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HUMAN – OTTER (*HYDRICTIS MACULICOLLIS*) CONFLICTS AND COEXISTENCE IN LAKE KIVU, RWANDA

A thesis submitted in partial fulfillment of the requirements for the degree of Master in Biodiversity Conservation and Natural Resources Management

By

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Kigali, October 2024

DECLARATION

I, **Placide NKUSI**, declare that this master's dissertation **''Human – Otter (*Hydrictis maculicollis*) Conflicts and Coexistence in Lake Kivu, Rwanda''** is the result of my own work in partial fulfilment of the requirements for the award of a master's degree in Biodiversity Conservation and Natural Resource Management at the University of Rwanda, College of Science and Technology and has not been submitted for any other degree at the University of Rwanda or any other institution. All sources that I have used or quoted have been indicated and acknowledged in the references.

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APPROVAL

I certify that this research project entitled "**Human – Otter (*Hydrictis maculicollis*) Conflicts and Coexistence in Lake Kivu, Rwanda**" was done under my supervision and has been submitted for examination with my approval.

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DEDICATION

To my supervisor, otter lovers, and all freshwater ecosystem enthusiasts.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
GoR	Government of Rwanda
HWCTF	Human-Wildlife Conflict Task Force
IUCN	International Union for Conservation of Nature
km^3 yr^{-1}	cubic kilomiter per year
LULC	Land Use Land Cover
MEA	Millennium Ecosystem Assessment
MINAGRI	Ministry of Agriculture & Animal Resources
mm yr^{-1}	millimeter per year
NISR	National Institute of Statistics of Rwanda
NP	National Park
PSTA4	Fourth Strategic Plan for Agriculture Transformation
RDB	Rwanda Development Board
REMA	Rwanda Environmental Management Authority
RPHC5	Fifth Rwanda Population and Housing Census
RTDA	Rwanda Transport Development Agency
SPSS	Statistical Package for the Social Sciences
SSC	Species Survival Commission
USAID	United States Agency for International Development
USD	United States dollar
USGS	United States Geological Survey

ABSTRACT

Freshwater biodiversity is believed to be more threatened than that of terrestrial and marine ecosystems. In Africa, 21% of freshwater species are threatened. Our study focused on assessing one freshwater otter species, the spotted-necked otters (*Hydrictis [lutra] maculicollis*) found in and around Lake Kivu, Rwanda. We aimed to explore conflicts between humans and otters to understand the nature of existing conflicts and identify other associated concerns to provide information to support conservation management strategies. The study was conducted in the sectors bordering Lake Kivu (Rubengera, Bwishyura, Mubuga, and Gishyita sectors) in Karongi district. We used a non-probability sampling method using purposive sampling of interviewees to identify and assess human-otter conflicts. To do this, we developed a semi-structured questionnaire and interviewed 26 study participants. We also used land use change detection methods to detect changes in land use and land cover on the lake shore zone over a 30-year period (1992-2022). Our interview results showed that there are prevalent conflicts between fish farmers and spotted-necked otters related to otter net damage and fish loss. Otters are trapped and killed during predation and damage to fish cages and their body parts have uses such as medicine and meat consumption. Furthermore, our analyses revealed that the otter habitat zone is under human pressure, leading to land use and land cover changes in addition to the 91 fish cages recorded during this study along the Lake Kivu shore. Overall, people's knowledge and awareness of the ecological importance and threats to otters will be key to developing conservation strategies for spotted-necked otters. In addition, compliance with Rwandan laws regulating fishing, aquaculture, and the environment in general is a possible solution to mitigate conflicts, enhance coexistence between humans and otters, and protect otters and their habitat range. An in-depth study on the conservation status and distribution of otters in Rwanda is recommended. This suggestion stems from the findings of this study, which highlighted a notable gap in Rwandan freshwater biodiversity, particularly concerning otters.

Keywords

Freshwater biodiversity, otter, conflicts, habitat degradation and loss, Land Use/Land Cover (LU/LC) change.

CHAPTER 1. GENERAL INTRODUCTION

1.1. Background

Lakes hold a big portion of the earth's freshwater, accommodate enormous biodiversity, and provide key provisioning, supporting, regulating, and cultural ecosystem services to people around the world (Lynch et al., 2023; Millennium Ecosystem Assessment (MEA), 2005; O'Reilly et al., 2015; Schallenberg et al., 2013). Freshwater ecosystems are among the most endangered ecosystems in the world considering how the declines in biodiversity are so great in freshwater ecosystems (Dudgeon et al., 2006; Sala et al., 2000). According to the 2022 International Union for Conservation of Nature (IUCN) Red List, one-third of freshwater species are threatened with extinction; this includes 58.5 % of freshwater turtles, 37.3 % of freshwater mammals, 21.7 % of freshwater fishes, 30 % of freshwater crayfish, and 29.9 % of amphibians, though these figures could be higher because this analysis excludes data-deficient species that may be threatened as well (IUCN, 2022). Dudgeon et al. (2006) grouped the major emerging threats to global freshwater biodiversity into five interacting categories: overexploitation, water pollution, flow modification, destruction, or degradation of habitat; and invasion of exotic species. All those major threats are closely linked to anthropogenic pressures (aquaculture, fisheries, nutrient enrichment, land-use intensification, etc.) (Long & Goethals, 2019). In addition, the growing use of freshwater resources due to the increase in the human population, the lack of other alternatives or the presence of unique aquatic ecosystem services (ecological, social and economic) available has driven emerging threats to freshwater biodiversity (Carpenter et al., 2011; Grizzetti et al., 2016; Millennium Ecosystem Assessment (MEA), 2005; Schallenberg et al., 2013; Vollmer et al., 2018).

The linkages between humans and nature often generates negative interactions between humans and wildlife, resulting in human-wildlife conflicts (Cook et al., 2022). Currently, human-wildlife conflict is one of the greatest challenges preoccupying conservation biologists (Cook et al., 2022; Dickman, 2010; Zimmermann et al., 2020). Among animal species involved in human-wildlife conflicts in freshwater ecosystems, otter species play a considerable part, and they are consequently victims of killings and hunts due to the predation and damages they cause (Akpona et al., 2015; Boustany et al., 2021; Cook et al., 2022; Dickman, 2010; Ergete, Balakrishnan, et al., 2018; Kone et al., 2021; Natalija et al., 2018).

Otters are semi-aquatic mammals in the carnivore family of Mustelidae which includes 13 species belonging to the subfamily Lutrinae (Duplaix & Savage, 2018; Foster-turley et al., 1990). Four species are found in Africa with three endemic to sub-Saharan region: Spotted-necked otter (*Hydrictis* [*lutra] maculicollis*), African clawless otter (*Aonyx capensis*), Congo clawless otter (*Aonyx congicus*), and a non-indigenous Eurasian otter (Lutra lutra) found in North Africa (Mason, 1990; Reed-Smith et al., 2018). All otter species occurring in Africa are listed by IUCN as Near Threatened under criteria A3cde though the populations are believed to be decreasing worldwide (Duplaix & Savage, 2018). For example, the Spotted-necked Otter (*Hydrictis maculicollis*) is believed to be extinct in Burundi, Ghana, Lesotho, and Togo (Reed-Smith et al., 2021).

In Rwanda, all three otter species indigenous to Africa are present (Rowe-Rowe, 1990). The African (Cape) clawless otter and Congo clawless otter are very rare; their distribution occurs mainly in marshes, around some lakes and along certain rivers, as well as in the rainforests and wetlands of Rwanda (for example, Nyungwe NP) (Reed-Smith et al., 2018; Rowe-Rowe, 1990). The spotted-necked otter, known as Inzibyi in Kinyarwanda, is the most abundant and lives exclusively in the open waters of the Rwandese lakes, where it mainly preys on fish (Lejeune & Frank, 1990). This species has been observed in lakes Muhazi, Kivu, Bulera, and Ruhondo (Rowe-Rowe, 1990).

1.2. Problem statement

Otters are considered as flagship and indicator species for healthy freshwater ecosystems (Duplaix & Savage, 2018). Thus, they can be used to promote the conservation of aquatic environments in areas where they are known or frequently seen (Dias et al., 2019) as long as they generate a positive perception of people as playful and charismatic animals (Foster-turley et al., 1990; Kruuk, 2006). However, where fisheries or fish farming activities are important and otters are present, human-otter conflicts may arise which may result in killing them due to their predation upon fish species and fishnet damage, or mainly based on the competition for shared, limited resources like land, water and/or food (e.g., fish) (Akpona et al., 2015; Vaclavikova et al., 2011).

The research done on the distribution of spotted-necked otter in Rwanda 30 years back showed that the untouched vegetation cover at that time all along Lake Kivu shores was one of the factors to sustain and even increase the population of otters in Rwanda considering that it was

helpful for their rest and breeding (Lejeune & Frank, 1990). However, from the year 1994 on, Rwanda has known rapid development and a high economic growth (Takeuchi, 2019) with consequence of a remarkable alteration along the Lake Kivu shoreline. For instance, the government of Rwanda has prioritized the development of maritime transport infrastructure in Lake Kivu where different ports are under construction in Rubavu, Karongi, and Rusizi (RTDA, 2021), in addition to hotels, roads, and power plant construction sites along the Lake Kivu shoreline. This is a possible major threat to otters as it was reported that they are decreasing throughout their range, mainly as a result of habitat degradation (Reed-Smith et al., 2018).

Furthermore, the Lake Kivu shoreline, together with its bays, has huge potential for cage fish culture (MINAGRI, 2011). This has motivated the private sector to develop commercial fish farms, as well as commercial and subsistence fisheries in Lake Kivu following the high demand in high-value animal protein to the Rwandan citizens (MINAGRI, 2011, 2018a; Niyibizi et al., 2022; Rurangwa & Kabagambe, 2018). Hence, fish farms attract otters which can then lead to conflicts between fish farmers and the otter population (Akpona et al., 2015; Reed-Smith et al., 2018). Moreover, in their habitat range, otter populations face polluted waters and degraded aquatic ecosystems due to the introduction of exotic species, such as Nile Tilapia (*Oreochromis niloticus*), and inadequate aquaculture practices (Reed-Smith et al., 2021).

In this regard, a thorough assessment of community perceptions of otters, their concerns and their needs is essential for the sustainable protection of our freshwater ecosystems. Considering that a lot of information regarding otter ecology, biology, and their conservation needs remains unknown (Duplaix & Savage, 2018), research is needed to develop conservation plans.

This research identified the nature of interactions between otters (Spotted-necked Otters) and humans and provide some constructive conclusion and recommendations.

1.3. Research objectives

1.3.1. General objective

To understand the nature of the conflict between otters and humans in Lake Kivu, Rwanda and provide information to support conservation management strategies.

1.3.2. Specific objectives

i. Identify damages and other concerns related to spotted-necked otter behaviours.
ii. Document people's (fish farmers, fishermen, local authorities, relevant private and government institutions) perceptions of spotted-necked otters.
iii. Assess people's attitudes towards spotted-necked otters and their conservation.
iv. Document lakeshore zone development and its impact on spotted-necked otters.

1.4. Research questions

i. What are the damages, concerns, and needs of local fish farmers and fishermen relevant to spotted-necked otter coexistence?
ii. What are people's perceptions of spotted-necked otter presence, damage, and loss?
iii. What are people's attitudes towards spotted-necked otters and their conservation?
iv. To what extent has the Lake Kivu shore zone changed or developed and its impact on spotted-necked otters?

1.5. Research hypotheses

- H0: There is no difference in attitudes towards spotted-necked otters and its conservation among groups (fish farmers, fishermen, and other stakeholders).
- H1: There is a difference in attitudes towards spotted-necked otter and its conservation among groups (fish farmers, fishermen, and other stakeholders).

- H0: There is no difference in attitudes towards spotted-necked and its conservation among people who know the value of otters and those who don't.
- H1: There is a difference in attitudes towards spotted-necked and its conservation among people who know the value of otters and those who don't.

1.6. Rationale of the study

It is of high importance to document the conflict between otters and humans in and around Lake Kivu. This study will develop potential solutions to conflicts between otters and humans and will help in the elaboration of best conservation practices for freshwater ecosystem conservation management. This will provide an opportunity to engage the local community by sharing knowledge and enthusiasm about why otters play an important role in our freshwater

ecosystem; thus, we can overcome conflicts and create new otter ambassadors in places where otter species are threatened.

1.7. Thesis outline

This thesis consists of six chapters. Chapter 1 is the general introduction which comprises the brief background about this research topic, the problem statement, the objectives, the research questions, the research hypotheses, and the rationale of this study. Chapter 2 consist of a literature review that provides a detailed literature supporting this thesis. Chapter 3 provides the methods used to collect data. Chapter 4 produces the results. Chapter 5 discuss the results. Chapter 6 gives a conclusion for this study and provides recommendations for future research and information to support conservation of otters and freshwater ecosystem.

CHAPTER 2. LITERATURE REVIEW

2.1. Literature background information

Freshwater ecosystems have a wide variety of species and habitats (Ottoni et al., 2023; Visser et al., 2023). Despite occupying less than 1% of the Earth's surface, freshwaters contain almost 10% of all known species, including nearly one-third of all vertebrates, so to be as well a hotspot for biodiversity (Strayer & Dudgeon, 2010). However, these surface freshwater ecosystems (lakes, reservoirs, and rivers) are among the most altered on the earth (Carpenter et al., 2011). The biodiversity of freshwater is more threatened than that of terrestrial and marine ecosystems (Collen et al., 2013; Sala et al., 2000; Wiens, 2016). Habitat degradation (e.g., land use change), over-exploitation, water pollution, invasive species, flow modification, and climate change are the major threats to global freshwater biodiversity mainly due to human activities (Dudgeon et al., 2006; Reid et al., 2019).

In the whole Africa, 21% of freshwater species are recorded as threatened (Darwall et al., 2011). Threats to African freshwater ecosystems are characterized by habitat transformation, pollution (i.e. in forms of eutrophication, domestic and industrial organic load, heavy metals, oil pollution, pesticides), impact of fisheries (overfishing, species composition change), invasive alien species, and climate change (Darwall et al., 2011).

