A COMPARATIVE STUDY ON THE FISH SPECIES COMPOSITION, DIVERSITY AND CATCH RATES AMONG THE FISHERIES RESERVES ON THE ZAMBEZI AND KWANDO RIVERS, ZAMBEZI REGION

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ABSTRACT

The Zambezi and Kwando Rivers in northeastern Namibia support vital floodplain fisheries that provide food, income, and seasonal employment for many local communities. However, increasing pressure from overfishing, habitat degradation, and climate change has highlighted the need to establish fisheries reserves to promote sustainable resource use. This baseline study evaluated fish assemblages, specifically species composition, diversity, and catch per unit effort (CPUE); across five fisheries reserves located along the Zambezi River (Sitwela, Kabweza, and Makangala) and the Kwando River (Luhingi and Qhuqhumupa). Gillnet surveys using both experimental and monofilament gillnets were conducted between 13 November and 13 December 2021. A total of 3,360 individual fish, representing 32 species, were captured. On the Zambezi River, Makangala had the highest species richness with 24 species, followed by Sitwela with 21 species, and Kabweza with 20. On the Kwando River, Luhingi recorded 17 species, while Qhuqhumupa had 12. There was no statistically significant difference in species diversity among the reserves ($H_{(4)}$=8.268, p=0.082). However, overall CPUE (by weight) varied significantly between sites ($H_{(4)}$=46.621, p<0.001), with Luhingi showing the highest CPUE (0.704±0.78 kg/set) and Kabweza the lowest (0.209±0.14 kg/set). Significant differences in individual CPUE were observed for two commercially important species: *Clarias gariepinus*($H_{(4)}$=26.783, p<0.001) and *Clarias ngamensis* ($H_{(4)}$=17.967, p=0.001), while no significant variation was found for *Serranochromis macrocephalus* ($H_{(3)}$=0.260, p=0.967). Similarly, mean fish sizes for *C. gariepinus* ($H_{(4)}$= 25.850, p<0.001) and *C. ngamensis* ($H_{(4)}$=14.660, p=0.005) differed significantly across sites, whereas no difference was noted for *S. macrocephalus* ($H_{(3)}$=0.779, p=0.885). Regression analysis showed that temperature had no effect on fish catch rates. However, reserve size explained 14% of the variation in catch rates. These spatial differences in catch rates for key commercial species may be influenced by factors such as the degree of protection, age, and size of the reserves. In particular, higher CPUEs in the Kwando River reserves may be attributed to stronger protection measures and longstanding conservation awareness compared to the more recently established reserves along the Zambezi River. These findings underscore the need for tailored, site-specific management strategies to ensure the

sustainability of fish populations across all five newly established fisheries reserves in the region.

Keywords: Fisheries Reserves, co-management, species diversity, fisheries management, baseline, assessment, Namibia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CBRM	Community Based Resource Management
CC	Community Council
CORB	Cubango-Okavango River Basin
CPUE	Catch per unit effort
DRC	Democratic Republic of Congo
FPAs	Fisheries Protected Areas
FR	Fisheries Reserve
IFC	Inland Fisheries Committee
IRI	Index of Relative Importance
KAZA-TFCA	Kavango-Zambezi Trans-frontier Conservation Area),
MFMR	Ministry of Fisheries and Marine Resources
NNF	Namibian Nature Foundation
SADC	Southern African Development Community
SD	Standard Deviation
SRM	Shared Resources Management
UNAM	University of Namibia
WWF	World Wildlife Fund

DECLARATION

I, Tukelo Lavinia Namitaa, declare that this thesis has been composed solely by myself. This study is a true reflection of my own research, and this work, or part thereof, has not been submitted for a degree in any other institution of higher education. I further confirm that appropriate recognition and credibility have been given within this thesis, where references have been made to the work previously done by others.

Signature:	Date:
Tukelo Lavinia Namitaa	Student no: 201506965

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DEDICATION

I solely dedicate this thesis and paper to the women in my life: my daughter Taya Paisley Nyambe who has always been my motivation and drive to succeeding, to my mother Ms. Mumbiya Samupwa for being a consistent supportive and dedicated believer in me and my grandmother Siniko Veronica Mainga for her humbling presence and teachings. With these people in my life, the curious and go getter in me has been able to take on challenges, encouraging me to become better for them as well as for myself, to build a better future, and a role model to look up to.

1. Introduction

1.1. Background of the study

Freshwater bodies are essential environments that serve as habitats for numerous living organisms (containing a biodiversity of flora, fauna, and microorganisms) (Dudgeon *et al.*, 2006) and provide essential ecosystem services to the adjacent human communities and wildlife, including the provision of water, nutrition, building material, and aesthetics (Palmer *et al.*, 1997). However, the global deterioration of freshwater resources is alarming. Freshwater biodiversity has experienced a steep decline, with wildlife populations decreasing by 83% since 1970; this decline is twice that recorded for marine and terrestrial ecosystems (Acreman *et al.*, 2020). This significant decline is likely attributed to unprecedented human disturbances to freshwater habitats, driven by an increasing human population (Reid *et al.*, 2019). Since 1960, global freshwater withdrawals have nearly doubled to meet the demands of irrigation, industry, and domestic needs, posing a severe threat to freshwater resources (Saunders, Meeuwig and Vincent, 2002). Similar to other parts of the world, natural resource use in Africa is characterised by overexploitation and unsustainable patterns, complicating efforts to achieve sustainable resource management (Malzbender and Earle, 2009).

Demand is the primary driving force behind nearly all activities, including fisheries (Welcomme *et al.*, 2010). As the global human population increases, so does the demand for food, leading to increased inland fish catches (Tran *et al.*, 2022). Although inland fisheries may not significantly impact the global economy, they are indispensable to riverine communities (Bakane, 2017). There is a growing trend towards discovering and adopting newer, efficient methods for exploit fish resources

and their supporting freshwater ecosystems, often without sustainable practices in place (Cooke *et al.,* 2023). This negatively affects vulnerable communities that depend on fish resources, which are particularly vulnerable to sudden changes in the economy and society. Inland fisheries in Namibia are intricately linked to the livelihoods of floodplain communities and are challenging to manage, particularly along the Zambezi, Chobe, Kwando and Kavango Rivers (Hay, 2022). Fisheries provide food security and income, particularly for women and children in poor riverine areas (Tweddle 2010). Management challenges arise from factors such as overgrazing, irrigation projects, illegal fishing, siltation, and shared fisheries with neighbouring countries, many of which are beyond the control of Namibia's Ministry of Fisheries and Marine Resources (MFMR) (Abbott *et al.,* 2007; Tweddle *et al.,* 2015; Hay, 2022).

The livelihood of the Zambezi Region is characterised by its inhabitants' combined dependence on farming, fishing, livestock, and other off-farm activities (Abbott *et al.* 2007). Fishing contributes mainly to the livelihoods of the local people by providing daily protein and income (Tvedten, 2002). It is important to note that the fisheries of the Zambezi and Kwando Rivers share resources with their neighbouring countries, namely Botswana and Zambia, due to an increase in the population on both sides of the rivers, especially on the Zambian side, and there has been evidence that the rivers are under pressure due to overfishing (Abbott and Campbell, 2009).

