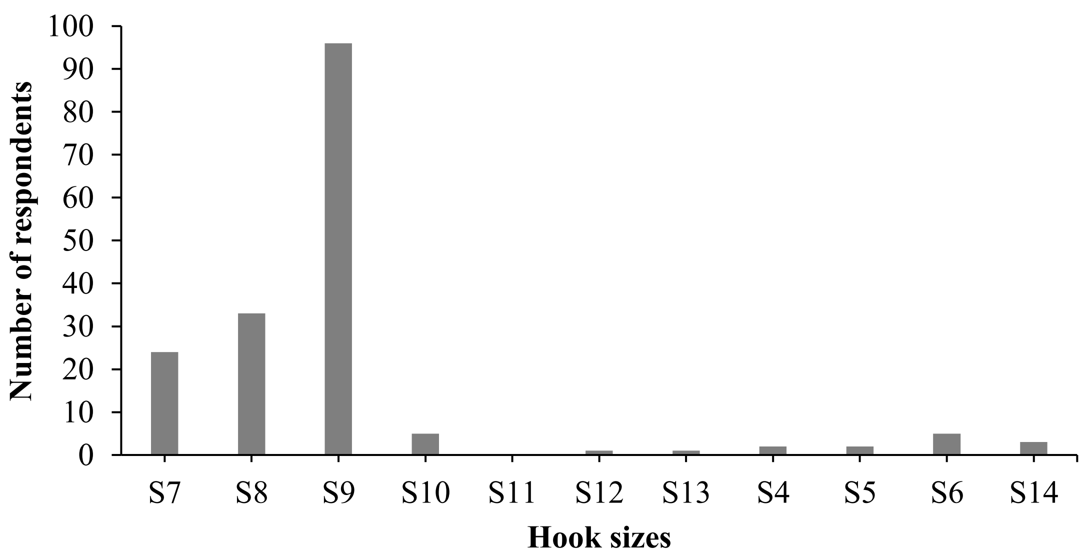

Figure 4. 6: The different hook sizes used by fishermen to catch Nile Perch

4.1.8 Number of Nile perch catches per fishing trip using varying number of hooks

One hook typically catches one fish; though the number of hooks does not necessarily equal the exact number of fish caught, a very high number of hooks set generally reflects a correspondingly high number of fish caught. The majority of respondents, 92 (55.4%), reported catching between 2 to 5 fish per night, making it the most common catch range. The smallest group, comprising only 2 respondents (1.2%), reported catching 20 to 30 fish per night, representing an exceptionally high catch rate. Notably, 3 respondents (1.8%) reported catching between 50 to 150 fish per night, indicating rare but very high catch rates among the fishermen using multiple hooks while fishing as presented in Figure 4:7 below.

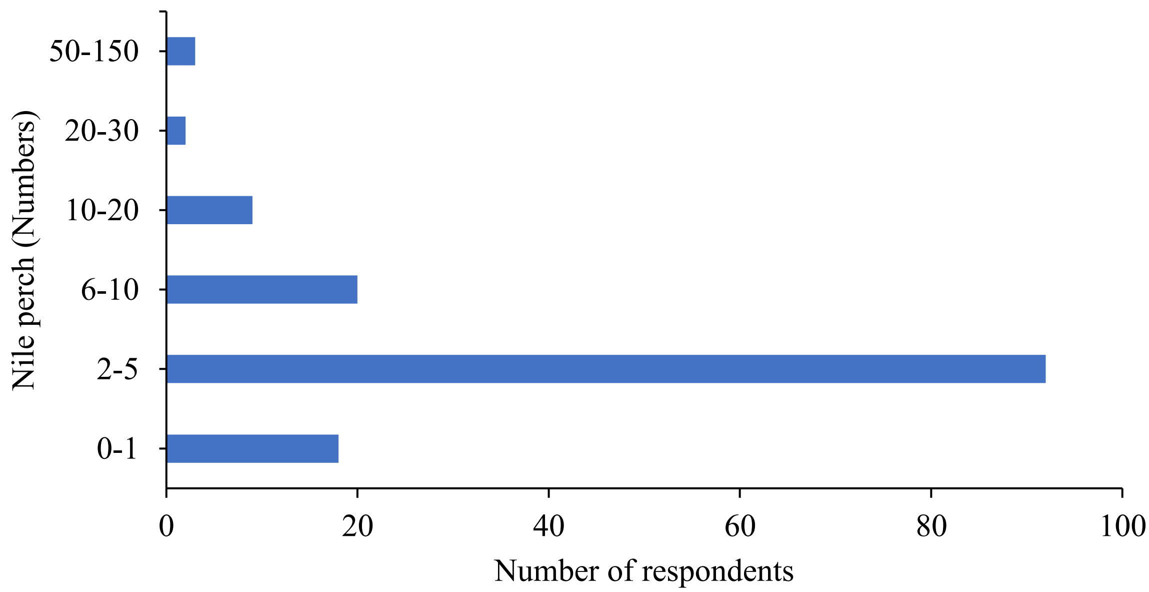

Figure 4. 7: The number Nile perch caught by fishermen

4.1.9 Pricing of Nile perch per kilogram

From the data presented in the Figure 4:8 below, the highest price at which Nile Perch was sold is UGX 22,000 and the least price was UGX 6000. The average price for Nile Perch is UGX

10,000/= - 15,000/=. However, the majority of the fishermen, 50 (32.9%) sell a kilogram of Nile perch at 10,000-12,000 UGX. These price ranges were mostly being influenced by size of Nile perch caught as revealed by some fishermen.

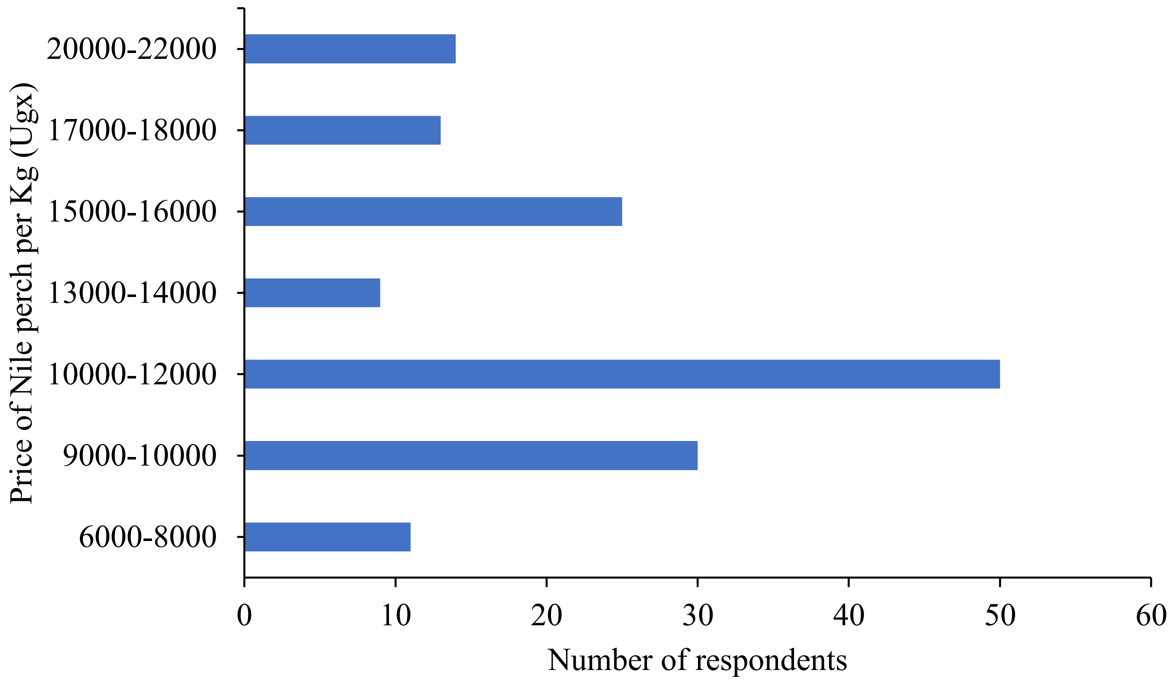

Figure 4. 8: Prices at which fishermen sell a kilogram of Nile perch

4.1.10 Sources of *M. kannume* (Kasulubana/Kasulu)

From Figure 4:9 below, 19 (18.3%) fishermen reported obtaining *Mormyrus kannume* bait directly from the lake or river. This suggests that a reasonable number of fishermen acquire the bait by fishing it from the Upper Victoria Nile river. The majority of respondents, 80 (76.9%), reported purchasing *M. kannume* bait from traders at landing sites, making it the most common source. However, the smallest group, 5 respondents (4.8%), utilized both the lake/river and landing sites as the bait sources.

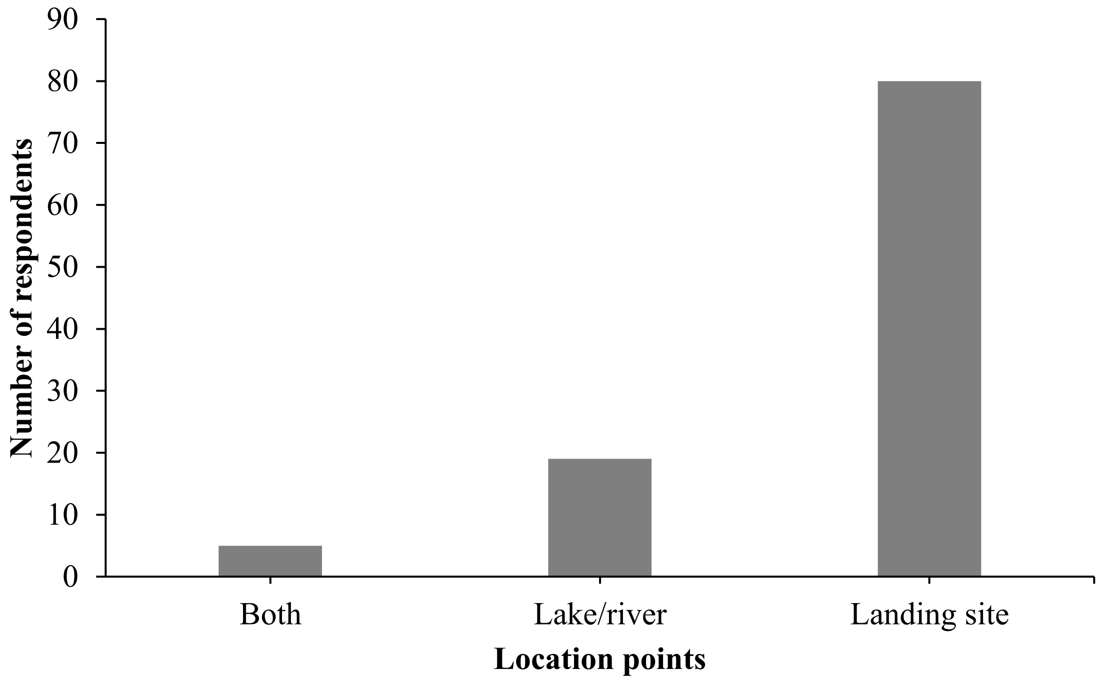

Figure 4. 9: The location points where the respondents obtain the *M. kannume*

4.1.11 Factors influencing preference of *M. kannume* among Nile perch fishermen

From the Table 4:2 below, the study revealed that majority of the respondents; 49 (63.6%) preferred elephant snout fish to other baits because of its effectiveness in catching Nile perch. However, personal fishing experience and higher returns on sale from Nile perch were the least cited reasons for preferring *M. kannume* over other baits, with each cited by 1.3% of fishermen.