In Eastern Africa, freshwaters are internationally renowned for their high levels of species richness and endemism, particularly within the Rift Valley lakes. The major threats to biodiversity in this region are identified as, but are not limited to, habitat loss and degradation, habitat fragmentation, predation, competition from introduced non-native species, and, in some cases, unsustainable use such as through fisheries (Darwall et al., 2005). In addition, a potential threat to freshwater biodiversity in Eastern Africa is the indirect impact of the alteration of water courses and over-abstraction of water, which is associated with high population growth and an increasing number of development projects designed to improve access to safe drinking water, sanitation, irrigation, and hydroelectric power in the region (Darwall et al., 2005).

Otters live in or around a variety of water bodies, such as wetlands, rivers, lakes, streams, and coastal areas, and are highly dependent on the aquatic environment, mainly because of their diet (composed especially of fish and crustaceans) (Kruuk, 2006). For the spotted-necked otter (*Hydrictis maculicollis*), a species of concern in this study, research conducted on Lake Muhazi, Rwanda, revealed that its diet consists almost entirely of small-to-medium-sized fish,

with a preference for haplochromis species (Lejeune & Frank, 1990). In the last three decades, spotted-necked otter in Rwanda was in suitable habitat conditions and favoured by the ban on the trading of pelts (Lejeune, 1989; Lejeune & Frank, 1990), however, it is now globally reported that it is decreasing throughout its range, mainly as a result of the alteration or degradation of freshwater habitats and riparian vegetation (Reed-Smith et al., 2021), others are killed for food or skins, or as a competitor for fish (Akpona et al., 2015; Reed-Smith et al., 2018; Rowe-Rowe, 1990), and habitat loss and increased conflict with people is impacting all otter populations (Reed-Smith et al., 2021).

Although all African otter species are still categorized by IUCN as Near Threatened, recent projections show a 25% population decline over the next three generations (Duplaix & Savage, 2018; Reed-Smith et al., 2018). It is likely that the otters of Rwanda are at great risk since Darwall et al. (2005) in his report about the status and distribution of freshwater biodiversity in Eastern Africa stated that the existing information on aquatic biodiversity in this region is inaccessible, dispersed, and disorganised.

2.2. Human-otter conflicts

Conflicts over wildlife, also known as human-wildlife conflicts, are characterized primarily by direct and recurring negative interactions between people and wildlife and involve a wide range of terrestrial and aquatic species, including elephants, primates, deer, crocodiles, otters, invertebrates, plants, and many more (IUCN, 2020; IUCN SSC HWCTF, 2020). These disputes happen when the behaviour and needs of wildlife contradict with those of humans (Zimmermann et al., 2020).

In the case of human-otter conflicts, the main reasons for conflict are that otters are opportunistic predators of fish, with fish accounting for approximately 80% of their regular diet (Jenkins et al., 1979); and the damages (fishing equipment damage) they cause (Akpona et al., 2015; Barbieri et al., 2012; Pooley et al., 2016; Rosas-Ribeiro et al., 2012; Vaclavikova et al., 2011). In different cases, the amount of damages attributed to the otters is considered small if compared to that of depredation (Barbieri et al., 2012). However, this was different in Benin, Africa, in the Hlan River, because the cost of otter damage to fishing equipment was greater than the cost due to fish loss, as one otter could take fish (and thus damage) from several nets (Akpona et al., 2015).

Furthermore, where conservation efforts succeed, wildlife populations increase, species recover and expand their ranges, and human-wildlife conflicts often follow (IUCN, 2020). In this regard, for example, in Central Europe (Natalija et al., 2018; Vaclavikova et al., 2011) and Western Brazilian Amazon (Rosas-Ribeiro et al., 2012), following their conservation efforts (e.g. hunting prohibition, and pelt trade restrictions), the status of otters has improved, but their increasing numbers have led to increased human-otter conflict. This means that it is necessary to take continuing conservation measures to maintain the otter population and mitigate human-otter conflict so that conservation is not a problem (Natalija et al., 2018).

2.3. People's perceptions of otters and their attitudes

The more people's concern for otters, the more negative their attitude toward reducing otter numbers will be, and the more strongly they will oppose otter management measures (Natalija et al., 2018). Torkar et al. (2010) reported in his study that knowledge levels correlate with attitudes, where people with greater knowledge of otters showed positive attitudes toward otters and their conservation.

Otter predation on fish species causes public opinion to diverge in areas with significant fishing or fish-farming activities (Dias et al., 2019; Vaclavikova et al., 2011). Studies showed that some behaviours of otters make fishermen develop negative perceptions and conflicts between them arise (Rosas-Ribeiro et al., 2012). Fishermen fishing near or in the areas most frequently used by otters have a more negative perception of otter interaction than the rest of the fishers (Barbieri et al., 2012). In areas where fish farming is a significant industry, some fish farmers perceive otters as a growing threat to their livelihood, and the otter is regarded as a pest species in some European countries (the Czech Republic and Austria)(Kranz, 2000).

2.4. Potential for fish aquaculture expansion, a temptation for otters

Fish production is a valuable provisioning ecosystem service provided by freshwater ecosystems (Carpenter et al., 2011). Declining fish stocks and increasing demand for fish have led to sharp rises in aquaculture production, and, the harvest of wild freshwater fishes and aquaculture make up an essential and rapidly growing source of protein for the world's populations (Naylor et al., 2000). In Africa, aquaculture production is around 2.5% of the total world aquaculture production where Eastern Africa, Northern Africa, and Western Africa contribute 0.25%, 1.75% and 0.5% respectively (Barange et al., 2018). As fisheries and aquaculture contribute in a significant way to food security and to the livelihoods of millions

of people (employment, supplier of nutritious food, generator of income and economic growth), in low-and middle-income countries food fish consumption is expected to increase between year 2012 and 2030 at a faster pace than in high-income countries motivated by the higher per capita economic growth, and sub-Saharan Africa is the region with the highest population expansion by 2050 and the only region with an expected increasing per capita food fish demand through 2050 because of the assumed income growth (Vannuccini et al., 2018). In 2019, the preliminary estimates were indicating a further growth in global per capita fish consumption reaching to about 20.5kg from 20.3kg estimated in 2017, with the share of aquaculture production in total available food fish supply overtaking that of capture fisheries (11.1 kg vs 9.5 kg) (FAO, 2021).

A few decades ago, Rwanda was at the lowest level in terms of per capita fish consumption compared to East Africa, Sub Sahara Africa, and the global levels of per capita fish consumption (MINAGRI, 2011). Hence, in the implementation plan of the Rwanda's national agriculture policy in its pillar of productivity and sustainability, there is a policy objective of developing aquaculture within an open-ended timeline where some of the actions are to promote private sector investment in cage fish farming, promote marketing of fish and aquaculture products and support value addition of fish and aquaculture products (MINAGRI, 2018a). Under the fourth strategic plan for agriculture transformation (PSTA 4), Rwanda aimed at increasing the annual fish production by 315% from the baseline of 27,000 tonnes in 2016/2017 to 112,000 tonnes in 2023/2024 counting mostly on several aquaculture investment projects planned and others underway (MINAGRI, 2018b).

It is in this light for example that in May 2022 the Rwandan government entered into agreements with a large scale fish culture private company called Kivu Choice Limited (Prime Minister, 2022) aimed at becoming the largest and most sustainable protein production and distribution platform in Rwanda. This Kivu Choice Limited already celebrated its first harvest of tilapia fish in March 2023 after the set-up of commercial floating cages on Lake Kivu in Nyamasheke District, in July 2022, and they have so far raised additional 35 million USD under his mother company (Victory Farms) for fish culture expansion in Rwanda and in East Africa in general (The New Times, 2023; WeAreAquaculture, 2023). Increased commercial use of Africa's fish resources, as well as increased reliance on fish as a protein source for local populations, is fuelling conflict between otters and fishermen (Akpona et al., 2015; Ergete, Hailemariam, et al., 2018; Reed-Smith et al., 2021).

2.5. Impacts of lake shoreline development

In large deep oligotrophic lakes like Lake Kivu, the shallow nearshore waters provide the most important habitat for animals to feed and breed, and it is in this area of the lake that humans are most likely to have an initial impact as the shoreline is developed (Elizabeth et al., 2008). Lakeshores have always been a preferred location for human settlement and other human activities (Liddle & Scorgie, 1980; Ostendorp et al., 2004), leading to shoreline development and the degradation of lakeshores (Brauns et al., 2007). Human population growth and rapid urbanization of rural areas are also increasing development pressure on lake shores (Wehrly et al., 2012).

Increased nutrient loads, boat navigation traffic, altered water levels, recreational activities, and shoreline reinforcement are all associated with residential development on lakeshores (Coops et al., 2003; Kahl et al., 2008; O'Toole et al., 2009; Vadeboncoeur et al., 2003). Shoreline development and changes in riparian land use have been identified as major drivers of littoral biodiversity loss; and, changes in littoral biodiversity as a result of habitat loss and degradation may disrupt species interactions, altering food web structure (Brauns et al., 2011). This destructive influence of humans on aquatic habitats (e.g., removal of bankside vegetation, shoreline development, habitat destruction, and aquaculture) has been behind the decline of otter species (Natalija et al., 2018).

2.6. Gap in the study of freshwater biodiversity in Africa

Various literature on freshwater biodiversity in Africa indicate that freshwater top predators, particularly otters, are understudied, omitted, and neglected, and their role and conservation needs are almost never considered. This is based, for instance, on the study conducted under the framework of IUCN about the diversity of life in African freshwaters by analysing the status and distribution of freshwater biodiversity throughout Africa (Eastern Africa, Western Africa, Northern Africa, Southern Africa, and Central Africa), where the selection criteria of priority taxa to base on that analysis were those taxonomic groups that provide obvious benefits to humans through direct consumption, or the more charismatic groups, and finally the taxonomic groups selected were fishes; molluscs; odonates (dragonflies and damselflies); crabs; and aquatic plants. (Brooks et al., 2011; Cuttelod & Malak, 2010; Darwall et al., 2005, 2009, 2011; Smith et al., 2009). With the excuse that it is not practical to assess all species, they recognized the importance of gathering information on other components of the food web

that are essential to the maintenance of healthy, functioning freshwater ecosystems, even if they are neither charismatic nor directly beneficial to humans. (Darwall et al., 2011).

Another example is an important study conducted on freshwater species of the Great Lakes Region by (BirdLife International, 2012) where different biodiversity groups were selected as baseline because they cover a wide range of trophic levels starting from fish (as top predators) down to primary producers (plants) and thereby provided a representative view of the overall ecology and conservation status of freshwater ecosystems for the Great Lakes region of east and central Africa; however, where there are otters, they are normally considered top predators over fish.

That bias in defining the true range of trophic levels in our freshwater ecosystem by overlooking the most dominant predator available will have an impact on our overall decisions, policies, and strategies, and as a result, freshwater biodiversity will be underrepresented in the development planning process.

CHAPTER 3. METHODS

3.1. Study area description

This study was carried out on the Rwandan side of Lake Kivu, in the western province, district of Karongi, within four sectors bordering Lake Kivu, namely Bwishyura, Rubengera, Mubuga, and Gishyita (**Figure 1**), where spotted-necked otters live, and fish culture and other development activities are prevalent. The selection and delimitation of this study area were based on two main factors: the certainty of data availability because the problem between humans and spotted necked otters was already suspected, and time and resource constraints because this research needed to be completed within six months on a limited budget.

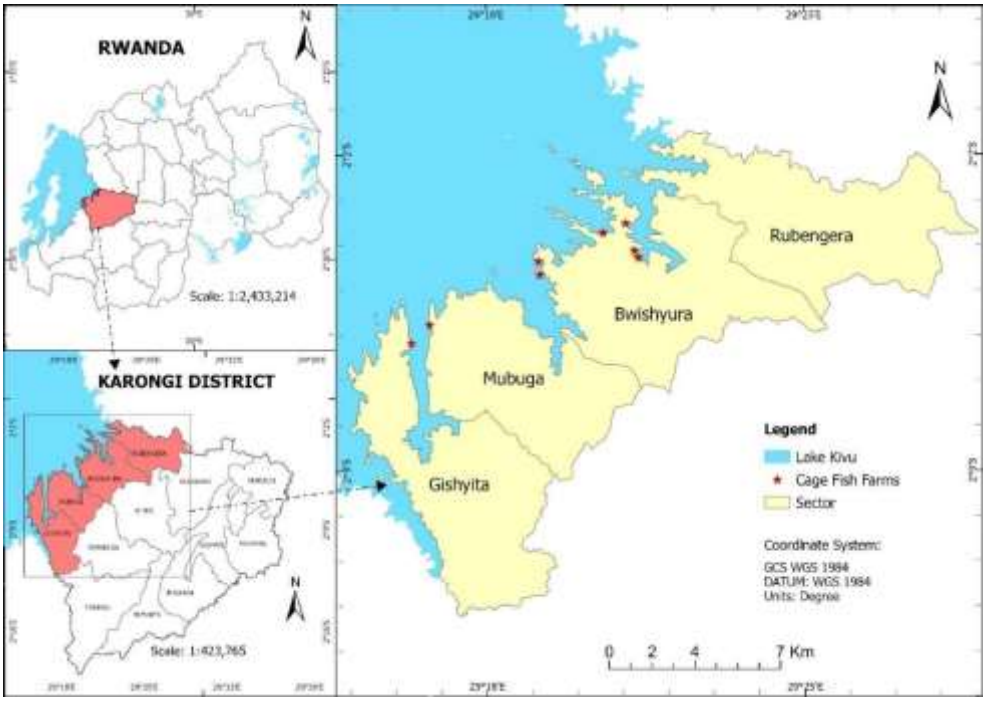

Figure 1: Map (right) showing the study area within the Karongi district and the locations of all eight cage fish farms visited (Source: Author, 2022).