At the global level, fisheries reserves, often referred to as fish sanctuaries or protected areas have emerged as critical tools in the management of overexploited fish stocks, the degradation of coral reefs, and the restoration of aquatic ecosystem resilience (Arthington *et al.,* 2016; Kenchington, Kaiser and Boerder, 2018; Eddy *et*

al., 2021). Reserves function by limiting extractive activities in specific river or marine zones. Their usefulness has been demonstrated through increased fish abundance, increased body size and trophic level, improved biomass and catch rates resulting to spillover effects to adjacent areas (Gell and Roberts, 2003; Stobart *et al.,* 2009). The principles of Community-Based Fisheries Management (CBFM) or blue economy is not a new theme in Africa, as the rural communities faced with the reality of climate change effects and the depleted fisheries resources they have long engaged. For instance, Kenya, CBFM has contributed to the fish stock recovery, economic resilience and community cohesion (Otundo, 2024). In Tanzania, the communities have been at the forefront of policy making and implementation of co-management strategies for small-sized fisheries (Allegretti, 2019).

Southern African countries, including Malawi, Zambia, and Botswana, have adopted transboundary co-management approaches for shared river systems like the Upper Zambezi and Okavango Delta, in collaboration with local communities and regional conservation initiatives (Cumming, 2008; Wolski *et al.,* 2009; Msukwa, 2010; Paisley and Curlier, 2019). In Namibia, the establishment of fisheries reserves has been a response to both declining fish stocks and increased exploitation pressures on floodplain river systems (Hackenberg *et al.*, 2022). The aim has been to rebuild fish biomass, protect biodiversity, sustain the livelihoods of riverine communities by promoting responsible access thereby enabling the communities to lead in the management of their natural resources (Ministry of Fisheries and Marine Resources, 2011; Mufune, 2015; Abbott *et al*., 2007).

1.2. Statement of the problem

There is an alarming decline in the fish stock of Namibian freshwater bodies, and in response, the Ministry of Fisheries and Marine Resources (MFMR) in conjunction with the Namibian Nature Foundation (NNF) has initiated the establishment of fisheries reserves on the Zambezi and Kwando Rivers, with the intent of mitigating the impact of overexploitation and implementing co-management strategies. However, there is currently no baseline study on fish species composition, species diversity, and catch rate statuses of these reserves since their establishment in order to determine whether they are well-positioned to fulfil their intended objectives of enhancing fish stocks of commercially important species. This study seeks to fill this gap by assessing and determining the baseline fish species composition, species diversity and catch rate of the five newly established fish reserves on the Zambezi River (Sitwela and Makangala) and Kwando River (Kabweza, Luhingi and Qhuqhumupa).

1.3. Research objectives

The specific objectives of this study are to:

a) Compare fish community structure among the newly established fisheries reserves.
b) Compare species diversity among newly established fisheries reserves.
c) Compare species composition among newly established fisheries reserves.
d) Compare the catch rates (CPUE) of the monofilament gillnets among the fisheries reserves, both for all species combined and for the three commercially important species (i.e., *Clarias gariepinus, Clarias ngamensis,* and *Serranochromis macrocephalus)* among the reserves.

e) Compare the mean sizes of three commercially important species (i.e., *Clarias gariepinus*, *Clarias ngamensis*, and *Serranochromis macrocephalus)* among the reserves.

f) Determine the influence of temperature on the catch rates (CPUE) of three commercially important species (*Clarias gariepinus, Clarias ngamensis*, and *Serranochromis macrocephalus* among the reserves.

g) Determine the influence of reserve size on the catch rates (CPUE) among the reserves.

1.4. Null hypothesis

H_{o1}: The fish community structure is similar among the newly established fisheries reserves.

H_{o2}: There are no significant differences in species diversity among the fisheries reserves.

H_{o3}: There are no significant differences in catch composition among the fisheries reserves.

H_{o4}: There are no significant differences in catch rates (CPUE) among the fisheries reserves, both for all species combined and for the three commercially important species(i.e., *Clarias gariepinus, Clarias ngamensis*, and *Serranochromis macrocephalus*) among the fisheries reserves.

H_{o5}: There are no significant differences in mean fish sizes of the three commercially important species (i.e., *Clarias gariepinus, Clarias ngamensis*, and *Serranochromis macrocephalus*) among the fisheries reserves.

H_{o6}: There is no influence of temperature on the catch rates of the three commercially important species (i.e., *Clarias gariepinus*, *Clarias ngamensis* and *Serranochromis macrocephalus*)

H_{o7}: Reserve size has no influence on catch rates (CPUE) of reserves.

1.5. Significance of the study

This study examines and compares fish assemblages among fisheries reserves to determine progress toward achieving the intended goal of fish sustainability and identify any changes. This information will ensure sustainable utilisation of fish stocks, management, and guide the milestones for the establishment of fisheries reserves in the region.

2. Literature review

2.1. Global status of freshwater fisheries

Global inland capture fisheries have experienced steady growth, with the latest annual catches of 11.3 million tonnes, representing 11–13 % of the total global fisheries catch reported in 2022 (Funge-Smith, 2018; FAO, 2024). The Asian region leads 7.1 million tonnes of inland fishery catch, accounting for 63% of the total, with China alone contributing 20% (Funge-Smith, 2018). Africa ranks second to Asia, with a higher catch per capita contributing 3.3 million tonnes (29.4%), primarily from the African Lakes region (FAO, 2024). The American continent's catch is estimated to be 346 thousand tonnes (3.7%), while the European regions contribute 392 thousand tonnes of catches (3.5%) (FAO, 2024). Oceania's catch is largely confined to Papua New Guinea, New Zealand, Australia, and Fiji, and the Arabian region has a limited reported inland fishery catch of 17 thousand tonnes (0.1%) (Funge-Smith, 2018; FAO, 2024). In 2015, global inland fishery production reached 11.47 million tonnes, equivalent to the full dietary animal protein of 158 million people (Funge-Smith, 2018; Hara and Njaya, 2016) and decreased to 11.3 million tonnes in 2022 (FAO, 2024). The estimated use value of inland freshwater fisheries, including hidden catches, is approximately USD 38.53 billion (Funge-Smith, 2018; FAO, 2020, 2024).

2.2. Inland fisheries in Africa

Africa's 63 river basins span over 54 political boundary countries (Ashton and Turton, 2009), which requires significant strategic considerations for the sustainable utilisation of freshwater resources (Reid *et al.*, 2019). African freshwater systems are diverse and encompass habitats, such as lakes, rivers, and associated floodplains, and

are essential for water, food, and other necessities (Malzbender and Earle, 2009; McIntyre, Liermann and Revenga, 2016). People living near rivers, fishers, and those connected to them take pride in their way of life, integrating it into their traditions, practices, and customs and forming a key part of their identity (Noble *et al.*, 2016; Kpenou, 2018). The benefits of consuming fish are well known, as they are rich in high-quality protein, essential fatty acids, and vital micronutrients such as calcium, iron, zinc, phosphorus, vitamin A, B-complex, and D, which are crucial for maintaining good health, especially the nutritional needs of growing children and pregnant women in the marginalised communities of Africa (Ngwenya, Mosepele and Magole, 2012; Roos, 2016). Furthermore, fishing is a key component of subsistence activities, supporting 75% of households across Africa (Turpie *et al.*, 1999).

African countries import 74% of their fishery products from other continents, with Asia and Europe contributing to 31% and 29% of imports, respectively. Intercontinental imports within Africa account for 26% of fishery product trade (FAO, 2024). Countries producing at least 50-75% of the continent's high output (3.3 million tons) include Chad, the Democratic Republic of the Congo (DRC), Niger, Sudan, Tanzania, Uganda and Nigeria (FAO, 2024). Uganda was ranked the 6th country globally to produce 445 000 tons of inland fisheries landings in 2022, followed by Tanzania (403 000 tons), Nigeria (355 000 tons), Egypt (343 000 tons), DRC (266 000 tons), and Malawi (187 000 tons). However, data on this sector remain limited, highlighting the need for more effective monitoring and management (FAO, 2024). Lake Victoria is estimated to produce one million tonnes annually (Kolding, Van Zwieten and Mosepele, 2016). Furthermore, fish consumption in

Malawi has been reported to decrease by 60% due to the decline in high-value species (Hara and Njaya, 2016).