Additionally, fishermen indicated that *M. kannume* helped them catch big and mature Nile perch compared to other baits (18.2%). Other reasons included less affect by seasonal changes, legal compliance as it aids them catch big and mature Nile perch legally accepted, and availability and affordability with some of the respondents saying that they were fishing it themselves (each noted 3.9%of the fishermen). Also, *M. kannume* is preferred due to the unique bait characteristics of; slippery nature, swinging better on the hook and staying longer on it before dying for a period of two to four days making it a perfect prey for Nile perch (3.9%). This also gives *Mormyrus kannume* a better advantage over other baits in catching Nile perch.

A chi-square test of independence ($\chi^2 = 196.77$, df = 7, $p < 0.05$) confirmed a statistically significant association between socio-economic factors and bait usage, indicating that these factors influence bait use.

Table 4. 2: Reasons for Preference of *Mormyrus kannume* bait in Nile Perch Fishing

Reasons for preference	**Frequency**	**Percentage (%)**
Effectiveness in catching Nile perch	49	63.6
Size and weight of Nile perch caught	14	18.2
Availability and affordability	3	3.9
Legal compliance	3	3.9
Seasonal variations	3	3.9
Unique bait characteristics	3	3.9
Personal fishing experience	1	1.3
Higher Sales Returns from Mature and big Nile Perch	1	1.3
Total	**77**	**100.0**

4.1.12 Influence of bait cost on fishermen's bait choice

From the Table 4:3 below, majority of the fishermen bought *M. kannume* at a price ranging from (1001-3000) Ugx, with an average cost at UGX 2000 making it more expensive than most alternative baits. Majority of the fishermen acquired catfish at (101-1000) Ugx, Mudfish at (101-500) Ugx, Synodontis at (1-1000) Ugx, Spiny eel at (1001-2000) Ugx, lungfish at (1001-2000) Ugx. In contrast, the majority of fishermen obtained haplochromines at no cost by catching them directly from both the lake and the river making them the cheapest bait available.

From the Chi-Square test results, most bait types (*Mormyrus kannume*, catfish, mudfish and synodontis), show that there is a significant relationship between bait cost and bait type. This is indicated by the extremely low P-values (*Mormyrus kannume*, catfish, mudfish, and *Synodontis* all have P =0.000, P<0.05). This suggests that the bait cost significantly affects the type of bait used for fishing Nile perch. However, for species such as *Haplochromines*, spiny eels, and lungfish, the P-values (that is 0.917, 0.594, and 0.99, respectively) indicate no significant association between bait cost and bait usage.

Table 4. 3: Relationship Between Bait Cost and Fishermen's Choice of Bait Types

	Bait cost (Ugx)											
Bait type	0	1-100	101-500	501-1000	1001-2000	2001-3000	3001-4000	4001-5000	Total	X2	df	P
Mormyrus kannume	12	0	0	7	39	37	8	1	104	156.696	54	0.000
Catfish	0	1	29	10	0	0	0	0	40	73.594	36	0.000
Mudfish	0	2	46	4	3	0	0	0	55	62.405	36	0.000
Synodontis	0	4	6	5	1	0	0	0	16	128.385	36	0.000
Haplochromines	9	2	2	1	0	0	0	0	14	25.122	36	0.917
Spiny eel	0	0	0	0	3	1	0	0	4	27.098	18	0.594
Lungfish	0	0	0	0	1	0	0	0	1	1.827	9	0.99

4.1.13 The influence of bait size on the size of Nile perch caught

From Figure 4:10, majority of the fishers (40.4%) preferred using *Mormyrus kannume* baits with a girth of 2.1-3.0 inches. The average preferred girth size by fishermen for bait was approximately 2.57 inches. Additionally, it was established that Fishermen catch a wide range of sizes of Nile Perch ranging from (1-100) Kilograms. On average, fishermen caught Nile perch weighing between (1-30) kilograms, indicating that smaller to medium-sized Nile perch were mostly caught. The least number of fish caught per fishing trip was (0-1) fish as reported by 18 respondents (10.8%). On average, most fishermen catch between 2 to 5 fish per night, indicating low to moderate catch rates among the surveyed fishers.

From the Fisher's Exact Test, P-value is 0.000 ($P<0.05$), which shows that there is a statistically significant relationship between bait size used and the size of Nile perch caught. This therefore indicates that the size of bait used influences the size of Nile perch caught by fishermen.

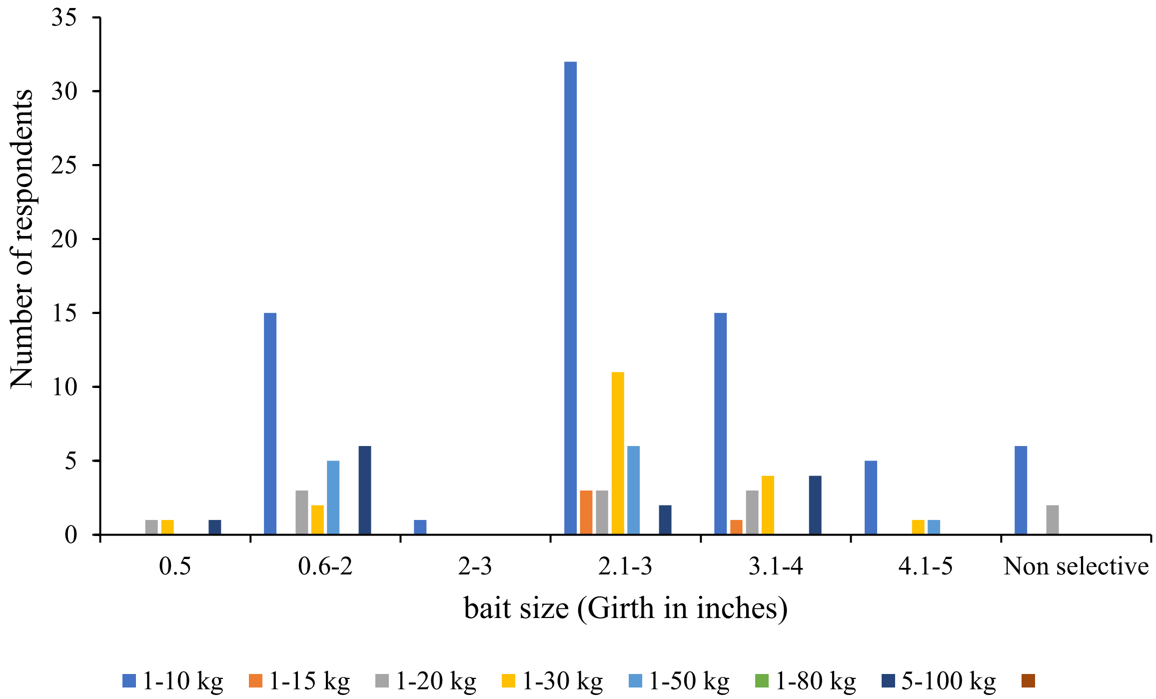

Figure 4. 10: Nile perch sizes caught using various sizes of *Mormyrus kannume* bait

4.1.14 The relationship between fisher's experience and the use of *M. kannume* as bait.

From Figure 4:12, the study revealed that the highest number of respondents who use *Mormyrus kannume* as bait are in the 11-20 years of experience, followed by the 1-10 years of experience group. The number of respondents who use *Mormyrus kannume* as bait is significantly higher than those who do not use it among fishermen with varying fishing experience. There were very few respondents with 31-40 years and >40 years of fishing experience that participated, however these were mostly using *M. kannume* as bait. The use of *M. kannume* appears to be popular regardless of one's fishing experience, but especially common among those with moderate fishing experience (11-20 years). Fishermen who did not use *Mormyrus kannume* opted for alternative baits, citing reasons such as high cost, limited availability, scarcity, and seasonality.

The result of Fisher's exact test; P-value of 0.000 ($P<0.05$), indicates a statistically significant relationship between fishing experience and the use of *Mormyrus kannume* bait.

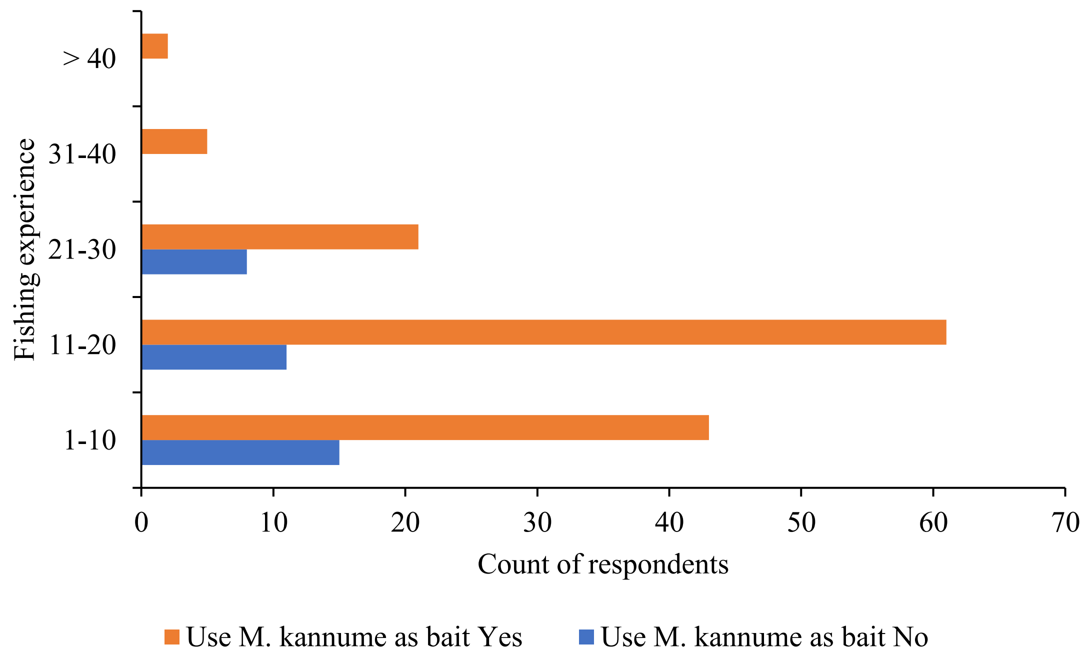

Figure 4. 11: Use of *M. kannume* as bait by respondents across different fishing experience levels

4.1.15 Relationship between Nile perch selling price and the preferred bait type by fishermen

From Figure 4:12, the highest price at which Nile Perch was sold is UGX 22,000 and the least price was UGX 6000. The average price for Nile Perch is UGX 10,000/= - 15,000/=. However, the majority of the fishermen sell a kilogram of Nile perch at 10,000-12,000 UGX.