Lake Kivu is an east African Rift lake located between Rwanda and the Democratic Republic of Congo (between 1°30’ and 2°30’ latitude south and between 28°50’ and 29°23’ longitude east) with the surface area of 2385km^2 of which 1000 km^2 is a part of the Rwandese side, total volume of 580m^3, at an altitude of 1463 m with the relatively small catchment of 5100 km^2 of which 2435 km2 is in Rwanda (Bärenbold et al., 2020; Schmid et al., 2021; Villanueva et al., 2008). It is an oligotrophic and meromictic lake (Sarmento et al., 2006) with the maximum depth of 485 m (Schmid et al., 2021) with average water depth of ~240 m (Roest, 1999; Villanueva et al., 2008). The lake is permanently stratified in its deep waters with the seasonal

mixing reaching only a depth of 60m and below it is dissolved gases mainly carbon dioxide (CO_2) and Methane (CH_4) with the respective approximate gas volume of 300 Km^3 and 60 Km^3 (Schmid et al., 2005).

Lake Kivu is characterized by two main seasons as in all eastern Africa region: a long windy dry season from June-September and long calmer rainy or wet season from October-May (Sarmento et al., 2006). Thus, these two seasons have an influence on the water balance of the lake as lake Kivu is fed in majority by precipitation (1404 mm yr^{-1}; 3.3 km^3 yr^{-1}), while losses by evaporation (3.4 km^3 yr^{-1}) equal approximately precipitation (Muvundja et al., 2009). Lake Kivu consists of five basins namely: Kalehe basin, Ishungu basin, Bukavu basin, Kabuno bay and the main basin where we find the deepest point (Schmid et al., 2021). It only has 29 fish species well described so far (Snoeks et al., 2012).

Fish farming started in Rwanda at the end of the 1940s during the Belgian colonial administration as subsistence fish farming activity characterized by low input and low output (MINAGRI, 2011). Rwanda's journey of transformation from a low-income to a middle-income country, by halving poverty and improving food security and nutrition by 2025, counts fisheries and aquaculture development among the important agricultural initiatives to achieve its targets, and has established policy actions to promote private sector investment in cage fish farming (MINAGRI, 2018a).

In Lake Kivu specifically, cage fish culture has been introduced since around 2000 by fishermen cooperatives through FAO and USAID funding, and commercial fish farms with the involvement of the private sector generally took place in 2013-2014 where the most farmed fish was Nile Tilapia (*Oreochromis niloticus*) (Rurangwa & Kabagambe, 2018). In the survey carried out in 2018 by Rurangwa & Kabagambe (2018) , there were six small-scale commercial fish farms registered under Rwanda Agriculture Board (RAB) consisting of 188 cages in total (total volume of 2220 $m^{3)}$ operating on Lake Kivu, and producing around 50 tons per year. During this study we counted eight cage fish farms in the Karongi district alone, so we expect the number of fish farms to have increased since 2018.

3.2. Study population, sample size and delimitation

The focus of this research was on Karongi District. The study centered on the spotted-necked otter (*Hydrictis [lutra] maculicollis*) and humans (fish farmers, fishermen, and stakeholders). A total of 26 people were interviewed during this study. These interviewees were selected following a non-probability sampling technique using the type of purposive sampling of interviewees (Andersson, 2015; Guest et al., 2006). The criterion of selection was based on the fact that every research question will be answered ensuring that all categories of people (fish farmers, fishers, and stakeholders) are represented. Among the 26 obtained interviewees, twelve were associated with fish farming activities, five were fishermen, and nine were other stakeholders (REMA staff, RDB staff, sector agronomists, and veterinarians).

Consequently, all people interviewed had the following considerable key positions in their respective roles: team leader, farm manager, fish farm business owner, president of a fishing cooperative, in charge of fish production sales and marketing, farm security guard and feeding, plankton and lake ecology specialist, lake scientist, biodiversity sector specialist, conservationist, environmental inspector, sector agronomist, and lastly, sector veterinarian.

3.3. Data collection

Data collection started from 21st October 2022 to 06th November 2022 following the reception of a research permit from the Rwanda Agriculture Board (RAB). The data collected falls into two main categories. Firstly, primary data: using a semi-structured questionnaire, 26 interviews were carried out to collect qualitative data responding to our research concerns related to (1) damages, losses, and other concerns related to spotted-necked otter behaviours; (2) documenting people's perceptions of spotted-necked otters; and (3) learning about people's attitudes towards spotted-necked otters and their conservation. Secondly, secondary data: GIS and remote sensing techniques were utilized to acquire data to document how Lake Kivu shore development has happened over time. In addition, the data from the National Institute of Statistics of Rwanda (NISR) were used to understand the relation between Lake Kivu shore zone development and population growth.

3.3.1. Primary data collection

A semi-structured questionnaire was elaborated following the approach of Akpona et al. (2015), Sifuna (2010) and Torkar et al. (2010) in order to gather all the necessary information about 1) socio-demographic data (sex, age, profession, etc.) of respondents, 2) fish farming and fishing activities, 3) otters' presence, damages, and other concerns 4) people's attitudes / perception towards spotted-necked otters and its conservation, and 5) the available mitigation and preventive measures against otter-human conflict. According to the type of informants (fish farmers, fishermen, or stakeholders), the questions were slightly altered, so each group had its own questionnaire for reasons of relevance. Although a direct translation into Kinyarwanda was provided for fish farmers and fishermen, the questionnaire was written in English.

Data collection started from 21st October 2022 to 06th November 2022 using a tool called KoboToolbox known to be suitable for researchers during field data collection in challenging environments (https://www.kobotoolbox.org, consulted in October 2022).

The following are the links to questionnaires used for fish farmers, fishermen, and stakeholders respectively:https://ee.kobotoolbox.org/x/EfMhbwcd,https://ee.kobotoolbox.org/x/NKG0Bejk, https://ee.kobotoolbox.org/x/1MIKKYef.

In addition, a variety of methodologies were utilized, including (1) direct visual observation and camera photography, and (2) handheld GPS (Global Positioning System) for collecting position coordinates.

Referring to the study's objectives and questions, the detailed methodology used is as follows:

3.3.1.1. Damages, loss, and other concerns related to spotted-necked otter behaviours

Damages and losses were defined in terms of property damages and fish loss due to otters. To ascertain which losses or damages occurred as well as other related issues, numerous questions were posed. We questioned the number of cages each farm has, whether or not they have all been the target of otter attacks, the estimated annual cost of property damage and fish loss, the time of day when otter damage and predation are most likely to happen, and what they do in the event of otter predation or damage. We also listened to their various suggestions and advice on the subject. Twelve fish farmers and five fishermen with varying responsibilities were questioned. In terms of property damage, we considered several factors, including the expected cost of net repair, materials costs (such as thread), human resource costs, net replacement costs

(if any), and how often it occurs in a year. For fish loss, we took into account the weight of fish that was lost, killed, or damaged and caused a loss of money. Additionally, we gathered data on each farm's or fisherman's annual fish production in kilograms as well as their respective annual incomes based on market prices per kilogram.

3.3.1.2. Document people's perceptions about spotted-necked otters

To assess people's perception towards spotted-necked otters, we held several discussions and questions with fish farmers, fishermen, and stakeholders. This documentation of people's perceptions was done via evaluating individual knowledge, beliefs, and myths about otters, and we gathered information on what everyone knows about the spotted-necked otter of Lake Kivu, how people value otters, whether the otter population in Lake Kivu has changed, whether they believe that otters are the only species to blame for losses and damage, suggestions made in response to otters' damage and predation, available preventive and mitigating measures, and any other potential issues.

3.3.1.3. People's attitudes towards spotted-necked otters and its conservation

A questionnaire containing 19 attitude statements with yes/no options was created (Sifuna, 2010; Torkar et al., 2010) and used to measure people's attitudes towards spotted-necked otter and its conservation. All 26 participants responded to yes/no statements.

3.3.2. Secondary data collection

Below, it is explained in detail how the data were acquired to study the Lake Kivu shore zone development. The data from the Rwanda population censuses of 2012 and 2022 (National Institute of Statistics of Rwanda (NISR), 2012, 2023) were utilized to support this study.

3.3.2.1. Lakeshore zone development and impacts to otters

Different change detection techniques were utilized to detect Land Use and Land Cover changes (LULC) in our study area consisting of particularly the sectors bordering the lake (Bwishyura, Gishyita, Mubuga and Rubengera) over a 30-year period. The total area of analysed land was 177.53 km^2. We took into account the first 50m from the shore along Lake Kivu water body, considered a buffer zone where if intact, should provide lake shore habitat for otters. This would later allow us to determine the extent of change to otters' habitat and how it has been impacted by human activity.

Landsat 5 images acquired on August 7, 1992, and July 8, 2012, Landsat 7 image acquired on June 5, 2002, and Sentinel 2 image acquired on August 25, 2022, were used for this study. The images were acquired via the USGS Global Visualization Viewer (https://glovis.usgs.gov) and Copernicus https://scihub.copernicus.eu/dhus/#/home). The selection of dates was based on the data availability, quality, and season similarities. The spatial resolution of the 1992, 2002, and 2012 images was the same (30 m), and the resolution of the sentinel 2 image was 10 m. Our LULC classes were put into four categories: Agricultural land, forest, Bare land, and Built-Up area (**Table 1**). A supervised classification was carried out using training areas followed by a ground truth verification via Google Earth Pro. Maximum Likelihood Algorithm was used to detect the land cover types in ERDAS Imagine 2014. The classification accuracy assessment was done by analysing the overall accuracy, the producer's accuracy, the user's accuracy, and the overall kappa coefficient was calculated. A detailed methodology is in **appendix 1**.

Table 1: Description of different LULC classes found in our area of study (Rubengera, Bwishyura, Gishyita, and Mubuga sectors).

LULC class	Description
Agricultural land	Agricultural area, plants, shrubs, grasslands,
Bare land	Areas devoid of vegetation, e.g., exposed rocks, landslide zones, beach, degraded forest area
Built Up Area	Settlements, hotels, industrial construction sites, and roads development
Forest	Dense forest, area under agroforestry

3.4. Data Analysis

Data entry and analysis were performed using Statistical Package for the Social Sciences (IBM SPSS Statistics 20). For all analyses, the level of statistical significance was set at $P < 0.05$. To assess and analyze people's attitudes toward the spotted-necked otter and its conservation, the 19 yes or no attitude statements were scored with one (1) point for each correct answer and zero points for each wrong answer. If the statement was formulated negatively to represent a negative attitude, the scores were reversed. The questionnaire was answered by each participant (n=26). One-way analysis of variance (One-Way ANOVA) was used to understand the disparities in attitudes and conservation views toward spotted-necked otters among fish farmers, fishermen, and stakeholders in order to better understand the needs for conservation and where to focus more awareness efforts. The three groups namely fish farmers, fishermen,

and stakeholders are considered as categorical variables and the total scores out 19 for each respondent are dependent variables. For a P-value less than 0.05, the null hypothesis (H0) was rejected, and if not, it was accepted.

An additional test using T-Test was conducted among respondents who answered yes or no to the question about otter value to determine whether there is a difference in attitudes toward otters and their conservation between those who see the value in otters and those who do not.

To analyse the lakeshore zone development, ERDAS Imagine 2014, and ArcGIS Pro 3.0 were employed at various stages of analysis.

To analyse the LULC changes in the buffer zone, I created a 50m buffer zone around each classified images (1992, 2002, 2012, 2022) using Buffer tool in ArcGIS Pro considering that boundary of these classified image is lake coastal line, so the buffer zone was created inside, and these images were converted from raster to polygon for further analysis.

A symmetric difference tool was used for removing that created buffer area in our classified images and after that, that buffer zone was splitted depending on the end of the lake coastal line with buffer zone. Finally, the areas were generated by ArcGIS Pro and further analysis was carried out in excel.

CHAPTER 4. RESULTS

Of the 26 respondents from the interviews, 23 (88.5%) were men and three (11.5%) were women. In terms of the statistical description of all respondents, 77% were over 30 years old, 76.9% were married, 53.9% had at least an A-level education, 15.4% had never attended school, and 54% had worked in the fish aquaculture business, fishing, or environmental conservation for more than 5 years. The majority of people (73.1%) had lived and worked in the Karongi district for long enough to be aware of otter presence and their behaviours (**Figure 2**).

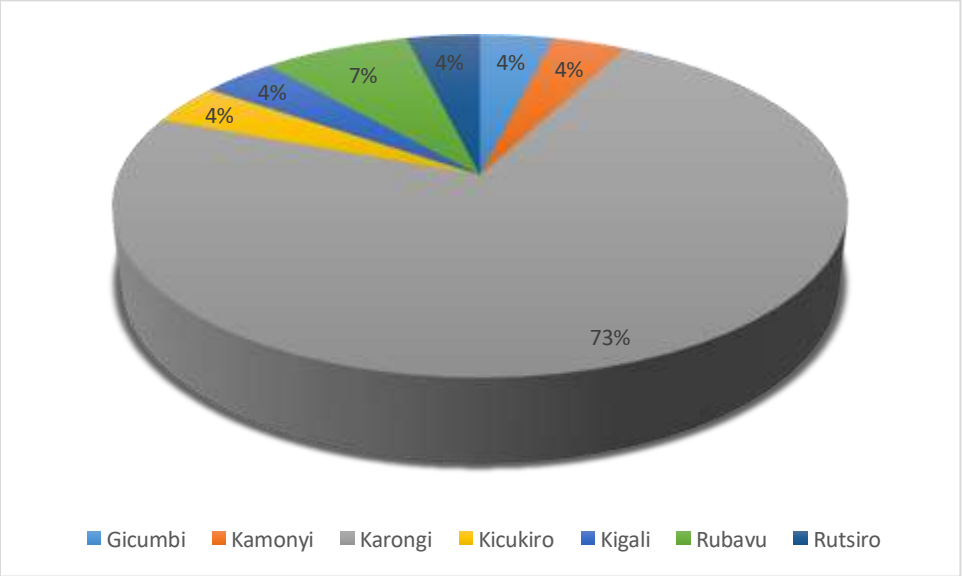

Figure 2: Residential areas of all respondents included in the sampling from Karongi District, Rwanda.

4.1. Fish farming and fishing activity

A total of 91 cages made up the eight fish farms in the Karongi district that we visited. Six fish farms and 75 cages out of 91 are in one sector of Bwishyura. These floating fish farms are located in bays and surface water bodies, close to the shore. Eight cages were the minimum and 17 were the maximum number per farm.