The inland fisheries market include species such as *Rastrineobola argentea* "Dagaa" a pelagic, freshwater ray-finned fish from lake Victoria and Lake Malawi and this product is traded and processed as animal feed in Tanzania and Kenya (Funge-Smith, 2018; FAO, 2020); another marketed species is the 'Kapenta' (*Limnothrissa miodon* and *Stolothrissa tanganicae*) from the lakes of Tanganyika, Kariba, Cahora Bassa and Kivu (Kolding, Van Zwieten and Mosepele, 2016). Additionally, large species of economic importance, such as *Oreochromis andersonii, Coptodon rendalli,* and *Oreochromis macrochir*, are largely targeted and traded by small-scale fishers in the Zambezi and Okavango Rivers (Peel, 2012; Simasiku, 2019).

Despite the importance of inland fisheries in Africa, excessive fishing pressure in river systems has historically resulted in the collapse of valuable fisheries, which either further degrades the food web or hurts on the ecosystem (Allan *et al.*, 2005; Welcomme *et al.*, 2010). In Africa, examples include Lake Kariba, where overfishing has resulted in fishing efforts exceeding the recommended level threefold, leading to a decline in the Lake Tanganyika sardine (*Limnothrissa miodon*) (Magadza, 2011; Marshall, 2021). Likewise, in Lake Malawi, overfishing has been linked to the collapse of the chambo (tilapia) and cyprinid fisheries (Jamu *et al.*, 2011).

2.3. Inland fisheries in southern Africa

Inland fisheries are major economic drivers in Southern African Development Community (SADC) markets. In particular, informal fish trade in Zambia is a major player, with many of its fish exports directed to the Democratic Republic of the

Congo (DRC) (Funge-Smith, 2018; Funge-Smith and Bennett, 2019). In Zambia, approximately 70 000 people rely on the Barotse floodplain fisheries in the western province of Zambia for food, employment, and income (Kolding, Van Zwieten and Mosepele, 2016). The productivity of this vital area is closely linked to seasonal flooding, which is essential for supporting local agriculture and fisheries (CGIAR, 2013; Cooke *et al.*, 2023).

In 2015, Mozambique and Zambia landed approximately 80 000 tonnes, which later rose to 129 000 tonnes and 109 000 tonnes, respectively, by 2022 (FAO, 2024). In the same year, Angola, Zimbabwe, and Namibia recorded landings of 38 514, 10 500, and 2 800 tonnes, respectively, whereas South Africa, Botswana, Eswatini, and Lesotho combined landed at less than 1 000 tonnes (FAO, 2018, 2020). Lake Malawi, which produces approximately 44 000 tonnes of fish annually, is shared by Malawi, Mozambique, and Tanzania (Weyl, Ribbink, and Tweddle, 2010). Similarly, Lake Kariba has been estimated to produce at least 30 000 tonnes of fish, supplying the Zambia and Zimbabwean fisheries markets (Marshall, 2021). Although these fisheries are crucial, several southern African countries have reported a steep and alarming decline in commercially important species such as the African Tigerfish (*Hydrocynus vittatus)*, the three Cichlids *O. andersonii, O. macrochir*, and *C. rendalli* in the Zambezi River (Simasiku, 2019; Jacobs *et al.*, 2022), and *L. miodon* in Lake Kariba (Marshall, 2021).

2.4. Status of inland fisheries in Namibia

Namibia is known to be a semi-arid country with only a limited number of perennial rivers, namely, the Chobe, Kavango, Kwando, Kunene, Orange and Zambezi Rivers which are shared with neighbouring countries such as Angola, Botswana, South

Africa, and Zambia (Curtis *et al.*, 1998; Gonzo, 2021). These rivers serve as water sources, nurturing floodplains, wetlands, and ephemeral lakes in the northeastern, northern, central, and southern regions (Naesje *et al.*, 2004; 2007; Simasiku, 2019). These rivers also serve as a source of income and employment, which supports the basic needs of rural communities, such as food, clothing, school fees, and health services and most of all; it also ensures that community members have access to fresh, nutritious food (Tall and Failler, 2015, Gronau, Winter and Grote, 2020). This highlights the need for sustainable fisheries management to support the well-being of riverine communities, as the value of inland fisheries in Namibia is estimated to be N$ 109 million, surpassing the value of game and trophy hunting (Forsythe, Letley and Turpie, 2018).

Namibia's inland fisheries are also characterised by a number of constructed state-owned dams, the Hardap and Neckartal dams found along the Fish River, the Von Bach dam, Omatako dam, and Swakoppoort dam found in Otjozodjupa Region, and the Naute dam in the Karas Region. The Hardap and Naute dams supply Namibia's mainland for human consumption and irrigation in agricultural green schemes (Lillie and Steyn, 2014). Moreover, central regions like Grootfontein and Otavi have caves and sinkholes, which are home to some of Namibia's unique and endangered fish species, including the blind catfish, *Clarias cavernicola*, and the Oshikoto tilapia (*Tilapia guinasana*), both endemic and crucial for conservation efforts (van Der Bank, 2019; Jacobs *et al.*, 2021).

2.5. Inland fisheries of the Zambezi region

The Zambezi Region, formerly known as the Caprivi Region, is located in the northeastern part of Namibia. It is home to the Zambezi/Chobe and Kwando/Linyanti

Rivers which contain diverse aquatic ecosystems such as open waters, rapids, sand bars, marginal vegetation, backwaters, temporal/seasonal and permanent *Mulapos* (standing water bodies), pans, and floodplains (van der Waal, 1996; Turpie *et al.*, 1999; Abbott and Campbell, 2009). Zambezi fisheries are segmented into commercial, recreational, and subsistence fisheries and are considered a major contributor to northeast inland fisheries. The subsistence fisheries sector is primarily composed of landless labourers, small-scale farmers, women, and children (Simasiku 2019). In contrast, commercial fisheries involve relatively larger, yet small-scale operations focused on harvesting fish for profit rather than personal consumption. Recreational fisheries, on the other hand, are predominantly characterised by tourist anglers engaged in sports fishing (Tweddle and Hay, 2011; Tweddle, 2017). Subsistence fishers employ various gear such as traps, spears, hook and line, weirs, scoop baskets, and gillnets, adapting to changes in the water level (Hay *et al.*, 2002). Commercial fisheries use modern gear, such as monofilament nets and drag nets. The rod and reel are mostly used by recreational anglers (Tweddle and Hay, 2011a; Tweddle *et al.*, 2015).

In the early 1980s, the catch per unit effort of 772 600 kg was estimated, with an estimated 466 active fishermen in 1980 on the Zambezi, Chobe floodplains, Liambezi Lake, Kwando and Linyati Rivers (van der Waal, 1990). Tweddle and Hay (2011a) estimated that the entire Zambezi Region's floodplains would yield over 6000 t/year. Fishing is of socio-cultural status in Zambezi region, often expressed as “If you don’t fish, you are not Caprivian” as emphasised by Tvedten (2002). The fish sold at the Katima Mulilo Open market originate from 25 different areas of the Zambezi River, highlighting the diverse and extensive reach of inland fisheries

(Simasiku, 2019). Because many landing sites are in remote areas, catches frequently go unrecorded and are primarily consumed locally (Simasiku, 2019).