The results from the Fisher's Exact Test ($P = .000$, $P < 0.05$) indicate a statistically significant relationship between the preferred bait type and the selling price of Nile perch. This shows that the type of bait used affects size of Nile perch caught and consequently the price at which Nile perch is sold.

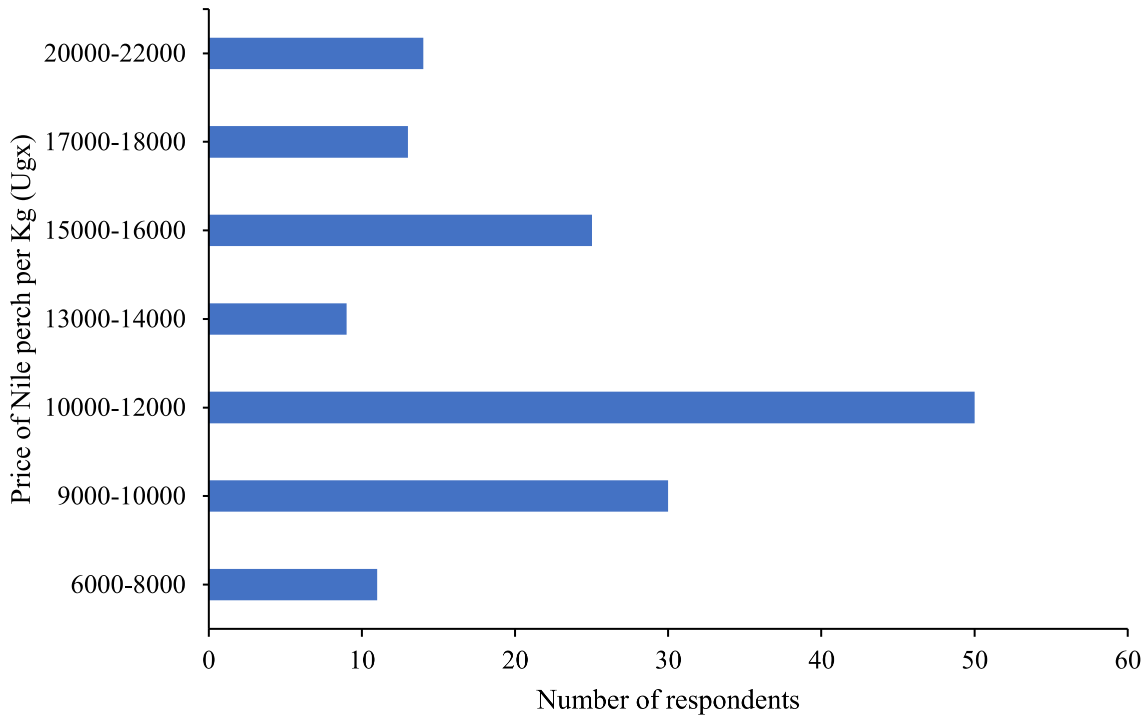

Figure 4. 12: Prices at which fishermen sell a kilogram of Nile perch

4.2 Sex ratios of *Mormyrus kannume*

A total of 1689 samples of fish were collected, 861 were females and 828 were males. The resulting ratio of 1:0.96 did not deviate significantly from the normally expected ratio of 1:1. Statistic(X^2); 0.64474 and the P-value is 0.422 (P>0.05). Similarly, monthly sex ratios (female to male ratios) did not deviate significantly from the hypothetical ratio of 1:1 as presented in Table 4:4. The reproductive characteristics were reflected in the female-to-male ratio of 1:0.96, indicating a higher prevalence of females compared to males.

From the Figure 4:13 below, the proportion of female fish is notably higher than males during the months of January, February, March, April, October, November, and December, ranging between 60% to 70%. This pattern strongly indicates peak spawning seasons. Female fish are frequently captured during these periods due to heightened activity associated with nest-seeking behavior, aggregation in designated spawning grounds, and increased vulnerability while engaged in reproductive activities. However, there is a more balanced distribution between male and female fish, in the months from May to September with the percentages being closer to 50% suggesting a period of post-spawning recovery.

Table 4. 4: Monthly sex ratios of *M. kannume* sampled from the Upper Victoria Nile

Month		**Females**	**Males**	**Sex ratios F/M**	**X^2**	**P Values**
January	2024	64	46	1: 0.72	2.871	0.412
February	2024	58	56	1: 0.97	4.609	0.203
March	2023	97	21	1: 0.22	0.279	0.964
April	2023	105	94	1: 0.90	8.807	0.032
May	2023	96	108	1: 1.13	6.378	0.095
June	2023	76	63	1: 0.83	11.708	0.02
July	2023	91	128	1: 1.41	5.23	0.155
August	2023	64	71	1: 1.41	2.79	0.424
September	2023	38	71	1: 1.87	6.71	0.082
October	2023	56	65	1: 1.16	8.53	0.036
November	2023	62	47	1: 0.76	2.91	0.406
December	2023	54	58	1: 1.07	2.318	0.314
Total		**861**	**828**	**1: 0.96**		

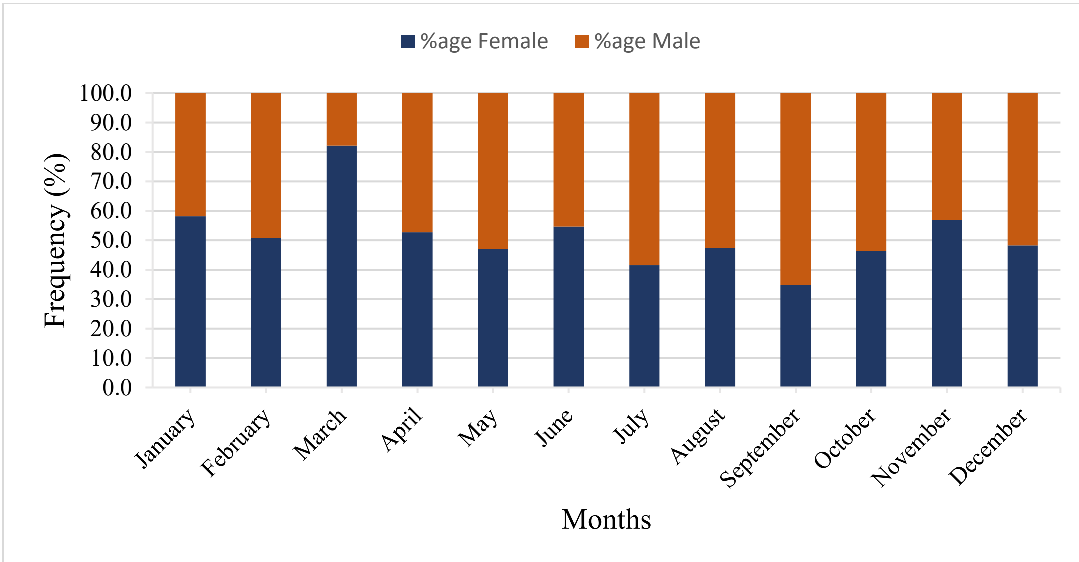

Figure 4. 13: Percentage composition of male and female samples of *M. kannume* sampled from the Upper Victoria Nile between March 2023 and February 2024

Table 4. 5: Number of individuals by class size for both females and males of *M. kannume*

Size class (cm)	Females	Males
10.5 - 14.9	252	236
15.0 - 19.9	416	402
20.0 - 24.9	136	146
25.0 - 29.9	45	35
30.0 - 34.9	3	5
35.0 - 39.9	5	1
40.0 - 44.9	2	0
45.0 - 49.9	0	0
50.0 - 54.9	0	0
55.0 - 59.9	1	2
60.0 - 64.9	1	0
65.0 - 67.5	0	1
Total	861	828

4.3 Size at Sexual Maturity

Histological criteria for gonadal staging were used to determine the different stages of gonadal maturity of the fish collected. The maturity ogive curve was used to estimate size at sexual maturity (L_{50}). Males attained their sexual maturity of 50 % at a Total Length of 23 cm while females matured earlier than the males at a length of 21 cm Total Length as shown in (Figure 4:14 and Figure 4:15).

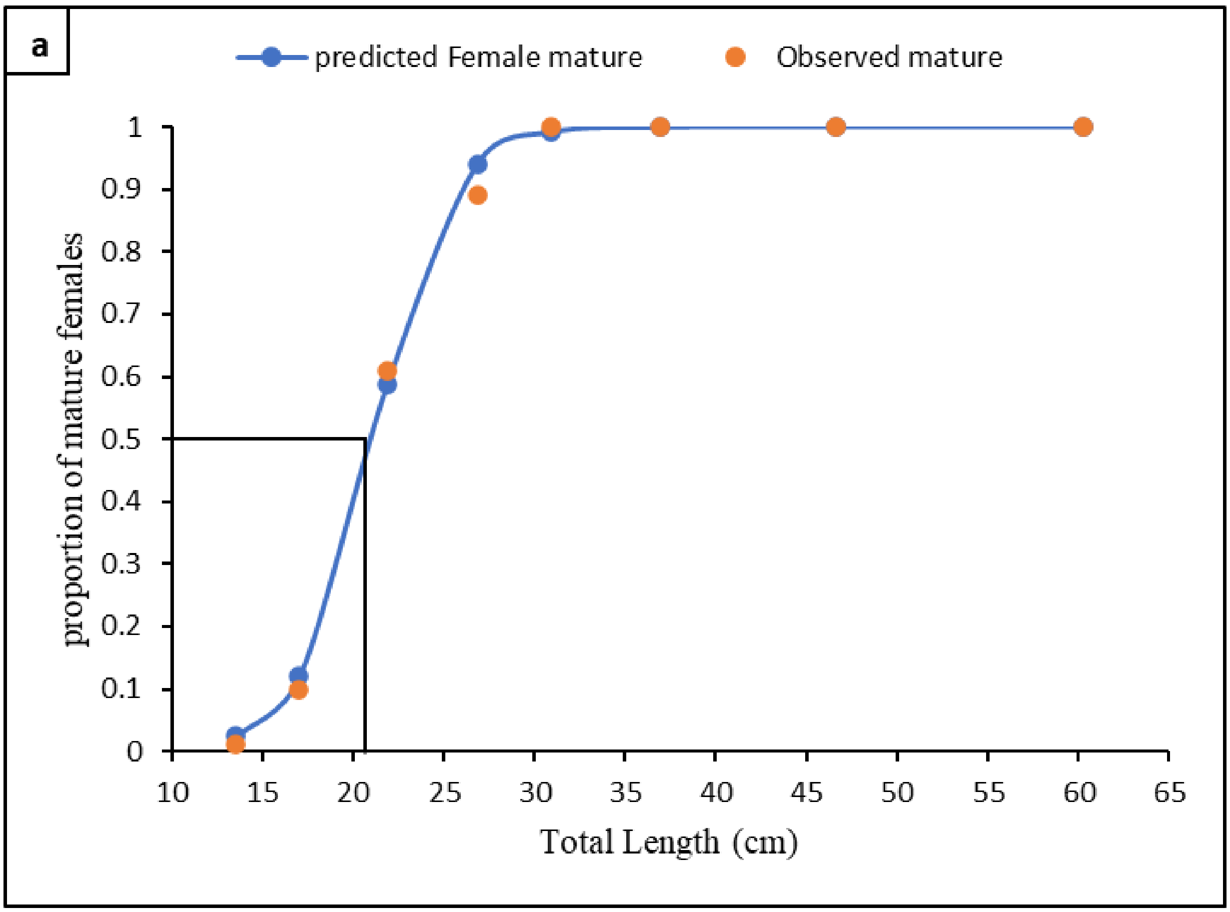

Figure 4. 14: Observed and predicted sexually mature females of *M. Kannume*, L50=21cm