Each cage farm was composed of a floating system, an anchor system that holds the cage and all its components into the lakebed, a mooring system that helps to hold the cage in the appropriate position based on the direction and depth designed and joins the cage at the anchor system, a cage bag (net bag), and additional nets for predator protection (birds and otters). The floating system, which is an important part of the cage and gives it its shape, was made up

primarily of metallic frames and plastic drums or aquaculture pontoons cubes (**Figures 3 & 4**). The anchor system was made of concrete blocks or heavy rocks, and the mooring system was made of ropes. According to the informants, tilapia (*Oreochromis niloticus*) is the fish species cultured in all fish farms.

Figure 3: Floating system made up of metallic frames and plastic drums (Source: Author, 2022).

Figure 4: Floating system made of plastic pontoon cubes (Source: Author, 2022).

Table 2: List of all fish farms in Karongi and their respective locations in Lake Kivu, Rwanda (source: Author, 2022).

No.	Name	Location	Longitude	Latitude
1	African Fish Farm Ltd.	Western Province, Karongi District, Bwishyura Sector, Kiniha cell	29.355207	-2.068947
2	Aquatics Farm Ltd.	Western Province, Karongi District, Bwishyura Sector, Kiniha cell	29.354341	-2.068546
3	Cooperative Ubumwe Nyarwanda	Western Province, Karongi district, Gishyita sector, Buhoro cell	29.272469	-2.102862

4	Hakisand Ltd	Western Province, Karongi district, Mubuga sector, Nyagatovu cell	29.279124	-2.095969
5	Lake Kivu Aquaculture Company Ltd.	Western Province, Karongi District, Bwishyura Sector, Gasura Cell	29.319612	-2.077530
6	Mukondwe Fish Farming Business Company Ltd.	Western Province, Karongi District, Bwishyura Sector, Kibuye cell	29.342843	-2.062028
7	My Hills Fish Farm Ltd.	Western Province, Karongi district, Kibuye cell	29.351115	-2.058575
8	Ucoopeveka Cooperative	Western Province, Karongi District, Bwishyura Sector, Gasura Cell	29.319107	-2.072548

According to the survey, fishing with nets is performed using wooden boats (trimarans or single boats) and fishnets with various mesh sizes (5 x 5, 6 x 6 ,9 x 9, 10 × 10 mm, and 3.5 x 3.5, 4 x 4cm). The table below shows that there are only five legally recognized cooperatives of fishermen in the Karongi district, with a total of 70 members.

Table 3: Authorized fishing cooperatives in Karongi District (source: Ucoopeveka Cooperative).

No	Cooperatives	Members
1	Ubumwe Nyarwanda	20
2	Twuzuzanye Kumwuga	14
3	Nyakarwa	9
4	Baraka	13
5	Terimbere	14
Total		**70**

Out of 70 people, only one person was fishing for larger fish species besides sambaza (*Limnothrissa miodon)*. At the time of this research, 110 fishnets were being used in Lake Kivu at Karongi, but only six of them were intended for large fish capture (i.e., tilapia). Out of the 110 fishnets, 25 are used on trimaran boats, and the remaining 79, known locally as imitego y'icyerekezo (Icyerekezo fishing nets), are used on single boats collectively for sambaza captures.

According to the respondents, the most common fish species caught are Sambaza (*Limnothrissa miodon*), tilapia, Rwanda Rushya (*Lamprichthys tanganicanus*), Kabambari (*Clarias gariepinus*), and inkweke (*Cyprinus carpio*), which is rarely caught.

4.1.1 Fish production and income

Only five out of eight fish farms and four out of five fishermen cooperatives have confirmed having sold products throughout the year. Three farms had no production: two were just getting started (they had only been in operation for two months), and the third failed to continue the project because it ran out of food and decided to sell juveniles. The average annual fish production (kg) per fish farm and fisherman was 13,740 kg and 2,355 kg, respectively. The average annual income per fish farm and fisherman was 40,650,000 Rwf and 4,749,000 Rwf, respectively (**Figure 5**).

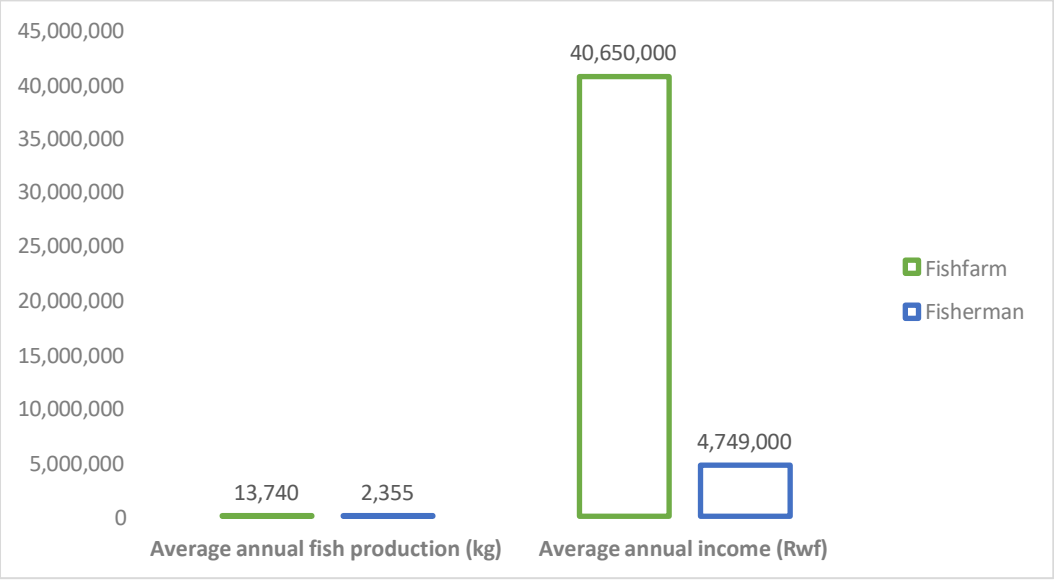

Figure 5: Fish production (Kg) vs income (Rwandan francs) from studied fish farms at Karongi District, Lake Kivu, Rwanda.

4.1.2. Otter damages and loss

Most respondents said yes that all cages and fishnets are vulnerable to otter attacks and damage. Only three people said no that not all cages are attacked. One said: "*no, otters have never approached our cages of fish nursery"*, other two said: "*we are always seeing otters swimming all around, but they have not yet attacked our cages, because our fishes are juveniles, only two months we have started this business"*. Following discussions with various interviewees, most fishermen fishing near the shoreline have experienced otter damage (**Figure 6**) except for

fishermen operating in Lake Kivu's pelagic zones. Most fishermen said: "*every time I fished near the shoreline, I was always fighting otters the whole night"*. Another one interviewed respondent said: "*I don't face any issue with otters, me, I always fish in the middle of the lake where there are not otters"*.

Figure 6: Fishermen repairing a net damaged by an otter during night fishing near the shore of Lake Kivu (Source: Author, 2022).

For many respondents, the most likely time of day for otter damage and predation was between 17h:00 and 00h:00 and early in the morning, between 3:30 and 6:00 a.m. A few other people stated that otters attack whenever it rains or when the weather is turning rainy.

In terms of property damage, all fish farmers and fishermen confirmed that otters only damage nets. Otter damage is estimated to cost, on average, 112,083 Rwf per fish farm (n=6) and 207,500 Rwf per fisherman (n=2) annually. In terms of fish loss due to otter predation, the estimated average annual monetary losses were 1,232,500 Rwf per fish farm (n=6) and 597,500 Rwf per fisherman (n=4). The average annual total loss was reported as 1,344,583 Rwf per fish farm and 805,000 Rwf per fisherman (**Figure 7**).

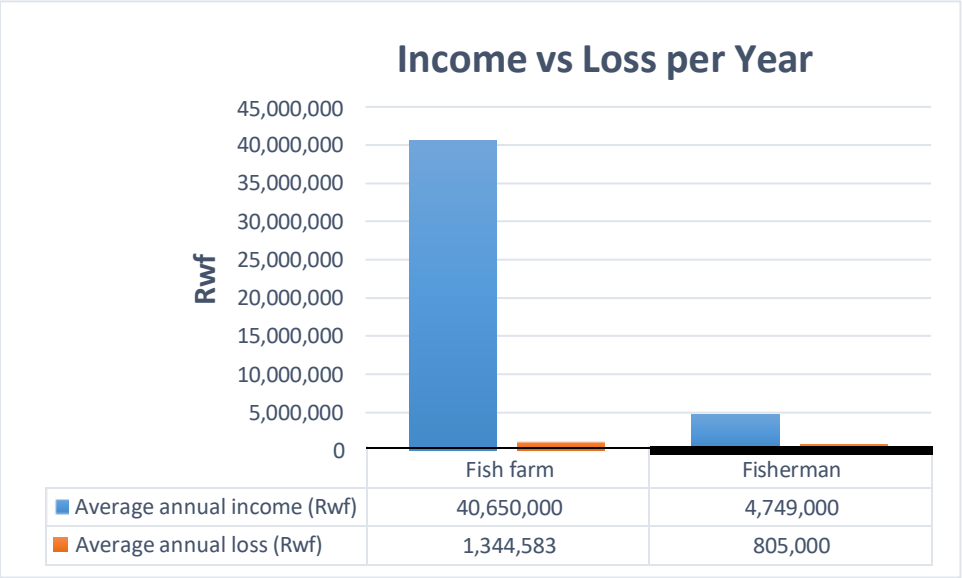

Figure 7: Comparison of fish production income and loss due to otter predation and damage.

When fish farmers and fishermen (n=17) were asked if otters alone are to blame for the damage and losses in Lake Kivu, 82.4 % said yes and only three (17.6 %) said no. Those who said no mentioned that there are bird species (**Table 4**) that normally feed on fish and occasionally come on top of the cage and injure the fish. However, they stated that this is a low-risk threat that is simple to manage.

Table 4: Bird species reported as fish predators (Source: Author, 2022).

Common Name	Vernacular Name	Scientific name
Hamerkop	Sarumfuna / Nyiramashoka	*Scopus umbretta*
Great Cormorant	Ishopfu/vu	*Phalacrocorax carbo*
Long-tailed Cormorant	Ishopfu/vu	*Microcarbo africanus*
Pied Kingfisher	Nyiramurobyi	*Ceryle rudis*
Malachite Kingfisher	Nyiramurobyi	*Corythornis cristatus*

Even though otters caused damage and losses, most people (88.2%) stated that otters have never caused them to leave or relocate elsewhere for aquaculture or fishing because there is no escape where otters don't live in Lake Kivu, and they are accustomed to the otters' behaviour (damage and predation).

4.2. People's perceptions about spotted-necked otters

4.2.1. Knowledge, beliefs, and myths about spotted-necked otters

Most people, particularly fish farmers and fishermen, knew a lot about the otters in Lake Kivu. Many respondents mentioned that different otter body parts (skin, penis) and excrement are medicinally useful, with the skin, for example, treating a disease locally known as inzibyi (abscess). They stated that otters are predators of fish species and enjoy hunting most on the species known as *Lamprichthys tanganicanus* (Rwanda Rushya), and that they are highly intelligent creatures with keen senses. All fish farmers and fishermen interviewed repeatedly praised them for being so hygienic that they never eat or defecate in the water. Others claimed that otters travel in families of two to three, and become violent once caught, but never provoke people or damage their crops. Few have confirmed that they consume otter meat and sell their skin. A pelt (skin) piece costs about 1,000 Rwf. The entire pelt costs between 5,000 and 10,000 Rwf.

Some of the respondents, in terms of myths, think that otters bring bad luck (umwaku in Kinyarwanda), and they prefer to call the otter a dog of Kivu in the morning instead of calling it inzibyi (otter). They said that if you see it or pronounce its name in the early morning, you risk not catching any fish for the rest of the day and may even lose your net in the water. Some respondents (e.g., other stakeholders than fish famers and fisher men) stated that they had heard of and seen otter species in Lake Kivu, and one said: *I know that they used to live in Lake Kivu and probably have ecologically gone extinct*. Another respondent (stakeholder) said in his own words: *otters got discovered recently, not scientifically known before 2010*. While most people were unaware of their existence in Lake Kivu.

4.2.2. Perceptions of Spotted-necked otter value

Among the 26 people (fish farmers, fishermen, and other stakeholders) who responded to the question of whether otters have a value to them, 42.3% said that they don't see any value in otters. Those who claimed that otters are valuable to them (57.7%) did so in terms of traditional medicine, food production, skin sales, ecological balance and regulation, tourism, and recreational advantages. Lastly, but certainly not least, a few only added that there might be an unidentified value because nothing exists in this world without a value.

4.2.3. Perception based on Spotted-necked otter damage and predation

Answers to the question of whether the otter population has changed in Lake Kivu or not were obtained from 21 of the 26 respondents. The five remaining didn't react because of uncertainty if otter population has changed in Lake Kivu or not. Fifteen out of 21 people believe the otter population has changed, while six believe there has been no change. According to 86.7 % (13 people) of those who reported noticing a change, one informant said: "*initially, otters are many, we never cease to see them".* second one said: "*the otter's population has increased, earlier, otters used to move in group of 2, but now I see them in group of more than six".* He continued: "*even now in this gulf there are so many kids of otters, they reproduce so fast, I often listen to kids' voice"*. There is another one who said: "*there are now more otters than they used to be, and it is obvious, see: no one hunts them, not easy to capture them, they don't have their predators, and the food is enough*". Only two people asserted that otters are less and that it is assumed that they do not reproduce quickly.

To assess people's perceptions following Spotted-necked otter damage and predation, respondents were asked for suggestions and inputs (ideas) that could improve coexistence between otters and fishermen/farmers and eliminate conflicts. Several individual points of view were expressed, but the recurring themes were to gather all otters and confine them in one location where they could be fed, monitored, and visited. This would restrict their freedom of movement and eliminate their ability to prey on fish. According to one fish farmer: "*relocating otters would be a good idea because the losses they cause outweigh the benefits they provide".* Few others suggested that the government should permit the clearing or removal of their habitat in various Lake Kivu bays.