Furthermore, Zambezi fisheries also include migrant fishers who encroach on the river system to satisfy the high fish demand in the urban areas of neighbouring countries, such as Zambia and the DRC (Abbott *et al.,* 2007; Tweddle *et al.,* 2015). Migrant fishers compete with local fishers who rely on fish for food security as a vital component of their livelihoods (Tweddle *et al.,* 2015; Simasiku, 2019; Cooke *et al.,* 2023). Fishery in the Zambezi Region focuses on specific fish species, primarily from the Cichlidae family, driven by demand in local and regional markets (Peel, 2012; Simasiku, 2019; Hay *et al.*, 2020). There is an increasing trend towards commercialisation, which contradicts *Namibia's Inland Fisheries White Paper*, which emphasises that inland fish should primarily serve subsistence purposes to benefit local communities (Béné, Macfadyen and Allison, 2007). This commercialisation has led to an increase in fishing activity over the years, contributing to the decline of the target fish species (Heider, 2012; Peel, 2012).

Lastly, natural resources such as aquatic foods (fish, water lilies, and other traditional foods), reeds, water, and timber from the Zambezi River sustain the livelihood of many people in the region (World Bank, 2010). Rivers play a crucial role in providing employment and income to households situated on and near floodplains (Naesje *et al.*, 2000; Abbott *et al.*, 2007; Flint, 2008). In the Sikunga area, one-third of households rely primarily on fisheries for sustenance and income (Gronau, Winter and Grote, 2020). Additionally, inland fisheries serve as a more accessible and affordable protein source for poor rural communities, often preferred over livestock

and other agricultural outputs, reducing land disturbance (Purvis, 2002; Thompson *et al.*, 2002).

2.6. Threats to the fish diversity in the Zambezi and Kwando Rivers

2.6.1. Illegal fishing gears

Unsustainable fishing and non-selective gear (monofilament gillnets, mosquito nets, and dragnets) lead to the harvest of juvenile fish in the Zambezi and Kwando Rivers (Simasiku *et al.*, 2017). This reduces the recruitment of fish stocks, denying them the opportunity to replenish (Simasiku, 2019). Fish stocks in the Zambezi River are under threat due to human-induced stressors, such as increased fishing efforts, river pollution resulting from rain runoff water containing agricultural fertilisers, and fishing in closed seasons and areas (Abbott and Campbell, 2009).

2.6.2. Invasive species and the decline of economic important species

The introduction of exotic species, such as Nile tilapia (*Oreochromis niloticus*), has led to interbreeding with the native three-spot tilapia (*Oreochromis andersonii*). Crossbreeding has produced hybrids that are genetically less resilient, impacting the strength and viability of local fish populations (Hackenberg *et al.*, 2022). Another invasive species that has been observed in the upper Zambezi is the aquaculture species called the Australian Red Claw Crayfish (*Cherax quadricarinatus),* known for its high productivity and rapid reproduction within just six weeks (Tribelhorn, Merron and Hocutt, 2022). This species poses a significant threat to local ecosystems as it feeds on vegetation and fish eggs, including those of an already stressed population of tilapia. Predation disrupts the successful breeding and recruitment of native species (Tribelhorn, Merron and Hocutt, 2022).

When a fish stock collapses, undesirable species are likely to replace the niche previously occupied by collapsed species. For instance, *Synondotis* spp. has been assumed to replace Cichlidae species in the Okavango River (Kangausaru, 2018). Furthermore, *Hepsetus cuvieri* is assumed to have replaced *H. vittatus* in the habitat of the Zambezi River (Kabula-Kabula channel) (Hay *et al.*, 2002). Studies by Hay *et al.*, (2002; 2012 and 2022) have highlighted that rising fishing pressures have significantly reduced populations of economically important fish species, including *H. vittatus, O. andersonii, O. macrochir* and *C. rendalli*. This decline has consequently led to a shift in the population dynamics of river systems, with these species being replaced by smaller fish.

2.6.3. The impact of climate change on fisheries

The effects of climate change are apparent across the Zambezi Region, rendering river systems particularly susceptible to such shifts (World Bank, 2010; Beilfuss and Nhemachena, 2017). Rising temperatures, altered precipitation, and changing weather extremes contribute to significant consequences, such as irregular flooding caused by increased variability in rainfall patterns, which further impacts ecosystems and aquatic life (Tirivarombo, 2012; Chisola, 2022). Alterations in freshwater systems can result in changes in water chemistry, affecting factors such as salinity, pH, and dissolved oxygen (DO) levels (Baldwin and Fraser, 2009; Herbert *et al.*, 2015). These factors contribute to changes in fish populations, altering fish size, abundance, and species composition (Allan *et al.*, 2005).

2.7. Co-management in established fish protected areas

Namibia's efforts to combat declining fish stocks have extended beyond policy and legislation, incorporating community-based management strategies like the creation

of Fisheries Protected Areas (FPAs) (Hackenberg *et al.*, 2022). FPAs are designated aquatic zones aimed at protecting spawning grounds and nurseries for juvenile fish, ensuring undisturbed recruitment, and providing stock for neighbouring areas through migrations (Richardson *et al.*, 2010; Tweddle and Hay, 2011b). FPAs were initiated by the Namibia Nature Foundation/World Wide Fund for Nature/Ministry of Fisheries and Marine Resources (NNF/WWF/MFMR) since 2001 as part of the "Integrated Co-management project for the Zambezi/Chobe Rivers. This project aimed to promote sustainable community-managed fisheries in this region (Tweddle, 2017; Imbwae *et al.*, 2023).

In 2016, the Freshwater and Fisheries Working Group was established under the Kavango-Zambezi (KAZA) Conservation Working Group to support sustainable fish use, harmonise legislation and facilitate cross-border collaboration (Hackenberg *et al.*, 2022). The key species targeted to be replenished by these initiatives were; *Oreochromis andersonii* and *Oreochromis macrochir*, which made up to 60% of the fish locally traded from the Zambezi River and Lake Liambezi (Tweddle and Hay, 2011). These reserves include smaller pools, backwater channels, and main stretches of the river, and approximately 10 fisheries reserves have been successfully established and gazetted in the Zambezi Region (Republic of Namibia, 2003, 2015, 2020) (Table 1). Local communities play a central role in managing established fisheries reserves in partnership with conservancies and nearby lodges (Hackenberg *et al.*, 2022). This collaboration enables effective monitoring of illegal activities, fosters community engagement in conservation efforts, and promotes sustainable practices (Acreman *et al.*, 2020; Cooke *et al.*, 2023). As communities ultimately benefit from increased fish stocks and catches over time, these efforts also stimulate growth in local businesses (Cooke *et al.*, 2023).

Table 1: Gazetted Fisheries Reserves and their Conservancies (2015 and 2020) in the Zambezi Region

Year	**Number of reserves**	**Reserves (Conservancy)**
2015	2	Kasaya (Impalila), Kalimbeza (Sikunga)
2020	8	Qhuqhumupa and Kalume (Balyerwa), Luhingi (Mayuni) Lwezuba and Kabweza (Lusese), Munga, Makumbi and Nsala (Nakabolelwa)

3. Research methods

3.1. Description of the study area

This study was conducted on the Zambezi and Kwando Rivers, located in the Zambezi Region of Namibia (Figure 1). The region borders Botswana to the south, Angola and Zambia to the north, and Zimbabwe to the east. The Zambezi Region is home to two perennial rivers: the Kwando/Linyanti River to the west, and the Zambezi/Chobe River to the east.