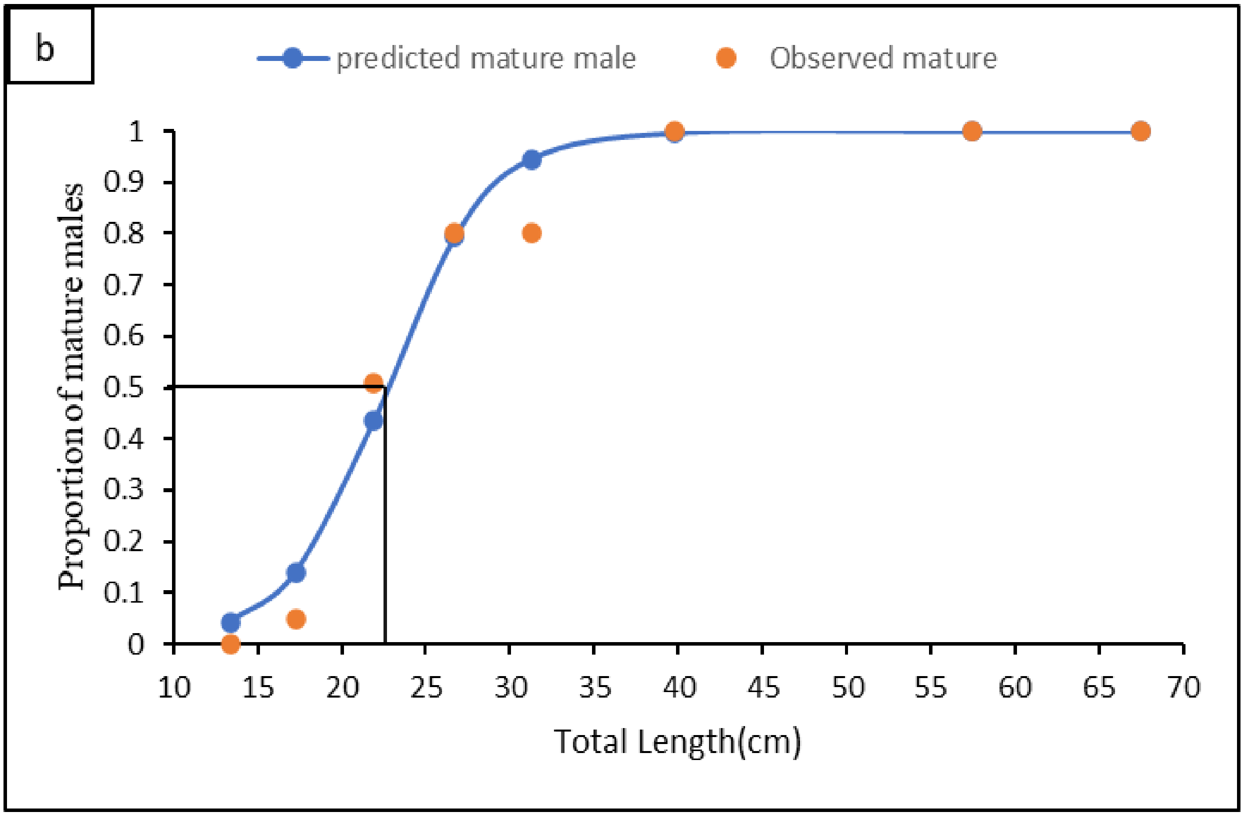

Figure 4. 15: Observed and predicted sexually mature males of *M. kannume*, L50=23 cm

4.3.1 Male testis

All male *Mormyrus kannume* have only one testis each (Figure 4:18) and gonad samples ranging from immature to mature stages of sexual maturity were collected for histological examination. The histological results indicated that immature males had only spermatogonia. In developing stages, successive spermatocyte stages developed in cysts, with the walls of the tubules containing different spermatogenic stages. In mature stages, the tubules were distended with spermatozoa, as shown in (Figure 4:16) below.

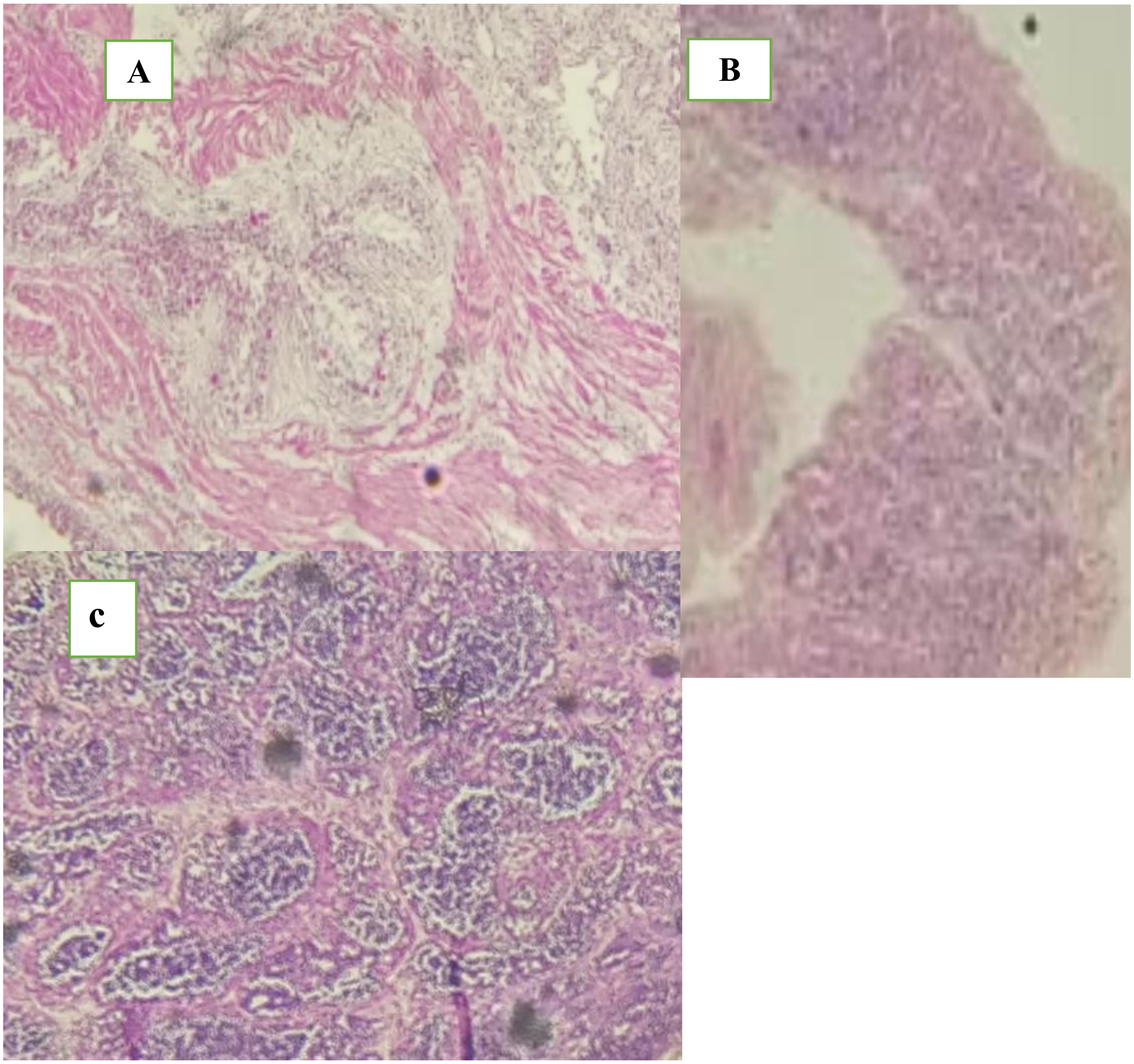

Figure 4. 16: (A) immature male gonad, (B) developing male gonad, and (C) ripe/mature male gonad of *Mormyrus kannume*

4.3.2 Female Ovary

Each female fish has a single ovary present (Figure 4:18), and gonad samples collected were ranging from immature to developing to mature stages. In immature female fish, only primary oocytes and oogonia were present. Gonads in the developing stage showed the appearance of the oolemma and the development of vitellogenesis. Mature gonads contained yolk globules that were developing centrifugally, as shown in Figure 4:17 below.