Another group of respondents believed that coexistence is possible by saying: we can use strong and high-quality nets that are resistant to damage and predation as well as carrying out regular farm maintenance and avoid distractions. One person (a fish farmer) stated: *I am grateful that at least some otter research is being done because I personally thought that otters from Lake Kivu were highly neglected and undervalued, and as a result, their effects, such as the fish losses and damages occurring, are not taken into consideration.* As a result (he continues), *I hope that otter awareness would increase and a compensation plan will be put in place, just like it is for other wild animals that damage crops and other property*. Others have accepted to live in such a situation because they see no other option.

Stakeholders placed strong emphasis on developing strong policies, involving stakeholders, and enforcing laws that protect buffers, shorelines, and biodiversity. Some stakeholders mentioned that: *"enforcement of existing laws is a key in conservation. There should be protected shoreline or extend buffer zone to avoid otter's habitat degradation. People need to be informed about biological diversity and their ecological functions"*.

4.3. People's attitudes towards spotted-necked otters and their conservation

I was able to determine the differences in attitudes toward spotted-necked otters and their conservation among three groups, including fish farmers, fishermen, and other stakeholders, by examining how people (n = 26) responded to various attitude statements (**Table 5**).

Even though spotted-necked otters can be a nuisance, many people have positive feelings toward them and are willing to support their conservation. However, there are some instances where more than half of respondents demonstrated an attitude supporting that there are too many spotted-necked otters in Lake Kivu and they are a great danger to the balance of aquatic organisms, and they believe that otters reduce fish populations to unacceptable levels. Some informants stated that if a spotted-necked otter repeatedly damages a fish farm or fishing net, they would agree with killing this animal, and a significant number who have no positive feelings toward the spotted-necked otter, argued that it is unnecessary to maintain the spotted-necked otter population in Lake Kivu if they can be found in other parts of Rwanda's water bodies, wishing if otter hunting was permitted by law (**Table 5**).

Whether informants were stakeholders, fishermen, or fish farmers, there was no statistically significant difference in their attitudes toward spotted-necked otters and their conservation ($P=0.118$), confirming the null hypothesis. However, a statistically significant difference ($P=0.000$) in attitude was observed between those who demonstrated or believe that otters have value and those who do not. A positive attitude towards spotted-necked otters and their conservation was demonstrated by those who understand or recognize the value of otters.

Table 5: Attitude statements used to document people's attitudes towards spotted-necked otters and its conservation.

No.	Attitude statements (n=26)	Yes (%)	No (%)
1	I have positive feelings toward the spotted-necked otter.	57.7	42.3
2	It is important to maintain a healthy spotted-necked otter population in Lake Kivu.	65.4	34.6
3	Spotted-necked otters have positive impact on tourism on Lake Kivu.	76.9	23.1
4	Spotted-necked otters have positive impact on ecological balance of Lake Kivu.	65.4	34.6
5	Spotted-necked otters reduce fish populations to unacceptable levels.	53.8	46.2
6	There are too many spotted-necked otters in Lake Kivu, and they are a great danger to the balance of water organisms.	61.5	38.5
7	The law should allow spotted-necked otter hunting. The spotted-necked otter is a dangerous beast.	38.5	61.5
8	It is important to maintain the spotted-necked otter population in Lake Kivu in the future.	69.2	30.8
9	It is unnecessary to maintain the spotted-necked otter population in Lake Kivu because they also exist in other parts of Rwanda water bodies.	46.2	53.8
10	It is important to maintain the spotted-necked otter population for future generations.	76.9	23.1
11	Whether or not I get to see otters, it is important to me that they exist in Lake Kivu.	73.1	26.9
12	It is important to me if other people enjoy the otter's existence in Lake Kivu.	88.5	11.5
13	Near threaten species, like the spotted-necked otter, have a right to live in Lake Kivu/Rwanda.	84.6	15.4
14	If a spotted-necked otter repeatedly causes damage to a fish farm or fishing net, I would agree with killing this animal.	57.7	42.3
15	I agree with the statement that lakeshores should be cleared even though this reduces the habitat of many freshwater animals, including otters.	7.7	92.3
16	I am willing to contribute (work, money, etc.) to spotted-necked otter conservation in Lake Kivu/Rwanda.	69.2	30.8
17	Despite its nuisance I support otter conservation.	84.6	15.4
18	Because of its nuisance I do not support otter conservation.	15.4	84.6
19	I have an indifferent position to otter conservation.	0	100

4.4. People's prevention and mitigation measures against spotted-necked otter

Questions were asked to learn about the practices and measures in place to prevent, reduce, and mitigate conflicts between spotted-necked otters and fish farmers or fishermen. Additionally, I asked respondents if they were aware of the law or policy governing the protection and conservation of otters and biodiversity, or if there had been any community awareness about otter presence and conservation. Many respondents across all groups stated that because everyone responds differently, there are no concrete measures taken to prevent or reduce conflict with otters. All fishermen contacted said there are no common safeguards in place. The only prominent alternative measures mentioned by fish farmers as helpful to them are hiring a security guard for day and night shifts, having a schedule for cage inspections and maintenance, and using strong and high-quality materials for their cage fish farms. Everyone has learned to add one more layer with a strong net protecting the inner net carrying fishes and the top of the cage is covered by an additional net to prevent bird attacks.

The fishermen stated that, to avoid conflict with otters, they stay away from the otter-dominated littoral zones when doing their fishing activities. One stakeholder mentioned that since the spotted-necked otter is a living wild animal, it must also have a predator to control its population naturally. Some people proposed creating a national fund for compensation and spreading knowledge about how-to live-in harmony with otters as a step to lessen conflicts between humans and otters.

Until now, the strategies used to combat otter damage and predation primarily involve remaining vigilant and chasing otters away once they appear by hurling stones or shouting at them; if not, killing them as soon as they approach the fish farm. Three fish farmers admitted openly to setting traps in otter paths and killing them with locally made metallic arrows mounted on wooden sticks, known as umugera (**Figure 8**). Sometimes an otter skin is placed on top of the cage to frighten off other otters (**Figure 9**). Another practice admired by a few fish farmers is the removal of shoreline vegetation in the vicinity of aquaculture areas to remove otter habitats.

Figure 8: Tool used to fight and kill spotted-necked otters once in a cage fish farm (Source: Author, 2022).

Figure 9: Spotted-necked otter killed after being caught in a fish cage and the otter skin being dried (Source: Author, 2022).

To determine whether there was any community-based awareness about otter conservation and coexistence, 25 respondents answered with a resounding no that it had never occurred, with one remaining unsure. A significant portion of respondents (68%) also mentioned that no known law or policy that governs the preservation and protection of otters exists in Rwanda. However, a small number of people, particularly stakeholders, who claimed that this law existed referred to the law n° 064/2021 of 14 October 2021, which regulates biological diversity.

4.5. Lakeshore zone development

Results showed changes in land use and land cover (LULC) in the zone bordering the lake for the last 30 years (**Figure 10**). Decline of agricultural land area and bare land area, deforestation, and an increase in built up area (characterized by settlements, hotels, industrial construction sites, and roads development were observed generally in the area of study (**Figure 11**).

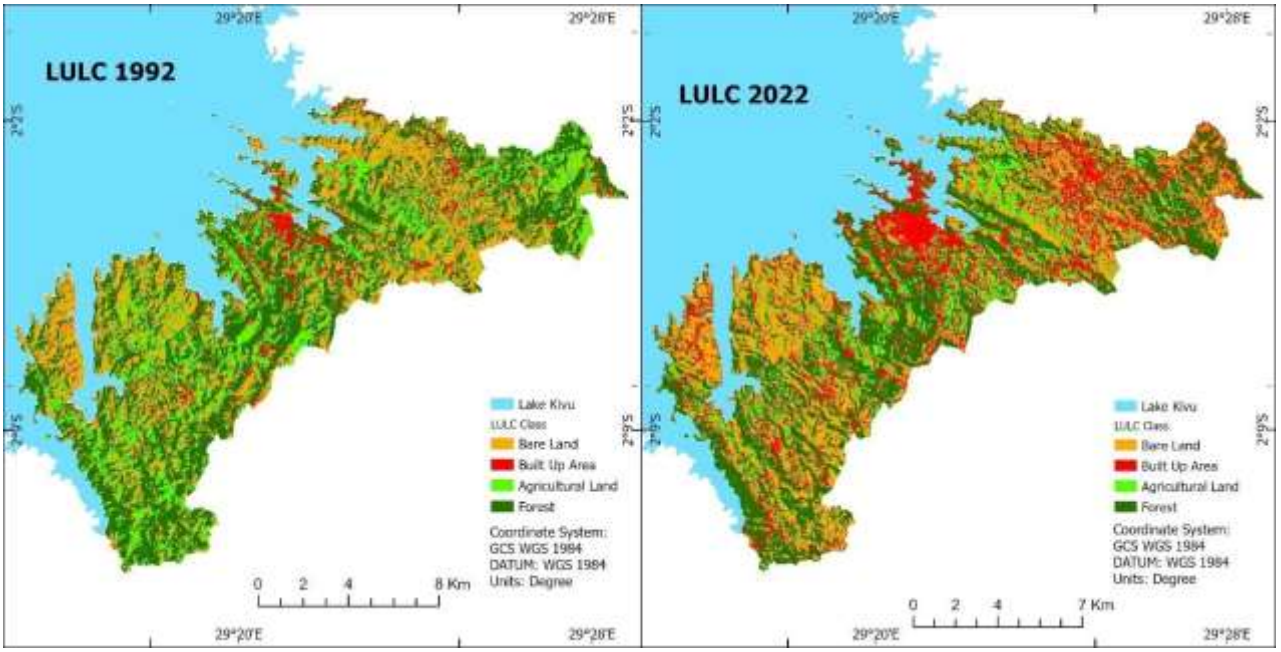

Figure 10: Land Use Land Cover map between 1992 and 2022 in the sectors of Rubengera, Bwishyura, Mubuga, and Gishyita, Karongi district (Source: Author, 2022).

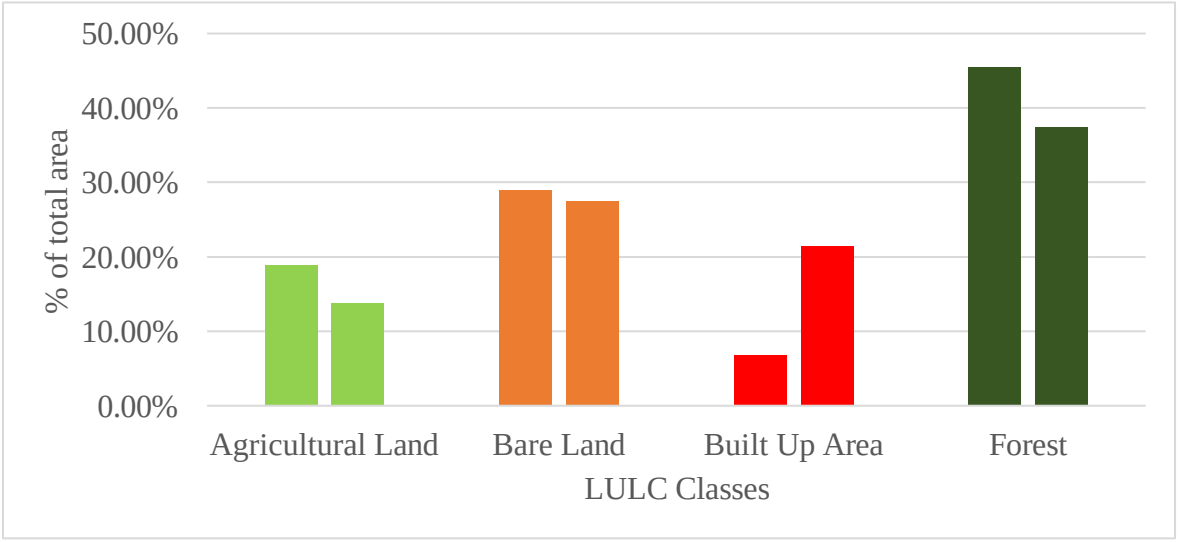

Figure 11: Changes in land use and land cover (LULC) in the period of 1992–2022 in Karongi (Rubengera, Bwishyura, Mubuga, Gishyita).

Analysis of the LULC change over the period of 30 years shows that each class individually has changed. Agricultural land area composed of crops, grassland, and shrubs reduced by 26.93%, forest area consisting of dense forest and agroforestry trees reduced by 17.76%, bare land area reduced by 4.96% while the built-up area consisting of settlements, hotels, roads, etc drastically increased by 213.15% by 2022 (**Table 6 & Figure12).**

Table 6: The net changes of classes of LULC in the period of 1992–2022.