Three selected fisheries reserves were sampled from the Zambezi River: Makangala (proposed), Sitwela (proposed), and Kabweza (gazetted) channels (Table 2). Makangala channel is located 17°40′6.46″ S and 25°5′46.86″ E in Ikaba Emerging Conservancy, directly connected to the Zambezi River and was characterised with a high concentration of submerged macrophytes such as water lilies, grass and reeds (Table 2), the channel was also observed to be most close to the Namibia-Zambia transboundary line. Sitwela Channel is located in 17°39′29.99″ S and 24°55′36.08″ E of the Nsundwa Conservancy while the Kabweza Channel is located 17°45′2.90″ S and 24°48′0.06″ E within the Lusese Conservancy, these two reserves were located in the floodplain regions of the Zambezi region, often isolated from the river during low water. They were characterized with similar vegetation structure, dense reeds along the edges and fewer lilies in the middle (Table 2).

Two other selected gazetted fisheries reserves were sampled on the Kwando River and the Qhuqhumupa and Luhingi channels. Qhuqhumupa channel is located 18°14′411″ S and 23°29′976″ E within the Balyerwa Conservancy and is characterised by dense reed beds on the edges of the channel, water lilies in the middle, and silty, turbid water. Luhingi Channel is located 17°49′463″ S and

23°20′124″ E in the Mayuni Conservancy, and this sampling site was characterised by dense reed beds and Hippo grass on the edges of the channel, as well as water lilies in the middle (Table 2).

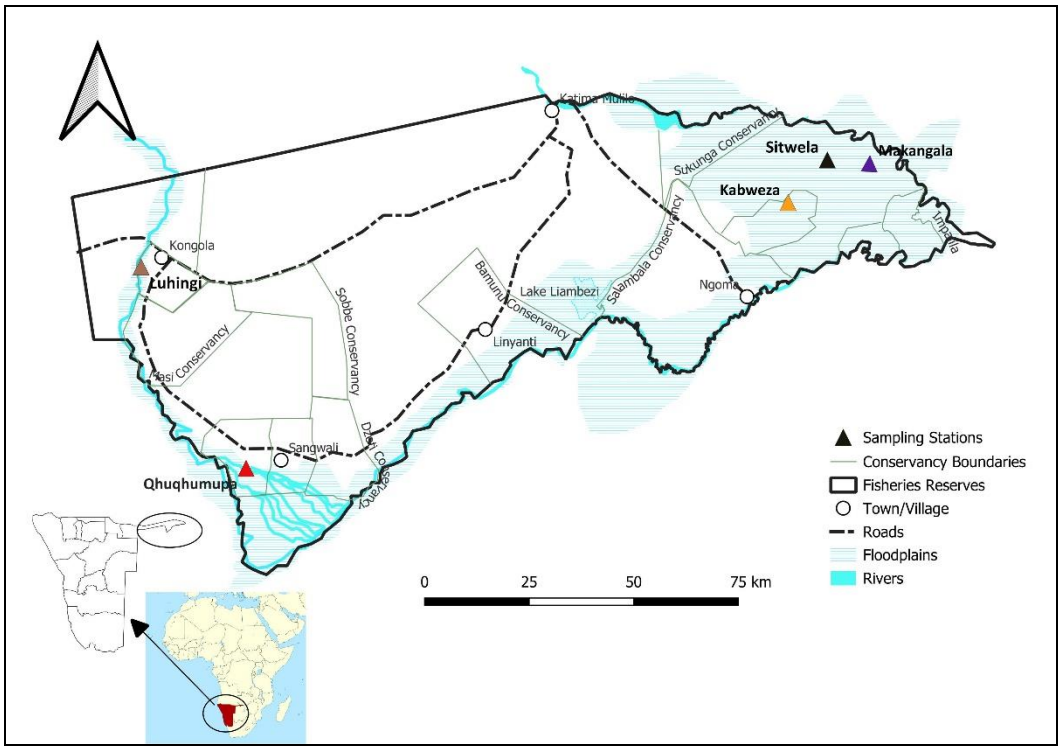

Figure 1: Map showing the sampling sites which are the fisheries reserves of the Zambezi Region sampled in November to December 2021 (QGIS ver. 3.38.0).

The Kwando River stretches through two National Parks which have been under protection by the Ministry of Environment, Forestry and Tourism since Nkansa Rupara and Mundumu National Park were gazeted in 1990, with Bwabwata National Park gazetted later in 2007. The river also falls within distinct traditional authorities and well-established conservancies of the Zambezi Region, namely; Luhingi falls in Mafwe traditional authority and Mayuni conservancy within Mundumu National Park and in proximity of the Bwabwata National Park and Qhuqhumupa reserve is located in the Mayeyi traditional authority, within the Balyerwa conservancy which is in close proximity of the Nkansa Rupara National Park.

Table 2: Descriptions (habitat and area) of the Zambezi and the Kwando River channel habitats and their respective conservancies sampled from November to December 2021.

Sampling Site	***Habitat and demarcated area***	***Conservancy name***	***River***
Kabweza	Isolated channel during low water, connected to the floodplains and river during high water Perimeter =4.9km (0.14km^2/ 14.3ha)	Lusese	Zambezi
Sitwela	Isolated channel during low water, connected to the floodplains and river during high water Perimeter =0.75km (0.03km^2/ 2.5ha)	Nsundwa (emerging conservancy)	Zambezi
Makangala	A backwater channel to the Mainstream Zambezi River Perimeter =2.83km (0.19km^2 /19.32ha)	Ikaba (emerging conservancy)	Zambezi
Luhingi	Isolated channel during low water, connected to the Kwando River by a connecting channel during high water Perimeter = 3.1km (0.29km^2/29.13ha)	Mayuni	Kwando
Qhuqhumupa	Distinctively isolated channel during low water, only connected to floodplains and tributaries that connect to the Kwando River Perimeter =0.6km (0.02km^2/2.35ha)	Balyerwa	Kwando

3.2. Flooding regimes

The topography of the Zambezi Region is flat, with an altitude ranging between 1100 m in the west and 930 m in the east. Seasonal floodwater transverses from river catchments and spreads laterally by overflow, creating a single, large floodplain in the eastern Zambezi Region (Lubbers *et al.,* 1990; Mendelsohn *et al.,* 1997). The

Zambezi/Chobe River usually reaches its peak flow between March and May, after which water recedes until the end of September. During the low water level months (November–April), the floodplains were dry and covered in terrestrial grasses.

In contrast, the Kwando River experiences shorter yet sporadic or unpredictable floods (Taylor *et al.*, 2017). Between June and August, floodwaters flow down the Kwando River and divert northeast along the Chobe River into the Linyanti Swamp, compared to the Zambezi flood, the Kwando receives small and inconsistent floods, with backwaters rarely inundated to the same extent (Taylor *et al.*, 2017). Such effects were evident in the Qhuqhumupa channel, which was observed to be completely isolated from the main Kwando River during the low water period. Silty water conditions and dense aquatic vegetation, primarily reeds and grasses.

3.3. Experimental design and data collection

A comparative, non-randomized field design was used with five distinct selected existing reserves, gillnets were set for two nights per sampling site, resulting in 10 fishing nights per trip and 20 fishing nights in two months. The field sampling was conducted from the 13th of November to 13th of December 2021. Two sets of 110 meters, multifilament experimental gillnets with variable mesh sizes (12, 16, 22, 28, 35, 45, 57, 73, 93, 118 and 150 mm) and a D-shaped scoop net with fine mesh was used to determine the catch composition among the fisheries reserves on the Zambezi and Kwando Rivers. In addition, four sets of 100 m monofilament gillnets with variable mesh sizes of 3” (inches), 3.5”, 4” and 4.5”, similar to those used by commercial fishermen on the Zambezi and Kwando Rivers, were employed to determine the catch rates of the three commercially important species of each reserve. Nets were set at 18h00 in the evening and retrieved at 06h00 the following

morning. The nets were connected in series and strategically set in shallow-vegetated backwaters at each site. The fish catches were recovered and placed in sampling bags per mesh size. Landed fish were sorted by species using the fish guides of Skelton (2001), enumerated, measured for total length or fork length to the nearest millimetre (TL or FL mm) using a meter ruler (depending on the species) and weighed whole to the nearest 0.1 grams (g) using a balance scale (inset model of the scale, and accuracy rating). The data were recorded on a spreadsheet and later computed in Excel for data analysis.