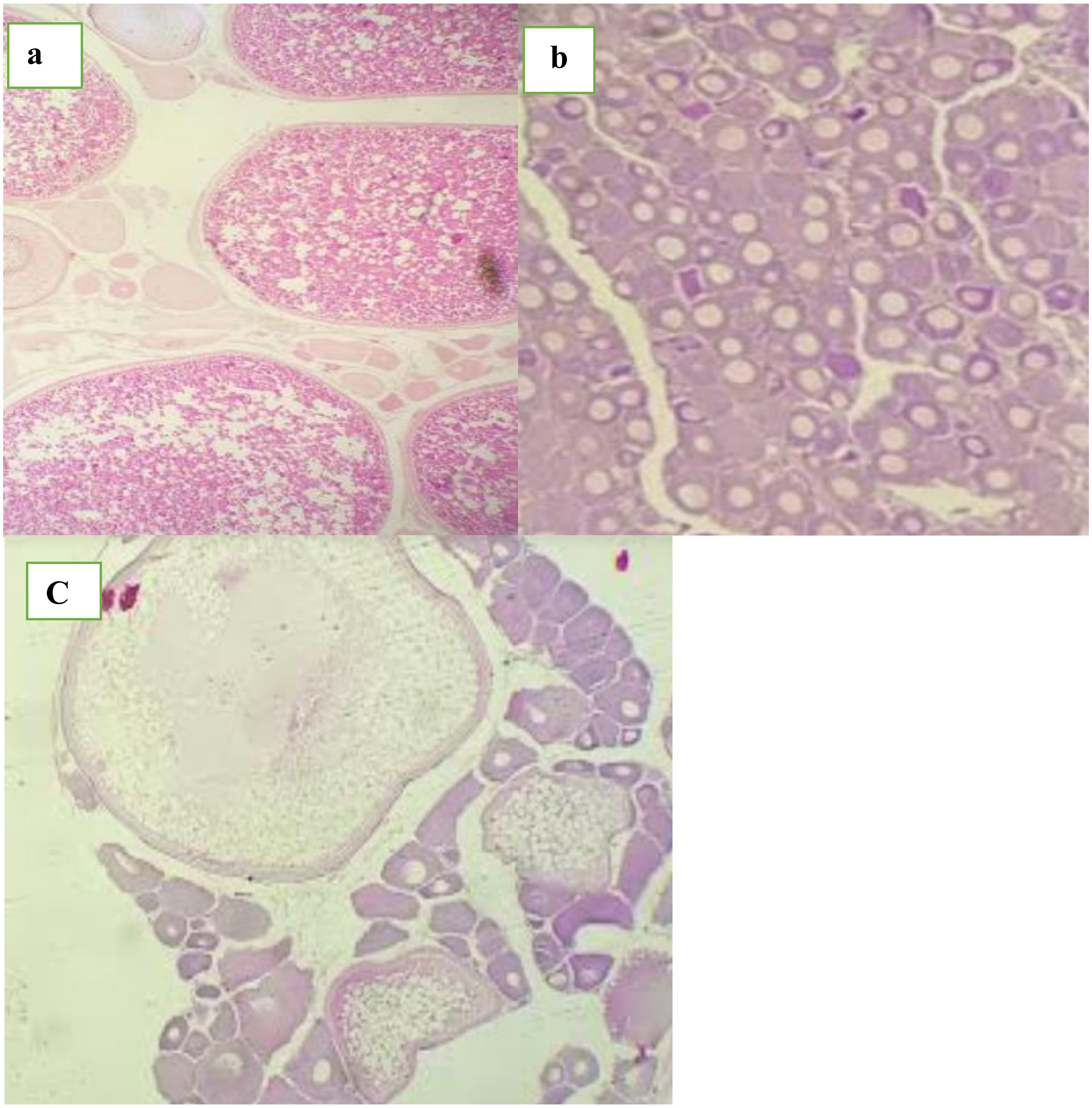

Figure 4. 17: (b) immature female gonad, (c) developing female gonad, (a) and ripe/mature female gonad of *Mormyrus kannume*

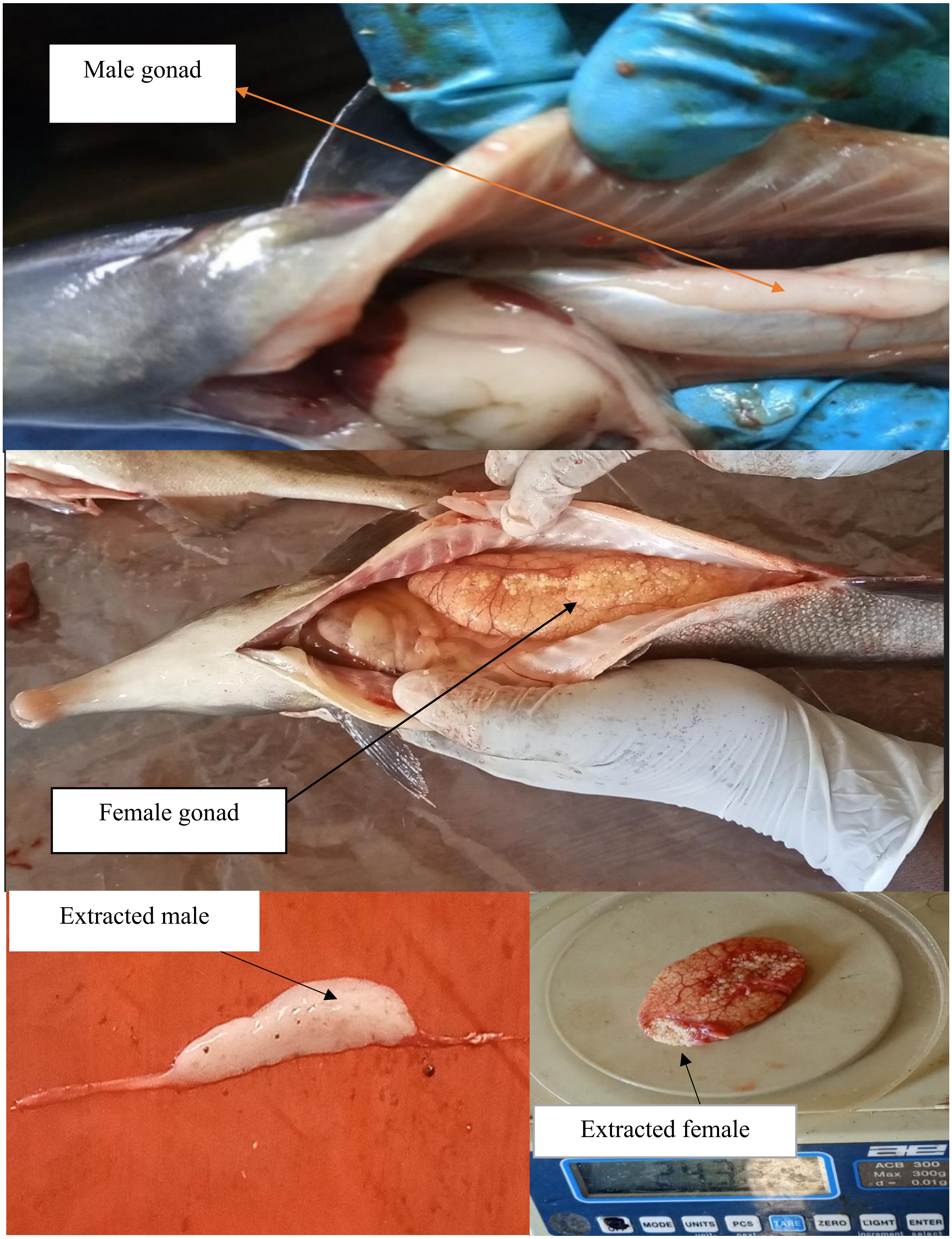

Figure 4. 18: Female and male gonads of *M. kannume*

4.4 Biometric parameters (Body length and body weight relationship)

This study provides the body length and bodyweight relationship of 1689 specimens of *Mormyrus kannume.* The total length (TL) of the fish samples collected ranged from 10.5cm to 67.5 cm with a mean value of 17.62cm ± 0.11. The fish body weight ranged from 10.84 g-2548.8 g with a mean value of 57.54 ± 2.52g. The females body weight ranged from 10.9 g to 1642.9 g with a mean value of 57.17 ± 2.90 g while their Total Length ranged from 10.6cm - 60.3 cm with a mean value of 16.10 ± 0.14cm. The males body weight ranged from 10.84g to 2548.8 g with a men value of 57.93 ± 4.16 g and Total Length ranged from 10.5cm - 67.5 cm with a mean value of 17.63 ± 0.16cm; (Table 4:6).

The relationship between body length and body weight was analyzed and expressed in an exponential equation ($W=aL^b$): Body weight (BW)= $0.0112TL^{2.9007}$ (R^2 = 0.9858), (Figure 4:19). The length-weight frequency distribution in Figure 4:19, shows that the fish samples collected dominated the class size ranging from 9 to 40 cm Total Length.

Table 4. 6: Size range of *Mormyrus kannume* samples collected

	All fish		Females		Males	
Size	**Range**	**Mean ± SE**	**Range**	**Mean ± SE**	**Range**	**Mean ± SE**
Weight (g)	10.84 - 2548.8	57.54±2.52	10.9 - 1642.9	57.17 ± 2.90	10.84-2548.8	57.93 ± 4.16
Standard length (cm)	9.5 - 59.2	16.15±0.10	9.5 - 54.3	16.10 ± 0.14	10.0 - 59.2	16.20 ± 0.14
Total length (cm)	10.5 - 67.5	17.62±0.11	10.6 - 60.3	17.61± 0.16	10.5 - 67.5	17.63 ± 0.16

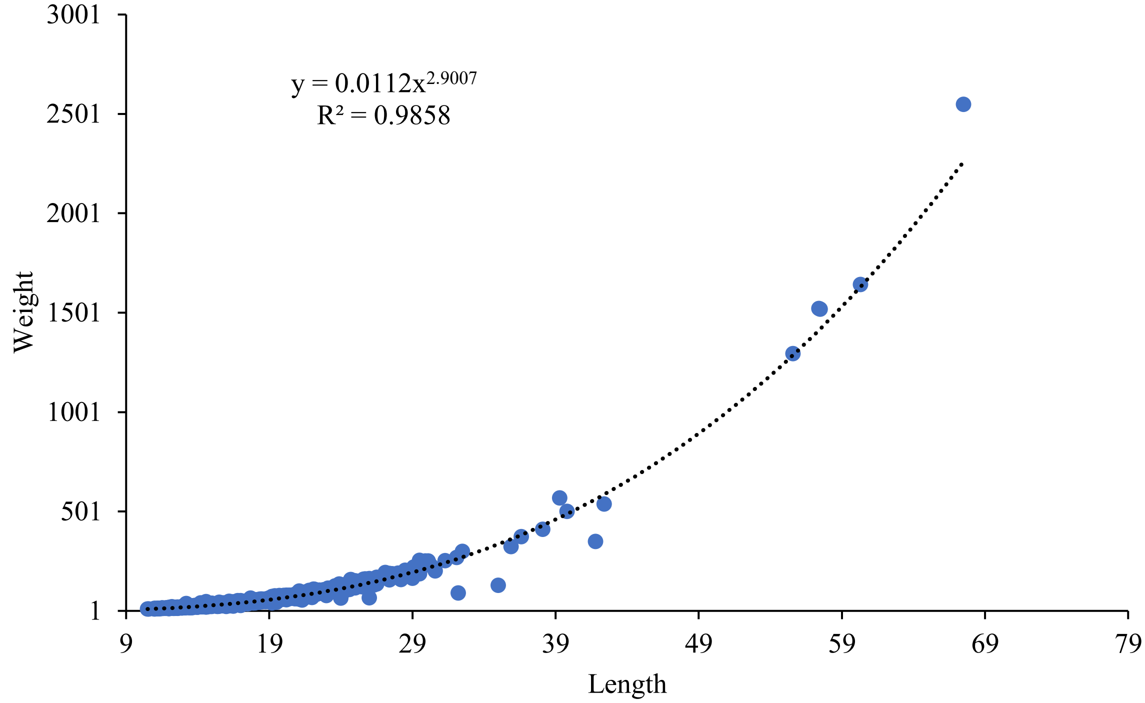

Figure 4. 19: Length Weight relationship of Elephant snout fish (M. kannume)-power model/regression

A logistic/sigmoidal function represented by the curved graph (Figure 4:19), represented a gradual transition of female and male *M. kannume* during their transition of growth. This reflects natural variation in fish growth and maturation making a curved sigmoidal relationship more appropriate than a straight-line model.