LULC Class	**Area in km^2**	**Percent**
Agricultural Land	-8.99	-26.93%
Bare Land	-2.55	-4.96%
Built Up Area	25.87	213.15%
Forest	-14.33	-17.76%

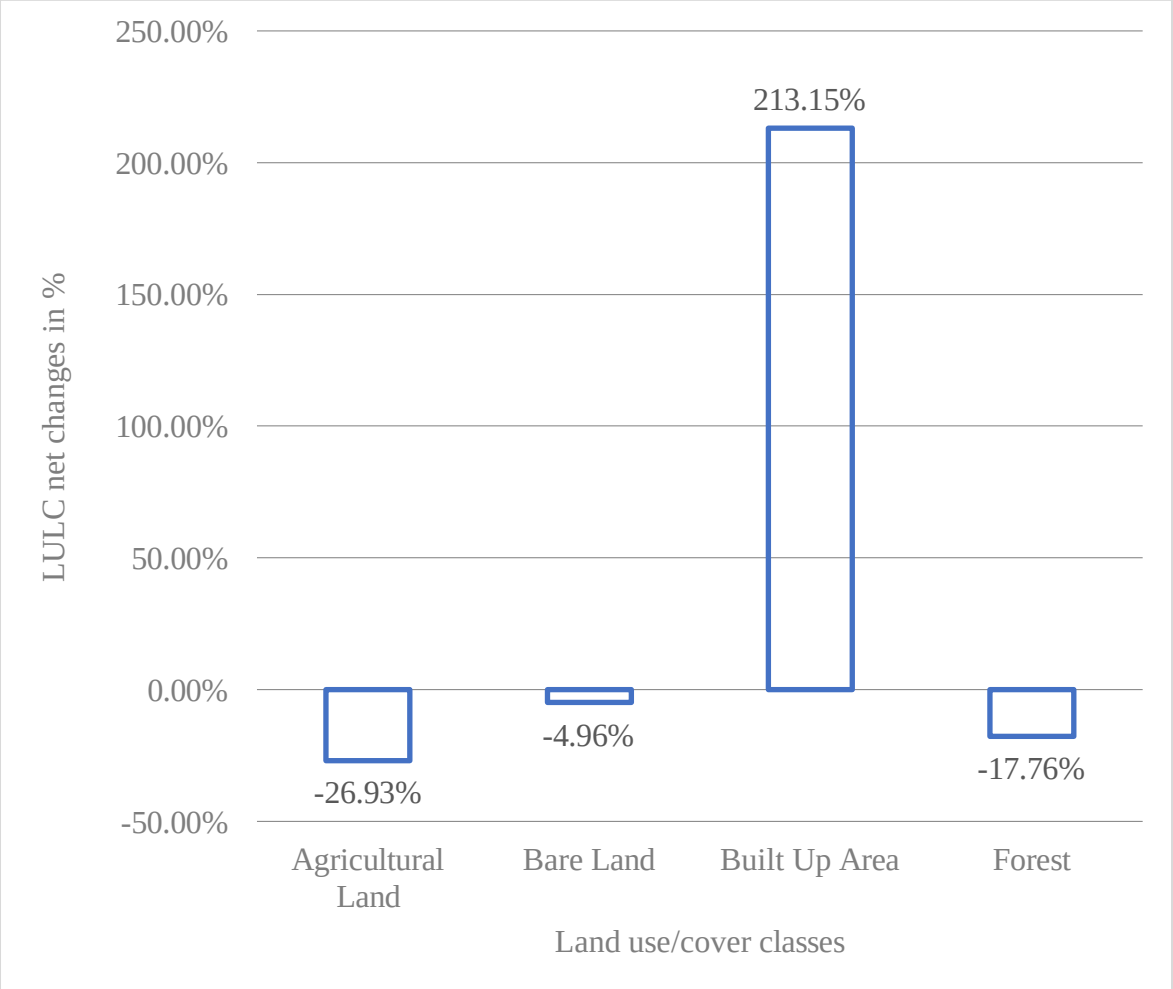

Figure 12: Net change in individual land use land cover classes between 1992 and 2022 in the study area.

Agricultural land area in 1992 included 33.40km^2 (18.81% of total area), which decreased to 24.41km^2 (13.75%) by 2022; 16.51% of the agricultural area changed into built-up, 23.38% changed into bare land, 29.68% changed into forest area, and 30.43% remained unchanged. Bare land was occupying 51.32km^2 (28.91%) within the total area in 1992 and decreased to 48.77km^2 (27.47%) by 2022; 43.02% of the bare land area in 1992 remained unchanged till now while 21.76% changed into built-up, 24.44% changed to forest and 10.78% was transformed into agricultural land. For the case of built-up area in 1992 (12.13km^2), by 2022, it had significantly expanded in surface area of 38km^2, an increase of more than three times by 2022. In 1992 there was 12.13km^2, and only 0.49km^2 changed into agricultural land, 1.65km^2 to forest, 1.69km^2 to bare land and 8.31km^2 remained unchanged. The forest area occupied a bigger area since 1992 though it dropped from 80.68km^2 (45.44% of total area) to 66.35km^2 (37.37%) in 2022. The results showed that this drop in forest area was due to some areas converted into built up area (13.01km^2 of forest area changed into built up), 17.20 km^2 became bare land, and 8.22km^2 became agricultural area though there are also some other areas which were also turned into forest to compensate. Only 42.25km^2 of forest remained unchanged as of 2022 (**Figure 13**). Appendix 2 contains a table that summarizes the overall LULC distribution in the studied area (1992-2022).

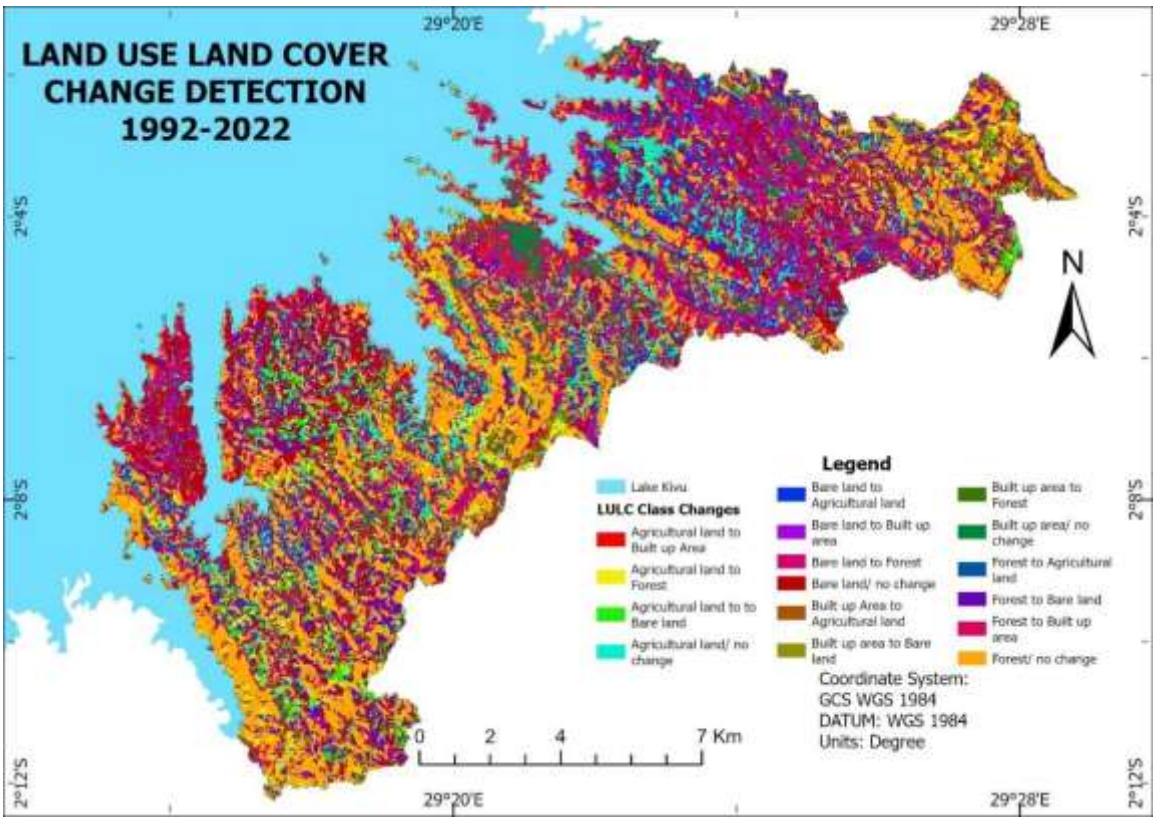

Figure 13: LULC change detection over 30 years period in the Rubengera, Bwishyura, Gishyita and Mubuga sectors (Source: Author, 2022).

4.5.1. Lake Kivu buffer zone change

Within the buffer zone of Lake Kivu, a decline in agricultural and bare land areas was observed, and the most important increase of land coverage (%) was noted for built-up areas (settlements, hotels, schools, and roads development) over the last 30 years (**Figure 14**).

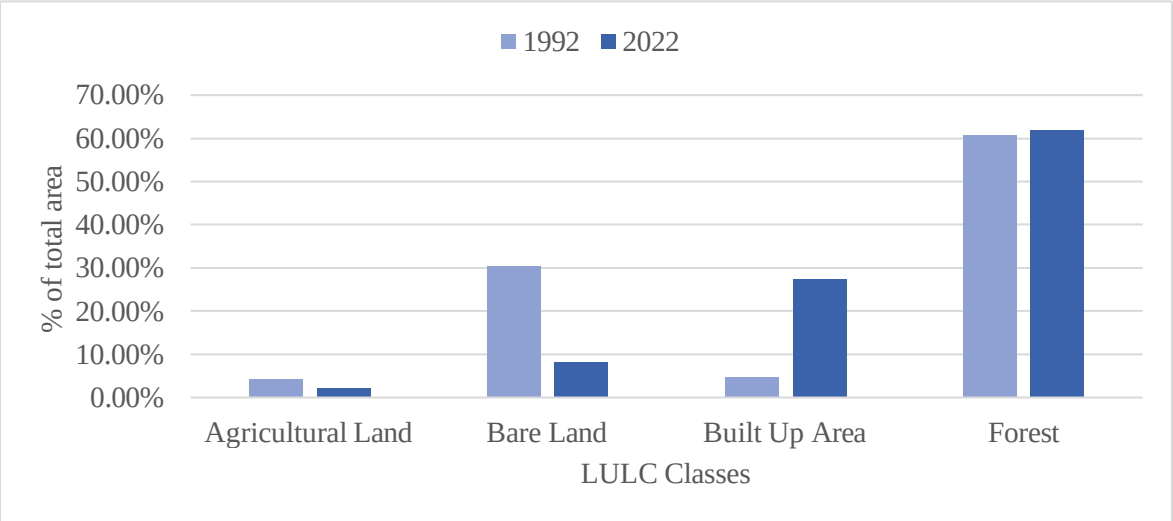

Figure 14: Changes in land use and land cover (LULC) between 1992–2022 in buffer zone.

Analysis of the LULC change over the period of 30 years shows that each class individually has changed in the biozone. When analysing how each class has changed individually, I realised that the built-up area increased by 496.77% from its initial square kilometres since 1992, forest area increased by 2.22%, and agricultural land area decreased by 48.90%, bare land area decreased by 72.83% (**Table 7** & **Figure 15**).

Table 7: The net changes of particular classes of LULC in the buffer zone.

LULC Class	**Area in km^2**	**Percent**
Agricultural Land	-0.09	-48.90%
Bare Land	-0.89	-72.83%
Built Up Area	0.92	496.77%
Forest	0.05	2.22%

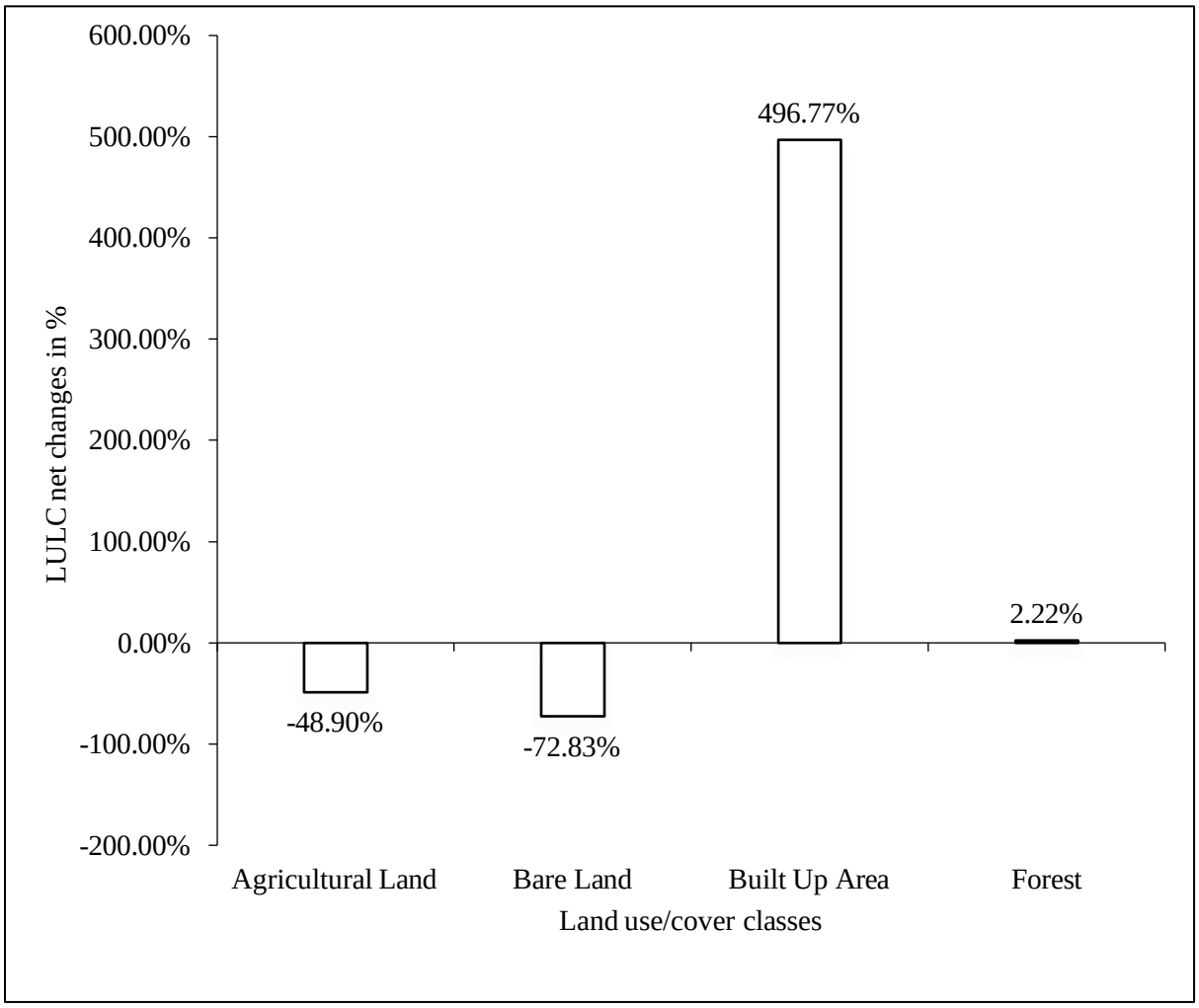

Figure 15: Net change in individual land use land cover class changes between 1992 and 2022 in the buffer zone.