Figure 2: Sampling gear (multifilament experimental (a) and monofilament commercial gillnets (b) and D-net (c)) used for data collection during November to December 2021 sampling period in the Zambezi and Kwando rivers.

Water parameters such as temperature was recorded using a universal handheld Hach multiparameter probe at the time of net retrieval at 06h00 each morning. GPS coordinates were also captured at this time to accurately document each sampling location. To determine the size of the fisheries reserves, official gazette documents were consulted where area boundaries were legally defined. For reserves that had not yet been gazetted, area estimates were obtained directly from Namibia Nature Foundation (NNF) personnel. To verify and supplement these values, reserve

coverage was further measured using Google Earth Pro through strategic digitization of mapped boundaries.

3.4. Data analysis

3.4.1. Species composition

The index of relative importance (IRI) was used to describe the species composition of all gears combined as presented by Hay *et al.* (2002), Næsje *et al.* (2004), Peel, (2012) and calculated as:

$IRI = (\%N + \%W)\ X\ (\%FO)$

Where %N is the percentage contribution of each species by number to the total/overall catch, %W is the percentage contribution of each species by weight to the total catch, and %FO is the percentage frequency of occurrence of each species.

3.4.2. Fish species diversity

Fish species diversity of all combined gears combined was calculated using the Shannon-Wiener index of diversity (H´) to measure the number of species weighed by their relative abundances in the selected sites, expressed as:

$$H' = -\sum p_i \ln p_i$$

where p*i* is the proportion of individuals in the *i*th species. According to the Shannon-Wiener index, individuals are randomly picked from an 'indefinitely large' population and assuming that all species are represented in the sample. The Shannon diversity index is usually between 1.5 and 3.5, with a high value indicating high species diversity.

3.4.3. Catch per unit effort

The catch per unit effort (CPUE) of commercially important species caught in monofilament gillnets was defined as the weight of fish caught per gear per hour and was calculated using the following equation:

$$\text{CPUE} = \frac{C_i}{E_i}$$

Where C_i is the catch of species i (in weight) and E_i is the effort used to obtain the catch (i). CPUE was standardised to the weight per gear per hour (kg/set).

3.5. Statistical analysis

Catch rate data (CPUE) and mean size data were assessed for normality and homogeneity of variances using the Shapiro-Wilk test in (IBM SPSS version 24). The non-parametric Kruskal-Wallis *H* test was used to determine differences in fish mean sizes and CPUE among the fish reserves. In the case of significant results, a post-hoc Tukey pairwise comparison was used to determine the source of variations among the sampling sites. Species assemblage was determined using Hierarchical Cluster Analysis. All statistical analyses were performed using SPSS version 24 and Pasgear II version. 2.13 2020, Biodiversity Pro ver. 2.00 1999 and Microsoft Excel, 2016. A 95% confidence level was used for all tests. All tests were considered statistically significant at $p<0.05$.

4. Results

4.1. Fish community similarity between sampled fish reserves

The similarity in fish catch composition of all gears combined among the sampling sites based on present and absent data (*Table 3*). The following species were present at all the sampling sites*; B. lateralis, P. longicapitus, S. intermedius, C. gariepinus, Synodontis* spp., and *C. ngamensis*.

Table 3: Species list (presence and absence) for the sampled reserves using the multifilament experimental gillnets, monofilament commercial gillnets and D-nets. Species presence is indicated with a cross (X).

Taxon	Kabweza	Sitwela	Makangala	Luhingi	Qhuqhumupa
Brycinus lateralis	X	X	X	X	X
Hydrocynus vittatus			X	X	
Micralestes acutidens			X		
Coptodon rendalli	X	X	X		
Oreochromis andersonii	X	X	X		X
Oreochromis macrochir	X	X	X		
Pharynchochromis sp.	X	X	X		
Pseudocrenilabrus philander	X	X	X		X
Serranochromis angusticeps	X	X	X	X	
Serranochromis macrocephalus	X	X	X	X	
Serranochromis altus			X		
Serranochromis jallae		X		X	
Sargochromis carlottae	X			X	
Sargochromis giardi			X		
Sargochromis sp.		X			
Tilapia sparrmanii		X	X	X	X
Clarias gariepinus	X	X	X	X	X
Clarias ngamensis	X	X	X	X	X
Parauchenoglanis ngamensis			X		
Enteromius bifrenatus					X
Enteromius fasciolatus				X	
Enteromius paludinosus	X	X	X		X
Enteromius poechii	X	X	X		
Enteromius radiatus	X	X	X	X	
Labeo lunatus	X	X		X	
Hepsetus cuvieri	X	X		X	X

Mastacembelus frenatus			X		
Synodontis spp.	X	X	X		
Mormyrus lacerda			X	X	
Petrocephalus longicapitus	X	X	X	X	X
Pollimyrus castelnaui	X				
Schilbe intermedius	X	X	X	X	X
	20	**21**	**24**	**17**	**12**

Further species assemblage similarities among the five reserves from all gears used is illustrated using a dendrogram (*Figure 3*). The hierarchical cluster analysis revealed two distinct clusters, with sub-clusters of reserves according to their degree of species similarity. The closest similarity was observed between Kabweza and Sitwela, sharing 87.8% similarity, followed by Sitwela and Makangala at 75.6%, and Kabweza and Makangala at 72.7%. These three reserves on the Zambezi River are grouped into the most cohesive sub-cluster. Luhingi reserve showed a lower similarity of 64.9%, forming part of the first cluster. In contrast, the second cluster indicates that Qhuqhumupa which exhibited the lowest similarity values with all other sites by 51.8% with both Luhingi and Makangala, and around 62.5% with Sitwela—indicating a more distinct species assemblage.

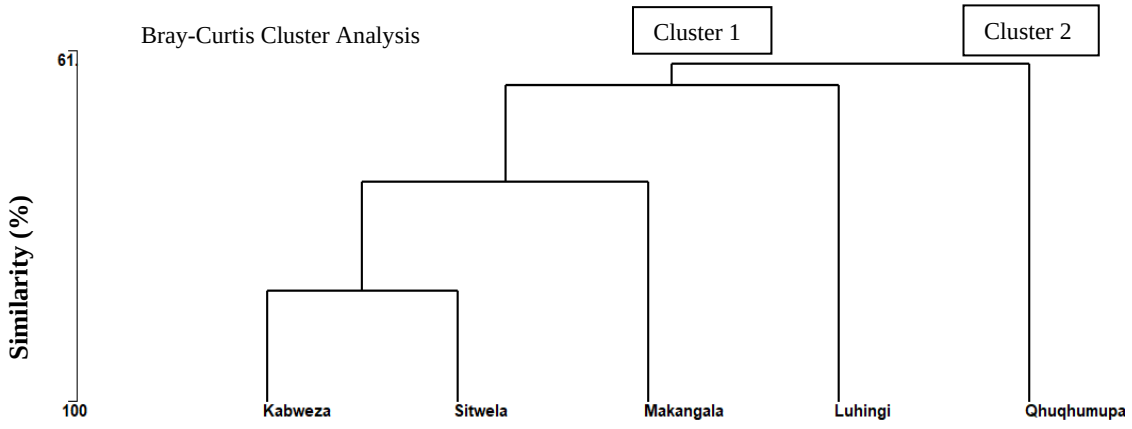

Figure 3: The fish species assemblages sampled using all sampling gears based on species presence/absence of the five sampling sites along the Zambezi and Kwando Rivers during November to December 2021.