A log transformed model using a spread sheet produced a linear equation for the best estimation of length-weight parameters (Figure 4:20). For a comprehensive understanding of the differences in growth rates and body proportions of *M. kannume*, individual analyses were conducted to determine the distinct b values for mature and immature males and females. The 'b' value for mature females was found to be 2.8, while for mature males it was 2.9. For immature individuals, both males and females had a 'b' value of 2.9 (**Error! Reference source**

not found.20). The b value being less than 3 suggests a negative allometric growth pattern. However, since the b value is close to 3, *Mormyrus kannume* exhibits nearly isometric growth. A strong relationship between Total Length and total body weight was observed in the sample, indicated by a high correlation coefficient of 0.9776. The positive value of the correlation coefficient reflected the slope as shown in (Figure 4:19). The b values also indicate that mature *Mormyrus kannume* have slightly different growth patterns, with mature females becoming a little bit slimmer and mature males maintaining a more consistent body shape as they grow. On the contrary, immature males and females exhibit nearly proportional growth in length and weight.

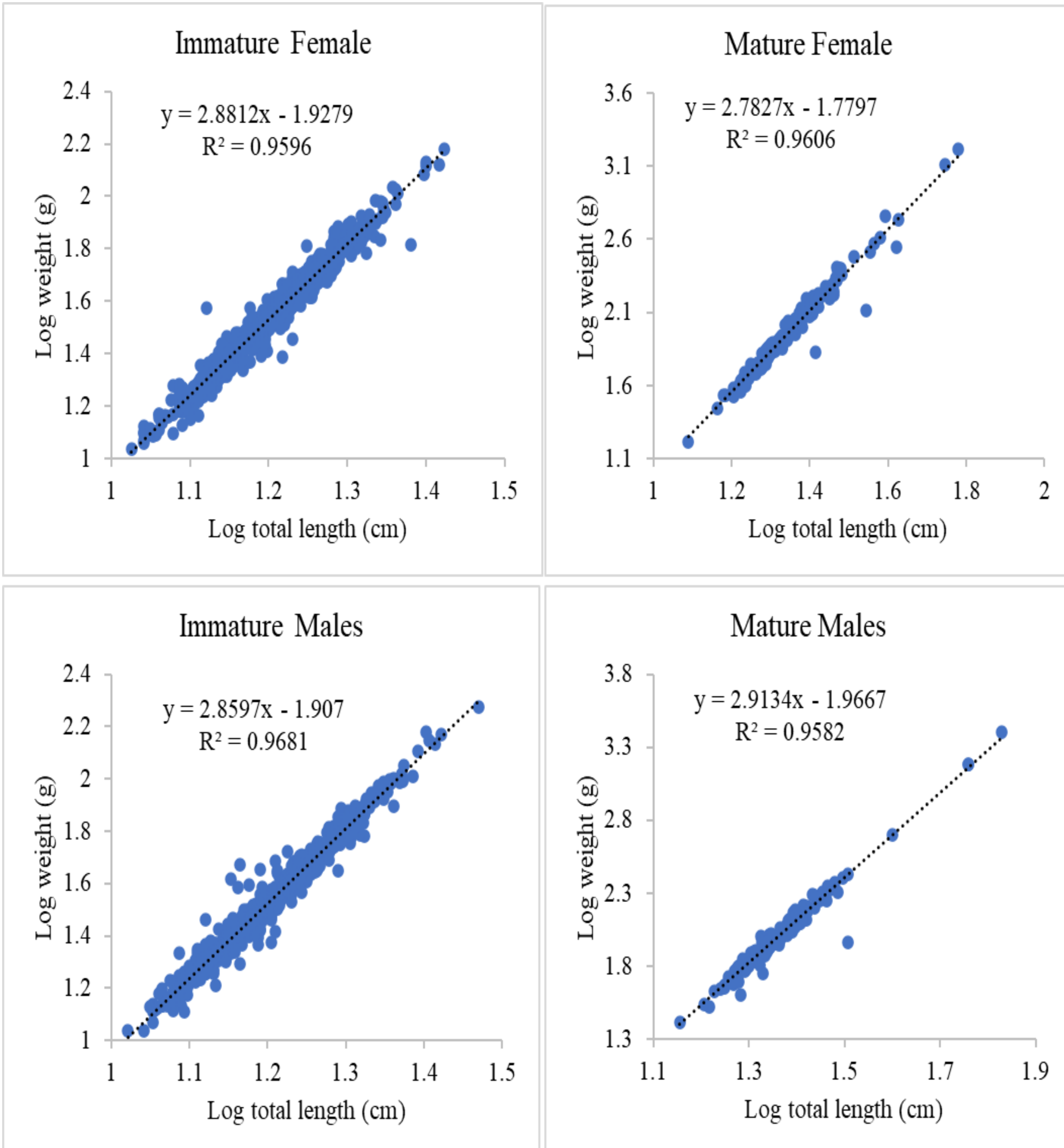

Figure 4. 20: Linear model of length-weight relationship of mature and immature females and males of Mormyrus kannume

4.4.1 Linear regression of Body length and body weight relationship

The P-values for both Total Length and weight are (0) <0.05, indicating that the result is statistically significant. Therefore, the null hypothesis is rejected and a conclusion made that there is a negative allometric growth between length and weight since $b<3$; ($b=2.9$).

Table 4. 7: Estimates of Length-Weight Parameters for *M. kannume* in Various regions by selected authors

Author	**Study site**	***a***	***b***	**R^2**
Present study	Upper Victoria Nile	Combined sexes-0.141993	Combined sexes- 2.90 Mature Female-2.78 Mature Male-2.91	Combined sexes- 0.98
Khallaf & Authman, (2010)	Bahr Shebeen	0.006982	3.033	0.998
Bassa, (2018)	Upper Victoria Nile	0.0001	3	0.938
Oduol, (1988)	Tropical man-made lake Kamburu Kenya	Mature Female-1.30906 Mature Male-0.115741	Mature Female -2.5615 Mature Male - 3.1564	Mature Female -0.87 Mature Male - 0.84
Ragheb, (2016)	Damietta branch Nile	0.006	3.063	0.997
Farrag *et al.*, (2022)	Lake Nasser Egypt	Females- 0.0177 Males- 0.0078 Combined sexes- 0.0081	Females-2.9531 Males-2.9553 Combined sexes-2.9453	Females-0.9374 Males-0.9527 Combined sexes - 0.9565
Fish base data based on Bayesian LWR estimates and genus body shape of *M. kannume*		a = 0.01202 (0.00696 - 0.02076)	b = 2.88 (2.73 - 3.03)	--------------

a - Intercept of the length-weight regression equation
b - Slope of the length-weight regression equation
R^2 - Coefficient of determination

CHAPTER FIVE: DISCUSSIONS

5.1 Socio-economic aspects relating to the use of *Mormyrus kannume* as bait in the Nile Perch fishery

Majority of the anglers along the Upper Victoria Nile and Lake Victoria preferred using *M. kannume* as bait to lure Nile perch citing its effectiveness in attracting Nile Perch. Majority of the anglers stated that this bait makes them catch larger and mature Nile Perch with high market value. This trend is supported by Nduwayesu *et al.,* (2023), who documented a substantial increase in Nile perch catch from 3.3 t in 2009 to 148.2 t in 2019, attributing this rise to the increased use of *M. kannume*. Similarly, Mkumbo & Mlaponi, (2007) reported that fishermen consistently caught bigger Nile perch using *M. kannume* compared to *Clarias* bait. These findings align with Alós *et al*., (2009) who demonstrated that bait type (shrimp) influences both catch rates and fish size. Also, the drive for profits in the Nile perch fishery compels fishermen to continuously seek more effective bait options, for profit maximization (Namisi, 2000).

There were various sizes (Figure 4:2), of *M. kannume* bait used for catching Nile perch, particularly based on its girth. Larger *M. kannume* were reported to be more effective for catching larger Nile perch, while smaller ones tend to mostly catch younger or smaller fish. The other suggested argument is that juveniles of *M. Kannume* are the only ones largely caught by the fishermen along the Upper Victoria Nile. The variations in the number of hooks used by individual fishermen are largely dependent on the level of investment as those with small scale investments use less hooks, and those with large investments apply large number of hooks. A related study suggests that the number of hooks used by an individual fisherman is closely influenced by an individual's level of income (Cinner, 2009). The frequent use of *M. kannume* as bait through setting hooks daily to catch Nile perch, indicated a high level of fishing activity among many fishermen. *M. kannume* bait is widely used on a daily basis by most fishermen, indicating its importance in their fishing activities for Nile perch.

Majority of fishermen used hooks of size 9 (Figure 4:6) and this was also observed by Mkumbo & Mlaponi, (2007). Majority of fishermen reported that they were using hook size 9 and others as low as hook size 3. Additionally, Bassa, (2011) reported that majority of the fishermen using *M. kannume* bait to catch Nile perch were using hook sizes 7, 8 and 9 with a bigger bait of *M. kannume* to catch bigger Nile perch.

The landing sites (Figure 4:9) serve as the primary and most preferred sources of *M. kannume* bait for fishermen. This is because the majority of fishermen purchased the bait from traders at these sites, who in turn, source it from fishermen on the Upper Victoria Nile. Though majority of the respondents used *Mormyrus kannume,* other fishermen also used it in combination with other baits. This was because they were unable to use *M. kannume* exclusively probably due its limited availability especially in landing sites that were far away from the Upper Victoria Nile where it is fished from. This forces the fishermen to rely on alternative baits such as catfish, mudfish, synodontis, haplochromines and spiny eel which are readily accessible. Mkumbo & Mlaponi (2007), reported that the use of *M. kannume* as bait was dependent on its availability thus showing adaptive strategies by fishermen to sustain their fishing activities. This also points to the fact that development of its domestication protocols could successfully increase its availability (Aruho *et al.,* 2018). This could effectively reduce over exploitation of *M. kannume* from the Upper Victoria Nile river.