CHAPTER 5. DISCUSSION

This study revealed that conflicts between humans and spotted-necked otters in Lake Kivu exist. We recorded that these conflicts are based on two main reasons: otter fish predation and fish net damage, leading to loss of harvest and damage costs. Similar conflicts have been reported in various studies in other countries (Akpona et al., 2015; Barbieri et al., 2012; Boustany et al., 2021; Ergete, Balakrishnan, et al., 2018; Ergete, Hailemariam, et al., 2018; Mcmillan et al., 2019; Rosas-Ribeiro et al., 2012). When analysing people likely to conflict with spotted-necked otters, we realized that the conflicts are significantly greater between spotted-necked otters and fish farmers than the rest of the fishermen. This is explained by the fact that all fish cages are permanently located in the same area as the otters' habitat range (near shoreline and bays), whereas other fishermen are fishing far away due to many legal restrictions, such as the legal prohibition to fish near the shore of Lake Kivu, being allowed only to fish in areas ranging from +30 m to 200 m away depending on which fish species are targeted, and being prohibited to fish in aquaculture concession areas (GoR, 2020). Foraging of spotted-necked otters is known to occur within 2-10 m of the shore (Kruuk & Goudswaard, 1990; Lejeune, 1989; Lejeune & Frank, 1990; Rowe-Rowe & Somers, 1998).

As a result, there weren't many respondents from fishermen who experienced otter attacks as most of them fish for sambaza (*Limnothrissa miodon*), and it's illegal to fish in bays. Their fishing zone extends more than 200 m from the shore (GoR, 2020); thus, less exposure to otters. Other large fish species (e.g., haplochromis, tilapia, and clarias) that fishermen expected to be near the shore were hard to obtain, and respondents in the study claimed that people do not enter that profession because the harvest is insignificant. Lake Kivu is known to have low fish diversity, with only 29 fish species and fishery yield is relatively low (Snoeks et al., 2012) compared to more than 300 fish species in Lake Victoria for example (Kruuk & Goudswaard, 1990).

Various studies have shown that spotted-necked otters, including those in Rwanda, prefer small fish (under 15 cm total length) as they are easier prey than large ones, preferably Haplochromis species, even though they eat large fish as well (*Clarias gariepinus and Oreochromis niloticus*) (Lejeune, 1989; Lejeune & Frank, 1990; Reed-Smith et al., 2021).

Despite the fact that research in Lake Muhazi, Rwanda, revealed that *Haplochromis* species dominated the diet of spotted-necked otters (Lejeune, 1989; Lejeune & Frank, 1990), it was

later contrasted after discovering that nile tilapia (*Oreochromis niloticus*) is also an important component of the diet after Haplochromis spp. (Kruuk & Goudswaard, 1990). Furthermore, informants (fishermen and fish farmers) mentioned during this study that the spotted-necked otters forage on a fish species called *Lamprichthys tanganicanus* (Rwanda Rushya), but this needs to be confirmed by a scientific study. It appears that otter diet preferences are subject to change as new exotic fish species are introduced and alter the food web. This occurred in Lake Victoria, where the spotted-necked otter was able to adapt to a new diet that replaced haplochromines following the introduction of nile tilapia (*Oreochromis niloticus*) (Kruuk & Goudswaard, 1990).

Though otters prefer small sized fishes, this research showed that fish cages containing juveniles are the ones that are not attacked by otters. According to the informants (fish farmers), otter predation and damage occurred between 17h:00 and 00h:00 and early in the morning, between 03:30 and 06:00, and is more common in bad weather. These times correspond exactly to the official fishing hours in Lake Kivu, which are from 5 p.m. to 7 a.m. (GoR, 2020) and there is less human disturbance on the side of fish culture areas during that time.

A large percentage of respondents (82.4 %, n=17) attribute all the losses (fish and property) to spotted-necked otters. However, it has been reported by a few people that other species, primarily birds, sometimes contribute to fish loss and damage, though the impact is reported to be insignificant by the respondents. This is not new information, as numerous studies have shown that in some European countries, great cormorants (*Phalacrocorax carbo*) and other birds have damaged fish farms more than otters (Barbieri et al., 2012; Kranz, 2000; Rauschmayer et al., 2008; Vaclavikova et al., 2011).

Based on the nature of conflict existing between Lake Kivu spotted-necked otters and humans, and the fact that there are currently no tangible solutions to mitigate the conflicts, otters are often trapped and killed as self-defence during fish predation and damages in aquaculture areas. If this conflict issue is not given the attention it deserves, it could cause fishermen and fish farmers to change their attitude and try to kill otters at large because it was reported that normally this interference of otters in fisheries is one of the factors motivating otter killings and sentiments to exterminate them (Ergete, Hailemariam, et al., 2018; Rosas-Ribeiro et al., 2012). The more people are concerned or care for otters, the more negative their attitude toward reducing otter numbers will be (Natalija et al., 2018). People develop negative attitudes about conservation because of wildlife damage and losses (Sifuna, 2010).

On the other hand, freshwater organisms are known to have long provided medicinal, veterinary, and pharmacological products (Lynch et al., 2023). While many informants in this study (42.3 %) stated that they don't know or see any value in otters, others repeatedly claimed to be aware of their importance, particularly for medicinal use of otter skin and excrement. This is likely to increase the chances of otter hunting for those services, even though I did not hear about any intentional otter hunting for this purpose during the study. Since 50 years, the trade of otter pelts has been forbidden in Rwanda, so the hunt has declined (Lejeune & Frank, 1990).

During our study, most people showed a positive attitude toward spotted-necked otters and their conservation where 54% of all respondents (n=26) answered 16 out of 19 attitude statements in a positive way. However, 57.7% of respondents (n=26) said that if a spotted-necked otter repeatedly causes damage to their fish farm or fishing net, they would agree with killing that animal, 53.8% believe that spotted-necked otters reduce fish populations to unacceptable levels, and 61.5% believe that there are too many spotted-necked otters in Lake Kivu, and they are a great danger to the balance of water organisms. The most conservation preoccupation discovered from this study is that all people interviewed (stakeholders, fish farmers, and fishermen) are at the same level of attitudes toward spotted-necked otters and their conservation (P=0.118). This highlights the importance of initiating conservation efforts and awareness among all stakeholders. However, people who had some knowledge about otters and acknowledge their values at least were the ones to exhibit a positive attitude toward spotted-necked otters (P=0.000). Hence, knowledge and awareness are key to the success of conservation of Lake Kivu spotted-necked otters. Similar scenario was discussed and concluded in research by Torkar et al. (2010) where people with greater knowledge had more positive attitudes toward otter conservation. Further deep research is recommended to determine other factors influencing people's attitudes (Torkar et al., 2010).

People's perceptions following Spotted-necked otter damage and predation are that spotted-necked otter population might have changed (increased), and some respondents recommended that otters be gathered in one place and managed in captivity or introduce another animal which can prey on otters for ecological balance. Otherwise, a compensation plan would be put in place, just like it is for other wild animals that damage crops and other property.

5.1. The spotted-necked otter as a bio-indicator of a healthy Lake Kivu ecosystem

When asked what people know about otters, all of the fish farmers and fishermen interviewed said that they are the first fish predators ever seen and praised spotted-necked otters for their hygienic behaviour of never eating and defecating in the water, thereby not polluting their water habitat. The only factor that has been observed to cause otters to bring their prey to the shore is when they catch larger fish that are difficult to eat in water (Kruuk & Goudswaard, 1990; Lejeune & Frank, 1990).

The respondents may have recognized a characteristic of otters: they are generally only found in areas with clean, unpolluted water, unsilted water, undisturbed bankside cover, and a sufficient food supply, and the opposite causes otter populations to disappear (Foster-turley et al., 1990; Reed-Smith et al., 2021). As a result of the spotted-necked otter being at the top of the food chain in Lake Kivu and living in those habitat conditional requirements, their presence in and around Lake Kivu indicates that the ecosystem is healthy.

5.2. Spotted-necked otter habitat range is under increasing human pressure

Potential factors in the decline of the otter population include accidental net drownings, pollution, habitat deterioration, and a reduction in the availability of food (Kruuk & Goudswaard, 1990). The first studies done in Rwanda on the distribution of Spotted-necked otter revealed that the unbroken vegetal cover along the shores, the absence of crocodiles, and, of course, the ban on pelt trading were the major factors for sustaining or even growing the populations of spotted necked otters in Rwanda (Lejeune, 1989; Lejeune & Frank, 1990).

However, the above should not be the case now, after more than 30 years, considering the results obtained from this research showing how the land cover has changed in the zone close to Lake Kivu. The greatest threat to otter habitat in the study area, including the buffer zone, is the significant increase of area occupied by infrastructure (**Figure 16**) and installations above lake surface waters. For instance, now the littoral zone of Karongi district is occupied by 91 fish cages, with 75 in the Bwishyura sector, around 15 hotels alongside Karongi lake shore, residential settlements, gas extraction facilities, and constructed roads.

Figure 16: Built up area in the buffer zone of Lake Kivu (Source: Author, 2023).

Lakeshores have always been a preferred location for human settlement and other human activities (Liddle & Scorgie, 1980; Ostendorp et al., 2004), leading to shoreline development and the degradation of lakeshores (Brauns et al., 2007). Human population growth and rapid urbanization of rural areas are also increasing development pressure on lake shores (Wehrly et al., 2012).

All those infrastructures and residential buildings in our study area have the potential to cause vegetation cover destruction, conversion, and loss along the shore, water pollution via wastewater discharges and sewage, aquaculture wastes, and other different human disturbances such as recreational beaches and erosion control structures along the shore (**e.g., Figure: 17**), as consequence contributing to the decline of Lake Kivu spotted-necked otters. In fact, the law n°48/2018 of 13/08/2018 on environment prohibits the following activities: to build an agricultural and livestock installation at a distance of fifty meters (50 m) away from the lake banks; to build in lakes and in the buffer zone at a distance of fifty meters (50 m) away from lakes (GoR, 2018). though the people are doing the opposite

Figure 17: Photos describing how Lake Kivu shoreline areas are converted day by day in the Bwishyura sector (Source: Author, 2023).

All these changes in land use and land cover especially the high increase of built-up area (e.g., +496.77% of built-up area in buffer zone since 1992) are associated with the human population growth in Rwanda and in the area of study specifically, which results in increasing demands for food (e.g., aquaculture expansion), energy (e.g., methane gas extraction for electricity and cooking), recreation and tourism (e.g., hotels, restaurants, beaches), and living spaces. The Fifth Rwanda Population and Housing Census (RPHC5) done in 2022 revealed that the Rwandan population went from 7,157,551 in 1991 to 13,246,394 in 2022 (National Institute of Statistics of Rwanda (NISR), 2023). The population growth was only slow between 1991 and 2002 (7,157,551–8,128,553), reflecting the high death toll of the 1990 war and the 1994 genocide against Tutsi, but between 2002 and 2012 and 2012 and 2022, the population growth was 8,128,553–10,515,973 and 10,515,973–13,246,394, respectively. These statistics are reflected in land use and land cover changes in our study area (**Figure 18&19**). These increasing demands due to increased human population cause changes in land cover, which

have a negative impact on the natural environment (Furgała-Selezniow et al., 2022). Figure 18 shows results from the National Institute of Statistics of Rwanda (NISR), (2012, 2023): population increase occurred in Karongi district between 2012-2022, and four sectors in proximity to shoreline (Rubengera, Bwishyura, Mubuga and Gishyita) were ones with high percentage of population increase (16% or above). These four sectors in lake shoreline zones alone contributed 58% of the whole total population increase in the district.

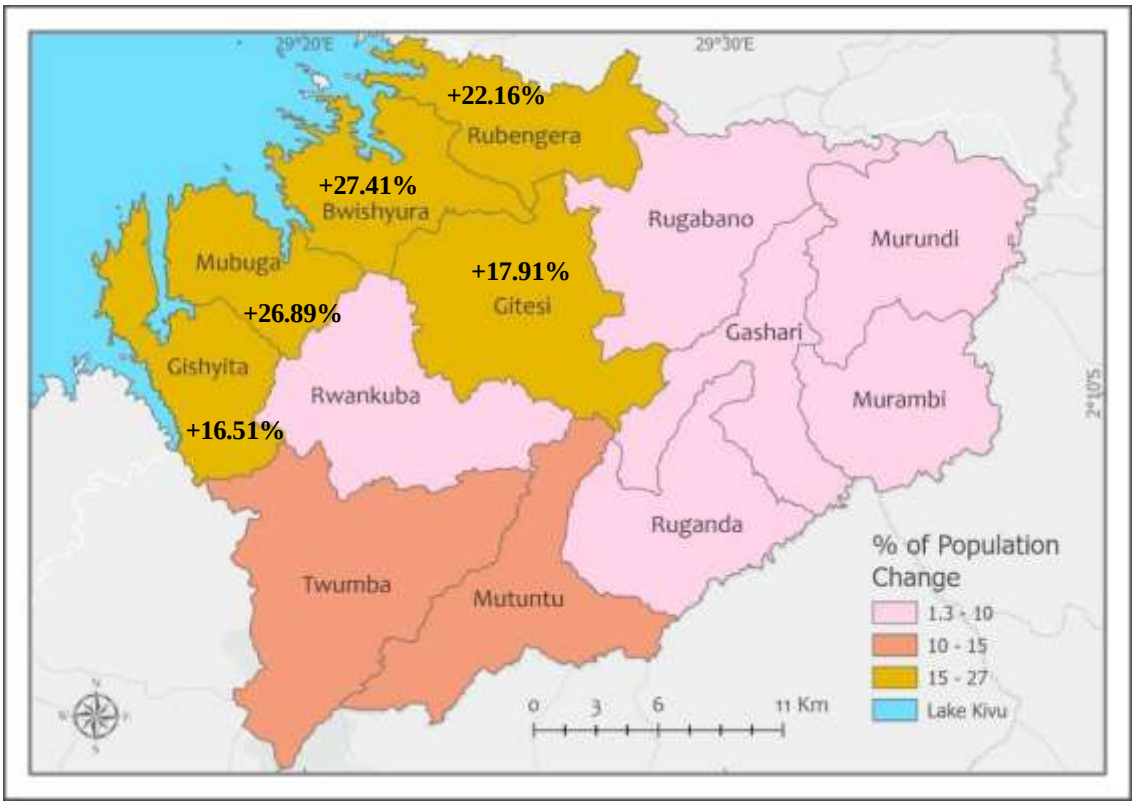

Figure 18: Population change between 2012 and 2022 by sector in Karongi district [Map source: Author, 2023; (National Institute of Statistics of Rwanda (NISR), 2012, 2023)].