4.2. Overall species composition

A total of 3360 fish weighing 128.07 kg, representing ten (10) families and 32 fish species, were recorded during the study period. Cichlidae (13 species) was the most diverse fish family, followed by Cyprinidae (6 species) and Mormyridae (4 species) (Table 4).

4.2.1. Species composition by sampling sites

Zambezi River

A total of 819 individual fish, representing 20 species, weighing a total of 35.3 kg, were recorded at **Kabweza**. The most important species, accounting for 84.5% IRI, were *Brycinus lateralis* (45.6%), followed by *Schilbe intermedius* (30.2%), *Clarias gariepinus* (7.7%), and *Petrocephalus longicapitus* (4.7%).

In **Sitwela**, a total of 1478 fish representing 21 species weighing a total of 27.3 kg, were recorded. The important species accounting for 87.7% IRI were *B. lateralis* (77.7%), followed by *Enteromius paludinosus* (3.7%), *S. intermedius* (3.4%) and *Synodontis* spp. (2.9%).

At **Makangala**, a total of 698 individual fish representing 24 species, weighing a total of 10.4 kg, were recorded. The most important species, accounting for 78.8% IRI, were *E. paludinosus* (57.0%), followed by *Synodontis* spp. (12.2%), *Micralestes acutidens* (5.6%), and *Serranochromis altus* (4.0%), respectively.

Kwando River

A total of 138 fish representing 17 species weighing a total of 40.6 kg were sampled at **Luhingi**. The most important species, accounting for 92.3% IRI, were *Schilbe intermedius* (47.2%), followed by *C. gariepinus* (21.1%), *C. ngamensis* (9.8%), and *H. vittatus* (7.6%).

A total of 227 individual fish representing 12 species weighing a total of 14.5 kg were sampled at **Qhuqhumupa**. The important species accounting for 92.3% IRI were *E. paludinosus* (46.2%) followed by *C. gariepinus* (29.0%), *C. ngamensis* (15.0%) and *S. intermedius* (4.5%).

Table 4: Species composition in number (No), weight (W) and index of relative importance (%IRI) for all fish sampled in gears combined, at Kabweza, Sitwela, Luhingi, Makangala and Qhuqhumupa channels on the Zambezi River and Kwando Rivers in November and December 2021.

Taxon	Zambezi River									Kwando River					
	Kabweza			Sitwela			Makangala			Luhingi			Qhuqhumupa		
	No	W (kg)	% IRI	No	W (kg)	% IRI	No	W (kg)	% IRI	No	W (kg)	% IRI	No	W (kg)	%IRI
ALESTIDAE															
Brycinus lateralis	439	5.24	45.6	1120	7.39	77.7	16	0.02	2.3	3	0.01	0.6	16	0.02	2.3
Hydrocynus vittatus							1	0.10	0.1	7	2.34	7.6			
Micralestes acutidens							98	0.20	5.6						
CICHILIDAE															
Coptodon rendalli	11	1.39	1.6	5	0.97	0.5	1	0.61	0.5						
Oreochromis andersonii	15	2.89	1.5	14	2.41	1.7	2	0.60	1.1				1	0.06	0.1
Oreochromis macrochir	15	2.76	1.4	3	0.48	0.2	2	0.46	0.8						
Pharynchochromis sp.	11	0.22	1	7	0.25	0.2	2	0.02	0.1						
Pseudocrenilabrus philander	1	0.00	0	10	0.03	0.2	3	0.01	0				3	0	0.1
Serranochromis angusticeps	1	0.15	0	2	1.42	0.2	3	0.47	0.9	1	0.46	0.3			
Serranochromis macrocephalus	7	2.35	1.7	7	2.10	1.5	4	0.77	2.8	2	0.56	0.8			
Serranochromis altus							4	2.32	4.0						
Serranochromis jallae				1	0.28	0				3	0.16	1.1			
Sargochromis carlottae	1	0.07	0							2	0.37	0.3			
Sargochromis giardi							1	0.18	0.2						
Sargochromis sp.				1	0.17	0									
Tilapia sparrmanii				27	0.31	1.1	17	0.24	2.9	2	0.01	0.2	4	0.06	0.5
CLARIIDAE															
Clarias gariepinus	10	11.75	7.7	5	4.58	1.5	1	1.58	1.3	25	23.06	21.1	12	7.22	29
Clarias ngamensis	1	0.18	0	5	2.70	1.4	2	0.88	0.8	12	10.56	9.8	12	6.1	15
CLAROTEIDAE															

Parauchenoglanis ngamensis							1	0.02	0						
CYPRINIDAE															
Enteromius bifrenatus													8	0	0.7
Enteromius fasciolatus										7	0	0.7			
Enteromius paludinosus	7	0.05	0.1	90	0.38	3.7	367	0.71	57.0				137	0.33	46.2
Enteromius poechii	27	0.25	1.8	5	0.04	0.1	3	0.01	0.1						
Enteromius radiatus	3	0.01	0.1	20	0.04	0.3	25	0.03	1.4	6	0.01	1.8			
Labeo lunatus	13	0.00	0.1	26	0.01	0.1				22	0.01	2.2			
HEPSETIDAE															
Hepsetus cuvieri	3	0.69	0.5	16	2.02	2.3				2	0.31	0.6	2	0.09	0.3
MASTACEMBELIDAE															
Mastacembelus frenatus							1	0.00	0						
MOCHOKIDAE															
Synodontis spp.	15	0.91	2.0	60	0.54	2.9	53	0.42	12.2						
MORMYRIDAE															
Mormyrus lacerda							11	0.13	0.5	2	0.69	0.9			
Petrocephalus longicapitus	86	0.78	4.7	22	0.25	1.1	24	0.14	3.8	7	0.35	4.2	6	0.16	1.2
Pollimyrus castelnaui	4	0.1	0												
SCHILBEIDAE															
Schilbe intermedius	149	5.60	30.2	32	1.01	3.4	5	0.04	0.3	33	1.61	47.2	25	0.48	4.5
Total number and weight (kg)	**819**	**35.30**		**1478**	**27.34**		**698**	**10.36**		**138**	**40.55**		**227**	**14.52**	
Total species		**20**			**21**			**24**			**17**			**12**	

4.3. Species diversity

4.3.1. Species diversity of all species caught in experimental gillnets among the fisheries reserves.

There was no significant difference in the species diversity index between fish caught using all three sampling gears among the fisheries reserves ($H_{(4)}$= 8.268, p=0.082). The median species diversity values recorded were as follows: Makangala channel (1.79 ± 0.38 SD), Kabweza channel (1.32 ± 0.50 SD) and Sitwela channel (1.25 ±0.58 SD), Luhingi channel was (1.40 ± 0.11 SD) and Qhuqhumupa channel (0.90 ± 0.34 SD). Although there was no statistical differences it important to note that the highest diversity was within the Zambezi river (Makangala reserve) while the Kwando river (Qhuqhumupa reserve) had lower species diversity.