There was a relationship between the size of *Mormyrus kannume* bait used and the size of Nile perch caught (Table 4:10), indicating that bait size plays a critical role in determining size of Nile perch caught. Furthermore, some respondents mentioned that using non-selective bait sizes could allow for the capture of Nile perch of varying sizes. This finding aligns with studies emphasizing the impact of bait size on fishing efficiency and selectivity (Ya *et al.,* 2019)**.** Such practices may have implications for fishing strategies employed in Lake Victoria and along the Nile River particularly in balancing catch efficiency with sustainable fishery management (Bassa, 2018). Another reason for use of *M. kannume* as a bait was its availability and affordability. The preference and use of *Mormyrus kannume* as bait was also attributed to its unique characteristics of staying longer on the hooks for an extended period between two to four days before dying. This is probably due to a more stable metabolic response and better control of stress hormones like cortisol (Oduol, 1988). The long period on the hook allowed the bait to remain actively dangling on the it which helped attract the predatory fish. Additionally, its slippery body texture allowed smooth and quick swallowing by predators making it easier for the Nile perch to get trapped easily on the hook. These findings align with those of Bassa, (2011), who noted that the preference for *M. kannume* as bait may be linked to its active dangling behavior while on the hook. According to Bassa, (2011), the bait's capacity to swim about for several hours after being hooked was a key factor in successfully attracting Nile perch.

From the study, the fishermen catch a wide range of Nile perch sizes (Figure 4:10) from small to exceptionally large fish (1-100 kilograms). Smaller-sized Nile perch are more commonly caught probably due to the declining Nile perch fishery (Bassa, 2011). However, the significant number of fishermen catching large to exceptionally large Nile perch, indicated varied fishing success and differing fishing techniques or bait preferences among the fishermen. The study therefore presents valuable insights into the size distribution of Nile perch caught by the surveyed fishermen, which is important for further development of management strategies in the Nile perch fishery (Bassa, 2018). The small sizes of Nile perch caught could also be due to use of small sized/juvenile baits as revealed through interactions with the fishermen; (Taabu, 2004; Paterson *et al.,* 2009; Mkumbo & Marshall, 2015).

The selling price of Nile perch was influenced by the size of Nile perch caught; with the larger fish fetching higher prices per unit weight than the smaller fish. The average price for Nile Perch was UGX 10,000/= - 15,000/=. However, the majority of the fishermen sold a kilogram of Nile perch at 10,000-12,000 UGX. A closely related price range from (10,000-18,000) Uganda shillings was reported by (Balirwa & Kamanyi, 2005). This emphasizes the value and motivation to continuously try to catch the bigger fish and the continued exploitation of *M. kannume* for catching the Nile Perch.

The results from the statistical analyses showed a significant relationship between bait cost and bait types used of *Mormyrus kannume*, catfish, mudfish and synodontis. Also, there is a significant relationship between fishing experience and the use of *Mormyrus kannume* bait. Additionally, the bait size significantly influences the size of Nile perch caught, which in turn affected its market price. Therefore, the socio-economic factors promoting the use of *Mormyrus kannume* bait in Nile perch fishery were fishing experience, bait cost, bait type, selling price of Nile perch, and bait size, highlighting the critical role these aspects play in its exploitation and utilization.

5.2 Sex ratios of *Mormyrus kannume*

From the study, there is no significant variation in the sex ratio of females to males (Table 4:4). This indicates negligible effects on the population, with a slightly higher prevalence of females to males in the population sample (Kendall & Quinn, 2012). According to Trindade-santos *et al.,* (2015), sex ratio is a crucial indicator for evaluating the population structure and its potential for reproduction.

A study on a similar fish revealed a 1:1 sex ratio though with males slightly higher than females (Scott, 1974; Oduol, 1988). These results align with the observations made by Conover & Voorhees, (1990) which indicate that sex ratios imbalances within a fish population tend to correct themselves over successive generations eventually stabilizing towards an equal proportion of females to males. The findings of this study also align with the results of other studies, where the ratio of female *Mormyrus kannume* was slightly higher than that of male (Bassa, 2018; Khallaf & Authman, 2010).

Therefore, the findings of the study indicate that the exploitation of *M. kannume* as a bait does not seem to affect the sex ratio of the population. Its population is stable and can support continuous reproduction and maintain genetic diversity. Furthermore, understanding sex ratios is essential for guiding the selection of broodstocks in induced spawning activities, which are crucial for successful reproduction of the species under captive conditions (Aruho *et al.,* 2013).

5.3 Size at sexual maturity of *Mormyrus kannume*

In management of fisheries, the minimum size limit for harvesting fish is typically based on the size at first maturity. Size at sexual maturity is defined as the size at which half of the individuals in a species are capable of reproducing. This regulation ensures that 50% of the fish population has the opportunity to breed before being caught (Ogutu-Ohwayo *et al.,* 2000). The calculated size at sexual maturity (L_{50}) (Figures 4:14 and 4:15) showed that males reached sexual maturity at a slightly higher length than females. However, majority of the baits collected were at a low size class than the size at sexual maturity of *M. kannume*.

The results of this study align with previous findings, indicating that female *Mormyrus kannume* mature earlier and at smaller sizes than males. The findings reported by Mkumbo & Mlaponi, (2007) showed that *Mormyrus kannume* was reported to first mature at, 34 cm Total Length. Also, Khallaf & Authman, (2010), found out that *M. kannume* fishes mature at a length of 28 cm and 30 cm for females and males respectively. Additionally, 50 % of the fish become mature at the length of 28 cm which is higher than the reported current size of *M. kannume* fishes along the upper Victoria Nile.

Although, the current law in Uganda does not specify the size limit of bait fish, it prohibits the use of basket traps to protect the fish species from being fished pre-maturely (Ogutu-Ohwayo *et*., 2000). The reducing L_{50} in a size class of 20-24.9 cm Total Length could be attributed to persistent use of basket traps along the upper Victoria Nile to capture the bait as these traps are non-selective in the bait size they catch (Bassa, 2011). In comparison with studies by other scholars, this study revealed a reduction in L_{50} of *M. kannume* (Khallaf & Authman, 2010; Mkumbo & Mlaponi, 2007). This greatly underscores the involvement of human role in over exploitation of the fish linked to increased demand for use as bait in the Nile perch fishery and to a lesser extent for food as revealed by the respondents in the survey that was conducted. The findings are evidence of a stressed population, as a result of overharvesting of both the females and males, which forced them to reach sexual maturity earlier in their life stages. According to

Karna *et al.,* (2011), excessive harvesting of fish forces them to reach sexual maturity earlier. This trend is further supported by findings of Aloo *et al.,* (2017) who reported a decline in the size at sexual maturity of Nile Perch over the years, a pattern commonly associated with intensified fishing pressure. A study on *Hydrocynus vittatus* Castelnau, in Lake Kariba, Zimbabwe showed that females reached maturity earlier in a response to intense poaching during the breeding season (Mhlanga, 2000).

Additionally, according to the theory of fisheries-induced evolution, fishing exerts significant selective pressures on fish stocks, leading to rapid changes in key traits and behaviors. Typically, size-selective fishing promotes earlier maturation, faster growth rates, and greater reproductive investment (Magqina *et al.,* 2021). The findings of this study align with these theoretical predictions. The size at sexual maturity of *M. kannume* is an important parameter in developing management strategies for the species, for sustainable use in bait industry while ensuring its enhanced conservation (Trindade-santos *et al.*, 2015). The length at sexual maturity is also important in aquaculture because knowing the L_{50} will guide the protocols for selection of the appropriate breeding size and induced spawning processes (Trindade-santos *et al.*, 2015).

5.4 Body length and body weight relationship of *Mormyrus kannume*

Mormyrus kannume fish presented a negative allometric growth pattern between length and weight ($b<3$) (Figure 4:19). This therefore means that the *M. kannume* fish becomes more elongated as they increase in size/weight. This finding is crucial for interpreting growth patterns and making informed decisions in the context of fishery biology and management (Kuriakose, 2017). The computed values for the b parameters for all immature and mature male and female *Mormyrus kannume* species, are closely related and lie within the acceptance ranges of approximately 2.5 to 3.5 (Froese, 2006). This indicates that the male and female fishes of *M. kannume* have a closely related body shape and growth pattern. The Length weight parameters; a and b (a- Intercept and b - Slope of the length-weight regression equation) results also lie within the Bayesian estimated 95% credible interval Length-weight relationship ranges of *Mormyrus kannume* as stated by fish base, where b=2.88 (Fish base, 2023). The results are similar to the study on *Mormyrus kannume* fishes along Lake Nasser Egypt , where b = 2.95 also indicating a negative allometric growth (Farrag *et al.,* 2022). These results however slightly differ from those of other scholars, where b≈3. This indicated an isometric growth, reflecting that an increase in weight led to a corresponding increase in length (Oduol, 1988; Ragheb, 2016; Bassa, 2018).

The physiological conditions of the fish are the most likely factor contributing to the observed slight reduction in b values. Other factors likely that can affect the b value include; seasonal fluctuations, physiological conditions, sex, gonadal development, and nutritive conditions of the environment (Olopade *et al.,* 2018). Also, the observed negative allometric growth, deviating from previous studies, with reported isometric growth (b≈3), points to the adverse effects of increased fishing pressure and the use of inappropriate fishing gear. These could have led to increased stress and physical damage, affecting the overall health and growth patterns of the fish. Stressed fish are more likely to divert energy towards stress mitigation and recovery processes rather than growth (Schreck & Tort, 2016). This energy reallocation can cause the fish to grow more in non-valuable parts, such as fins and head, rather than increasing their overall weight proportionally with their length as reported by (Le cren, 1951, Olopade *et al.,* 2018). This could have resulted in negative allometric growth, where fish grew more in length than in weight, lowering the b value (indicator of growth pattern).

Additionally, the lower b value in females compared to males could be due to the added physiological stress of gonadal development and reproduction, making females more susceptible to the adverse effects of fishing pressure and thus showing a higher deviation from the isometric growth pattern (Olopade *et al.,* 2018). This dual impact of fishing-induced stress and reproductive energy demands explains the lower b values in females than males observed in the current study. This finding is crucial for interpreting growth patterns, assessment of the relative condition of fish and making informed decisions in the context of fishery biology and management (Benchikh *et al.,* 2018).

The linear regression analysis confirmed a strong positive linear relationship, between the body length and weight of *Mormyrus kannume*, with statistically significant P-values ($P < 0.05$). Therefore, these findings emphasize the need for informed management strategies to address the impact on the fish's physiological conditions and ensure sustainable fishery practices.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

This study was very key in understanding population dynamics of *M. kannume* under human imposed pressure/anthropogenic pressure. This social-economic and biological data (sex ratios, size at sexual maturity and body length and body weight relationship) of *Mormyrus kannume* are very key in the development of management strategies of *M. Kannume* to address the already caused effects and preserve it from extinction in the long run.

6.2 Conclusions

The socio-economic factors that influenced bait selection in the Nile perch fishery included bait cost, fishing experience, the selling price of Nile perch, and bait size. *M. kannume* was found to be the most preferred bait due to its effectiveness in catching Nile perch. However, its high cost and limited availability have forced fishermen to use it in combination with alternative and less effective baits. This shows a key challenge in the sustainable use of bait within the fishery.