Human population growth has already been identified as a potential threat to spotted-necked otters in research conducted in Rwanda in 1989, and competition for fish resources is only expected to increase. Hunts and killings due to fish net damages and fish predation caused by otters are happening, as well as clearing of shoreline cover and transformation of wetlands, which occur frequently and lead to the disappearance of otters' refuge (Lejeune, 1989). In regions where studies have been conducted about spotted-necked otter, otter populations have been declining in areas of increased human population and presence (Reed-Smith et al., 2021).

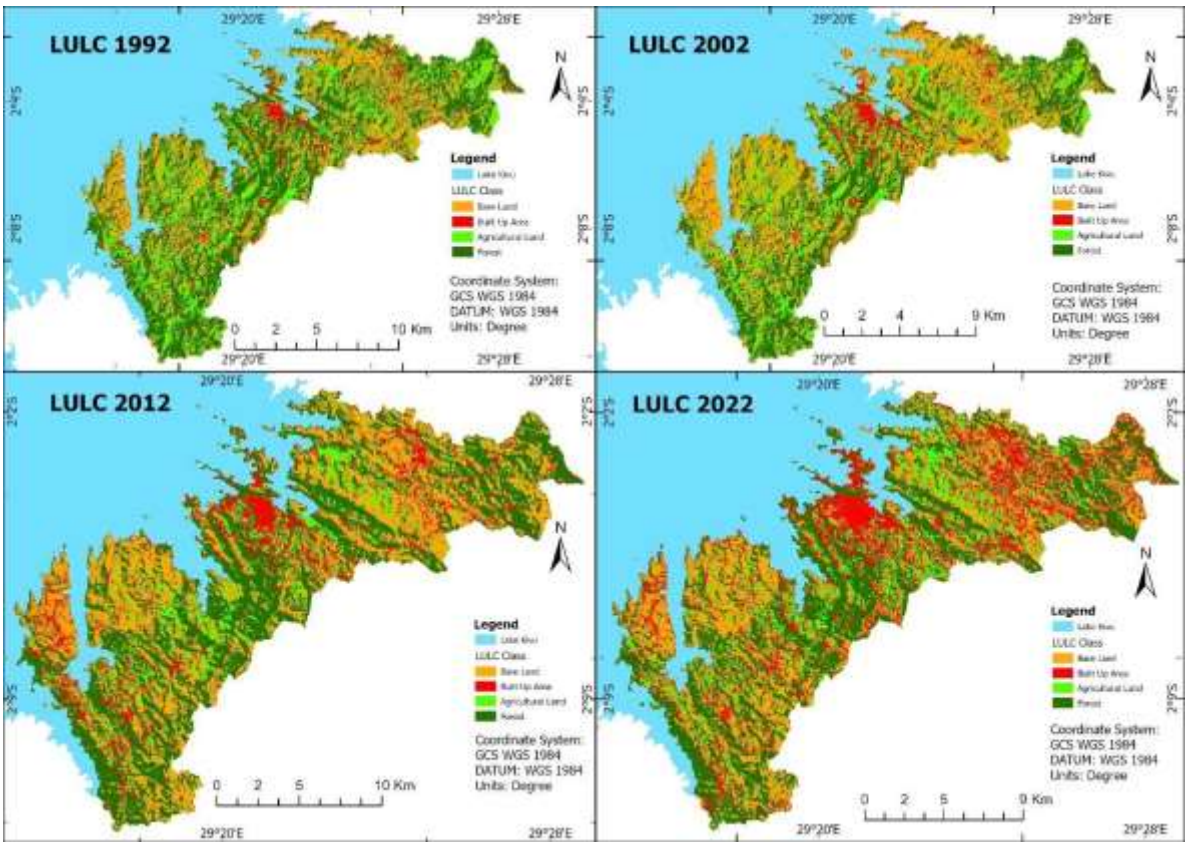

Figure 19: Map correlating land use and land cover (LULC) changes with population growth in Rwanda (Author and National Institute of Statistics of Rwanda (NISR), 2023).

CHAPTER 6. CONCLUSION and RECOMMENDATIONS

This study discovered that there are conflicts between humans and spotted-necked otters in Lake Kivu. These conflicts are caused by two main factors: otter fish predation and net damage, resulting in harvest losses and damage costs. The cost of fish loss exceeds the cost of net damage. According to the research informants, spotted-necked otters prefer the fish *Lamprichthys tanganicanus* (Rwanda Rushya) to the haplochromines and nile tilapia reported 30 years ago as the dominant diet for spotted-necked otters. This is related to how the food web is changing as a result of newly introduced fish species.

The only fish cages that are not attacked by otters are those containing juveniles. The best times for spotted-necked otter fish predation and damage were reported to be in the evenings and early morning hours. In addition, they frequently attack fish cages in bad weather according to the informants. As a result, the spotted-necked otter is the dominant predator in both the terrestrial and aquatic environments of Lake Kivu though some bird species were also reported but with minor impact. Consequently, all fishermen and fish farmers sought a compensation plan, as is provided when other wild animals cause damage to crop and other property around national parks.

Based on the fact that no fisherman who respected the official fishing zones had their nets or fish catches attacked by otters, this study reveals that compliance with the law regulating aquaculture and fisheries in Rwanda (ministerial order no. 001/11.30 of 11/12/2020 regulating aquaculture and fisheries) should be a win-win solution to both the mitigation of conflicts between fishermen and spotted-necked otters and enhance coexistence, and the conservation of reproduction areas. This study found no differences in attitudes toward spotted-necked otters and their conservation among fishermen, fish farmers, and other stakeholders interviewed, implying that all groups of people should have the same level of awareness about otters and their conservation needs. However, this research revealed again that the more people are aware of otters and their values, the more they have a positive attitude, which confirmed that a lack of knowledge and awareness is behind all the threats spotted-necked otters are undergoing.

Based on the results of the interviews, this study concluded that the spotted-necked otter can be used as a bio-indicator species for a healthy freshwater ecosystem. This emphasizes how considering it as a flagship species of Lake Kivu will be advantageous to promote a healthy lake ecosystem.

The spotted-necked otters' habitat range (shoreline zone) is changing as a result of increased human population in the area leading to natural habitat conversion and loss. Consequently, it may lead to their decline in the future if nothing is done to protect shoreline habitat, and the sectors bordering Lake Kivu were found to be under greater human pressure than the other Karongi sectors. In terms of biodiversity conservation and protection, the Bwishyura sector requires more attention. All the above contrast what was said in the last three decades ago by Lejeune & Frank (1990) that the unbroken vegetation cover along the shores contributed to the wellbeing and population increase of spotted necked otters in Rwanda.

Besides human population growth, other prevalent threats encountered are based on (1) tradition such as using body parts and fur of otters for medicinal uses, (2) attacks by setting traps by fish farmers who see them as fish eaters and damaging nets, (3) meat consumption as few of informant confirmed eating them. No otter hunting case was recorded in this study.

Based on a literature review for this study, there is still a gap in African freshwater biodiversity, with otters, for example, never being taken into account among other freshwater species in order to develop conservation strategies and have a picture of the overall ecology and conservation status of freshwater ecosystems. This poses a significant threat to them as well as the entire ecosystem.

Recommendations

i. A complete study on the status and distribution of otters in Rwanda is needed.
ii. The focus of much past work in Rwanda and the region has been terrestrial biodiversity. However, freshwater is the most threatened ecosystem. There is a clear need for a stronger focus on freshwater biodiversity as well.
iii. We can stop otter decline through education, training, awareness, and research.
iv. All categories of people (illiterate, educated, young, adults, fishermen, fish farmers, and other stakeholders) need the same level of awareness about otters and their conservation needs.
v. More efforts in the enforcement of environmental laws and regulations are needed.
vi. Enforcing and regulatory authorities to conduct compliance audits against environmental laws and regulations, share findings, come up with corrective actions and improvement opportunities, and ensure the closure of non-compliant findings.

vii. Enforcing and regulatory authorities to conduct regular environmental monitoring, inspections, and audits against their specific EIA requirements for high-scale development projects located on the Lake Kivu shore zone. This should happen throughout all project implementation phases (ex: construction, commissioning, operation, and decommissioning).

viii. During shoreline development, avoid hard seawalls at the shoreline and adopt a bioengineering approach instead. Bioengineering uses native plants, biodegradable materials, and sometimes rock to recreate a stable shoreline that mimics natural shorelines.

ix. Preserve the function of the shoreline by respecting the buffer zone boundaries as stipulated by the law, regardless of the significance of the development project to come.

x. The state should add otters found in Rwanda to the list of animal species that must be protected. This is referred to in the law no. 48/2018 of August 13, 2018, on the environment, which states that in order to protect biodiversity, the state has the obligation to establish a list of species of animals and plants that must be protected depending on their role in ecosystems, their scarcity, their aesthetic value, their threat to extinction, and their economic, cultural, and scientific roles.

xi. From the respondents to avoid conflict with otters, it was found helpful to stay away from the otter-dominated littoral zones when doing their fishing activities. In addition, using a security guard for day and night shifts, having a schedule for cage inspections and maintenance, and using strong and high-quality materials for their cage fish farms have been supportive. Everyone has learned to add one more layer with a strong net protecting the inner net carrying fishes and the top of the cage is covered by an additional net to prevent bird attacks.

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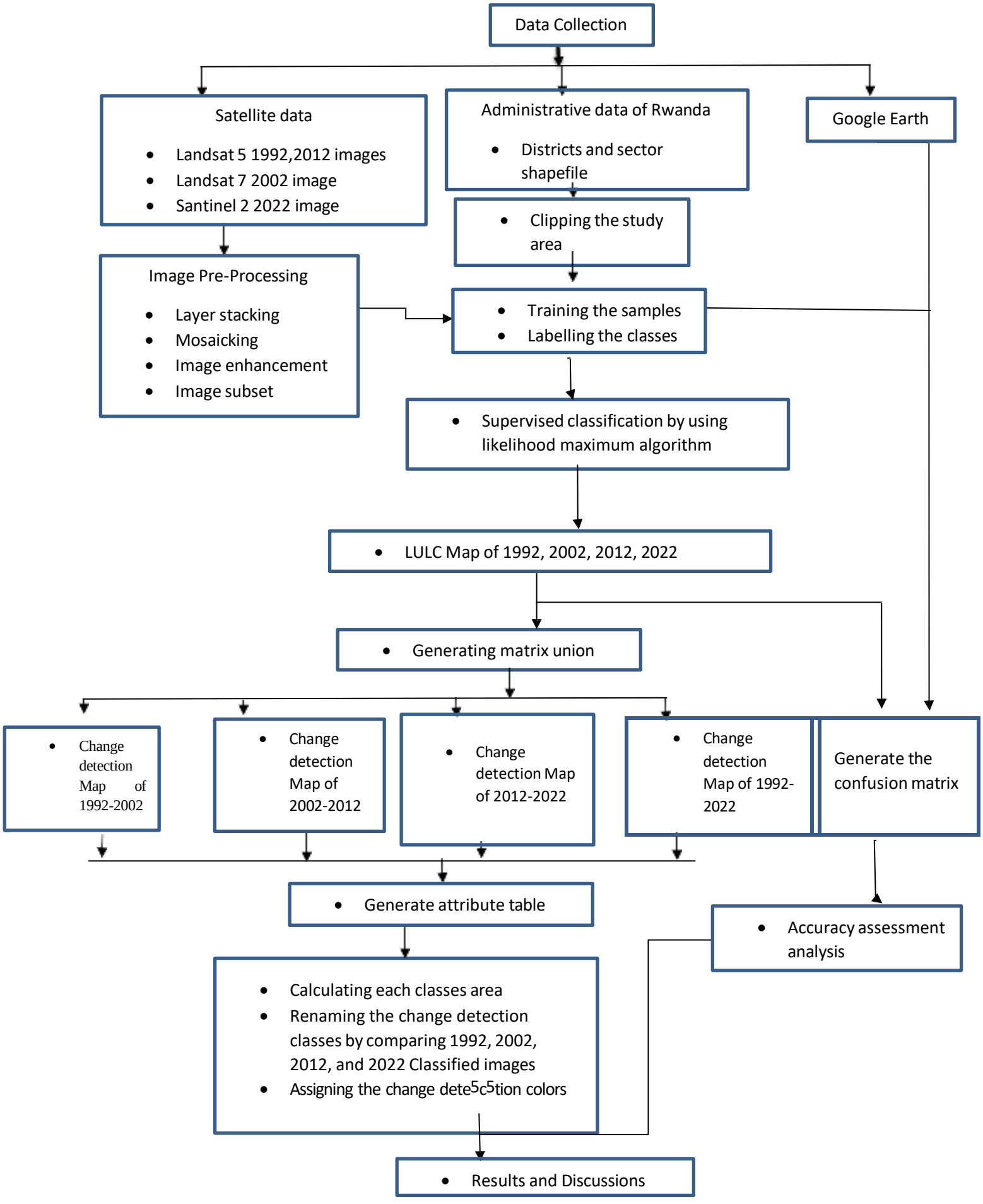
APPENDICES

Appendix 1: Schematic diagram for LULC change detection from 1992-2022.



Appendix 2: Overall LULC distribution in the studied area (1992–2022).

LULC Class	1992		2002		2012		2022	
	Area in sq. km	Percentage	Area in sq. km	Percentage	Area in sq. km	Percentage	Area in sq. km	Percentage
Agricultural Land	33.40	18.81%	33.50	18.87%	17.29	9.74%	24.41	13.75%
Bare Land	51.32	28.91%	66.56	37.49%	60.51	34.08%	48.77	27.47%
Built Up Area	12.13	6.84%	15.42	8.69%	21.87	12.32%	38.00	21.40%
Forest	80.68	45.44%	62.05	34.95%	77.86	43.86%	66.35	37.37%
Total	177.53	100.00%	177.53	100.00%	177.53	100.00%	177.53	100.00%