Mormyrus kannume in the Upper Victoria Nile is being overexploited, with all sampled individuals falling within or below the maturity sizes (23 cm for males and 21 cm for females). Although the sex ratio of 1:0.96 is close to the expected 1:1, the continuous harvesting of fish at immature sizes could affect the species' natural reproductive success. This shows a direct relationship between harvesting patterns and reproductive sustainability.

Mormyrus kannume in the Upper Victoria Nile showed negative allometric growth, with mature females and males having reduced b values (2.8 and 2.9 respectively). This means the fish becomes more elongated as it grows, which could probably be a response to fishing pressure and the use of inappropriate fishing gear such as basket traps. The change in growth patterns points to the possible long-term effects of current exploitation practices and fishing pressure.

6.3 Recommendations

1. Promoting alternative bait options by conducting research into locally available, affordable and effective alternative baits to reduce dependency on *M. kannume* and help mitigate the impact of scarcity and high costs.
2. Captive breeding programs for *Mormyrus kannume* should be developed to ensure a sustainable supply of bait and reduce fishing pressure on wild stocks.
3. MAAIF along with the Fisheries Directorate, should implement gear restrictions by banning basket traps and promoting selective fishing - to control the harvesting of immature *Mormyrus kannume*.
4. Research should be conducted on developing size-selective fishing gear for *Mormyrus kannume* to promote its effective conservation and management of its populations.
5. Adopt a co-fishing management approach that enforces conservation regulations while fostering collaboration among fishermen, researchers, and policymakers to ensure sustainable bait use.
6. The Ministry of Agriculture Animal Industry and Fisheries should develop and implement policies regarding bait use for all water bodies in Uganda.
7. Conducting longitudinal studies to avail information on the fishery stocks of *M. kannume* and track changes in sexual maturity stages concerning sex and weight variations over time to provide deeper insights into management strategies of *Mormyrus kannume.*
8. Conduct trials on bait size selectivity of *Mormyrus kannume* in relation to Nile perch size catchability, to determine the optimal bait size to be used by the fishers.

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APPENDICES

Appendix 1: Questionnaire

Questionnaire for identifying the socio-economic aspects relating to the application of elephant snout fish bait in the Nile Perch fishery.

Dear sir/madam,

I am in my second-year at Kyambogo University doing a Master of Science in Conservation and Natural Resources Management and I kindly request your participation in this data collection which will be relevant to my research study.

Name ---

Occupation---

Contact---

Location--

1 a) For how long have you been in the fishing business?

____

b) Which species of fish do you normally catch with baits?

i) Nile Perch (Mputa) ☐
ii) Tilapia (Ngege) ☐
iii) Lung fish (Mamba) ☐
iv) Others, specify--
----

c) Which baits do you normally use to catch Nile Perch?

i) *M. kannume* (Kasulubana/Kasulu) ☐
ii) Catfish (male) ☐

iii) Mudfish (nsonzi) ☐

iv) Synodontis (nkologo) ☐

v) Others, specify --

----

d) What is the most preferred bait in catching Nile Perch?

…………………………………………………………………………………………

e) Why do you prefer the one you stated/give reasons why?

……………………………………………………………………………………………

f) Have you ever used *M. kannume* to catch Nile perch?

i) Yes ☐

ii) No ☐

2. If you have ever used *M. kannume* (kasulubana/kasulu) to catch Nile Perch;

a) Which size (estimated length) do you always prefer for use?

……………………………………………………………………………………………

b) How many baits do you use per fishing?

……………………………………………………………………………………………

c) On how many hooks?

……………………………………………………………………………………………

d) How often do you set the hooks?

i) Daily ☐

ii) Once a week ☐

☐

iii) Twice a week
iv) Others,
v) specify
……………………………………………………………………………………..........

e) What is the hook size used?

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

3. What is size (kgs) of the Nile Perch caught?

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

4. How many fish are caught by the hooks you set per night?

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

5. How much do you sale a kilo of Nile perch?

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

6. Where do you get the *M. kannume* (kasulubana/kasulu)?

i) Landing site……………………………………………………………………………..
ii) Lake/river……………………………………………………………………………….

7. Based on the time of your expertise in the use of *M. kannume* bait (kasulubana/kasulu), comment on its preference with other baits.

…………………………………………………………………………………………………

8. How much do you buy one piece of *M. kannume*?

i) 1,000/= ☐
ii) 2,000/= ☐
iii) 3,000/= ☐
☐

iv) 4,000/=
v) Other prices, specify--

9. How much do you buy other baits?

i) Catfish (male) ☐
ii) Mudfish (nsonzi) ☐
iii) Synodontis (nkolongo) ☐
iv) Others, specify---

Thank you for your knowledge.

May God/Allah bless you abundantly in your fishing business

- End

Appendix 2: Fish sample data collection sheet

Date	SNO	Standard Length	Total Length	Weight	Sex	Stage of sexual maturity
30/7/2023	MK574	21	22.4	98.81	F	3
July	MK575	21.4	23.5	103.55	F	2
July	MK578	20.2	21.6	75.18	M	2
July	MK579	18	24	65.67	F	1
July	MK580	18.1	20.3	59.75	M	1
July	MK581	19.2	21.6	81.2	F	2
July	MK582	17.1	19.2	52.7	F	1
July	MK583	17	18.3	47.87	M	1
July	MK584	17.2	18.5	50.23	F	1
July	MK586	17.8	19.2	58.09	M	1
July	MK587	16.5	18	42.16	F	1
July	MK588	16.5	17.7	41.62	F	1
July	MK589	20	22.1	82.94	F	1
July	MK590	18	19.2	40.18	M	2
July	MK591	16	19.5	44.61	M	1
July	MK592	19	21.1	78.28	F	3

Appendix 5: Informed Consent Form

Kyambogo University
Knowledge and Skills for Service

P.O.BOX 1 KYAMBOGO TEL. 0414-285035/041-2895037/287502/287343

email: arkyu@kyu.ac.ug, website: www.kyu.ac.ug

CONSENT TO VOLUNTARY PARTICIPATION IN A RESEARCH STUDY

Study title: The effect of Nile Perch bait fishery on the reproductive and biometric parameters of *Mormyrus kannume* along the upper Victoria Nile.

Investigators:

1. **Name:** Dr. Asiyo Ssanyu Grace

Address: Department of Biological Sciences.

Kyambogo University, P. O Box 1, Kampala.

Tel; +256-782-353.

email; assanyu@kyu.ac.ug

2. **Name:** Dr. Aruho Cassius

Senior Research Scientist

National Fisheries Resources Research Institute – Kajjansi (NaFIRRI-ARDC)

National Agriculture Research Organisation (NARO)

P.O.BOX 530 Kampala

Tel. +256392840028/+256704655443

email: aruhoc@gmail.com; caruho@yahoo.com

Introduction

- You are being asked to take part in a research project on "The effect of Nile Perch bait fishery on the reproductive and biometric parameters of *Mormyrus kannume* along the upper Victoria Nile".
- You were selected as a potential participant because of your experience in the area of fishing near the Upper Victoria Nile.
- It is optional to engage in this project study. Prior to choosing to take part in this research project, kindly take the time to read this complete form and ask any questions.

Purpose of the study

Ultimately, this study will be submitted to Kyambogo University's Department of Biological Sciences as one of the conditions for the reward of a degree of Master of Science in Conservation and Natural Resources Management.

Description of the Study's methods

If you accept to take part in this fact-finding, you will be requested to give a response to some inquiries relevant to the *Lates niloticus* bait fishery in line with its effects on the reproductive and biometric parameters of *Mormyrus kannume* along the Upper Victoria Nile.

Risks of Being in this Study

The study has risks of disclosing private information concerning the usage of juvenile baits and unlawful fishing techniques along the Upper Victoria Nile to acquire *Mormyrus kannume* bait.

Privacy

The results of this research will be retained completely secretive. All research records will be stored in a password-protected, encrypted file and all electronic data will be encrypted and secured. Any information that could be used to identify you won't be included in any report we publish.

Payments

There will be no compensation for taking part in the study.

Right to Refuse or Withdraw

You have a choice on whether or not to participate in this research study. You can decide not to take part in this research study at any moment without it having an impact on your relationship with the study's researchers, the researcher, or Kyambogo University. You have the right to reject responding to some questions completely, to leave the dialogue altogether any point in time, and to ask that the interviewer not use any of the information you provided during the interview.

Right to Report Concerns and Ask Questions

You have the right to ask me questions before, during, or after the research regarding this study and receive my responses. Please feel free to contact me, Mbaho Eunith, at meunith2@gmail.com or by phone at +256-789-595-019/+256-755-986-617 in case of any more inquiries about this research study at any time. You can ask to receive a summary of the study's conclusions. Contact Dr. Asio Santa Maria, the department head of biological science at Kyambogo, at santahmariah@yahoo.co.uk if the researchers have not answered all of your queries regarding your rights as a study participant.

Consent

By signing below, you confirm that you have read the material above and that you have chosen to take part in this study as a research participant. You will be given a signed copy of this form, together with any other printed materials the researchers of the study deem significant, to keep.

Name: …………………....................

Signature of participant: ……………………

Age.…………. Date (DD/MM/YY): …………………………………………………

Name: …………………………. Signature of the Interviewer: ………………………………..

Date (DD/MM/YY): ……………………………………………………

Appendix 6: Introductory letter

KYAMBOGO UNIVERSITY

P. O. BOX 1 KYAMBOGO, KAMPALA - UGANDA
Tel: 041 - 285001/2 Fax: 041 - 220464/222643
www. Kyambogo.ac.ug

Department of Biological Science

21st January 2023

The Director of Research NaFIRRI
Jinja

Dear Sir/Madam,

RE: INTRODUCTORY LETTER FOR CONDUCTING A FINAL YEAR RESEARCH

This is to introduce to you **Ms. MBAHO EUNITH** with Registration Number **21/U/GMSM/14324/PE** a second-year student of Kyambogo University pursuing a Masters of Science in Conservation and Natural Resources Management.

As partial fulfilment of the requirements for award of Master's degree, she is required to conduct a research project. The title of the research is **"The Effect of Nile Perch Bait Fishery on the Reproductive and Biometric Parameters of *Mormyrus Kannume* along the Upper Victoria Nile".**

We humbly request that you give her an opportunity to access as much relevant information as possible from your organization/area, and we assure you that any information accessed will be used for academic purposes only.

Please accept our gratitude and appreciation in advance.

Yours faithfully,

Asio Santa Maria (PhD)
HEAD OF DEPARTMENT

KYAMBOGO UNIVERSITY
BIOLOGICAL SCIENCE DEPT.
☆ 21 FEB 2023 ☆
P. O. BOX 1, KYAMBOGO