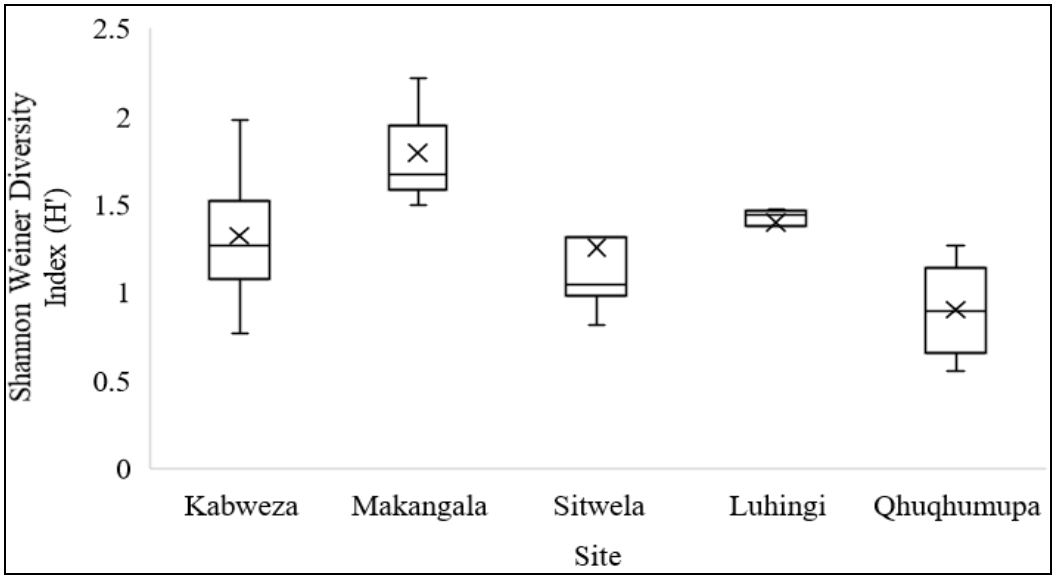

Figure 4: Fish species diversity (H') of all gears combined among the fisheries reserves on the Zambezi and Kwando River. Note: Middle bar represents median value, boxes represent the lower (25%) and upper (75%) quartiles, and whiskers represent the lowest and highest H' and x indicates the mean.

4.4. Catch Per Unit Effort of all species combined in monofilament gillnets

There was a significant difference in the CPUE of all species combined in the monofilament gillnet catches among the sampled sites ($H_{(4)}$=46.621, p<0.001). The highest CPUE was recorded in the Luhingi (0.704 ± 0.78 SD) and Qhuqhumupa channels (0.480 ± 0.215 SD) in Kwando, followed by the Makangala channel (0.372 ± 0.35 SD), Sitwela channel (0.312 ± 0.28 SD), and Kabweza (0.209 ± 0.14 SD) in the Zambezi River. Turkey pairwise test indicate that there was a significant difference in catch per unit effort between Kabweza and Luhingi (H=-77.262, p<0.0001), between Luhingi and Sitwela (H=66.521, p<0.0001), between Makangala and Luhingi (H=53.395, p=0.005), between Qhuqhumupa and Kabweza (H=-60.082, p<0.001), and between Sitwela and Qhuqhumupa (H=49.341, p=0.014). However, there was no difference between Makangala and Qhuqhumupa (H=-366.214, p=0.447) and between Qhuqhumupa and Luhingi (H=17.180, p=1.000).

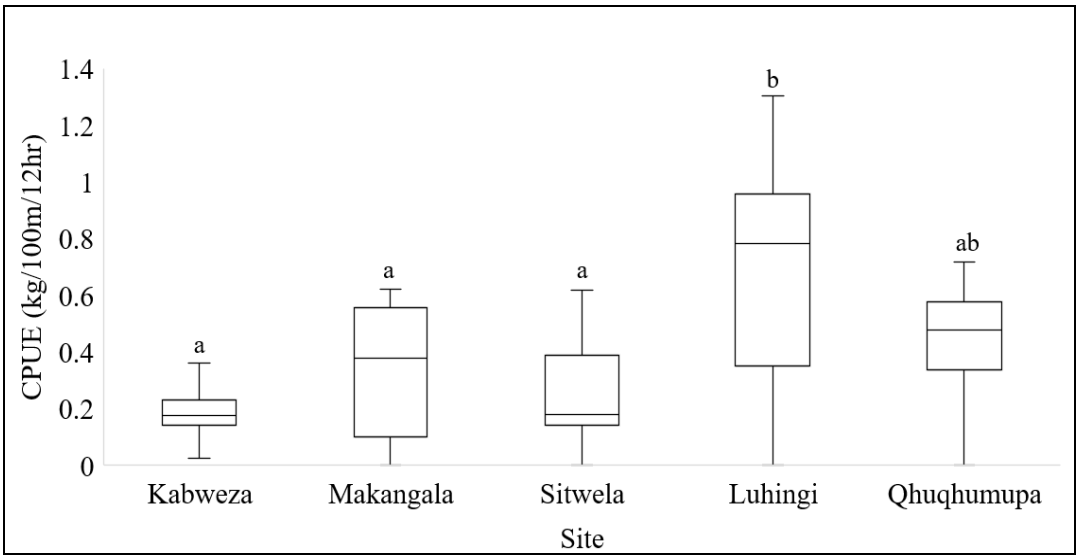

Figure 5: Catch per unit effort (kg/set) of fish sampled with the monofilament gillnets at different sites on the Zambezi and Kwando Rivers from November and December 2021. Note: X indicates the mean.

4.4.1. Individual catch rates (CPUE) and mean length of the three commercially important species in monofilament gillnets.

4.4.1.1. Individual catch rates (CPUE) and mean length of the three commercially important species in monofilament gillnets.

The catch rates of these three commercially important species are listed in Table 4. There was a significant difference in the CPUE of *Clarias gariepinus* (H (4)=26.783, p<0.001) among the sampling sites (Table 5). The highest CPUE of this species was reported at Sitwela (1.053 kg/100m/12hr), Luhingi (0.883 kg/100m net/12hr) and Kabweza (0.451 kg/100m net/12hr), and the lowest median CPUE in weight was recorded at Qhuqhumupa (0.416 kg/100m/12hr). Turkey pairwise test indicate that there was a significant difference in catch per unit effort of this species between Kabweza and Luhingi (H=-22.160, p<0.005), Kabweza and Sitwela (H=-23.200, p<0.005) and between Qhuqhumupa and Luhingi (H=19.160, p<0.005) (Table 5). However, there was no difference between Kabweza and Makangala (H=-38.000, p=0.116) or between Luhingi and Makangala (H=-15.840, p=1.000).

Similarly, there was a significant difference in CPUE of *C. ngamensis* among the sampling sites ($H_{(4)}$=17.967, p=0.001) (Table 5). The highest CPUE of this species was reported at Luhingi (0.780 kg/100m net/12hr) followed by Qhuqhumupa (0.513 kg/100m net/12hr), Makangala (0.437 kg/100m net/12hr) and the lowest was recorded in Sitwela (0.397 kg/100m net/12hr). Turkey pairwise indicates a difference between Qhuqhumupa and Luhingi (H=-10.723, p=0.047) and between Luhingi and Sitwela (H=-14.442, p=0.028). Nonetheless, there was no difference between Kabweza and Makangala (H=-5.000, p=1.000), between Luhingi and Makangala

(H=18.042, p=0.094), between Kabweza and Sitwela (H=-8.600, p=1.000), between Kabweza and Luhingi (H=-23.042, p=0.149). However, there was no significant difference in the CPUE in weight for *S. macrocephalus* observed among the sampling sites ($H_{(3)}$=0.260, p=0.967).

Table 5: Catch-Per-Unit-Effort (CPUE) in weight (kg/set ± standard deviation) of *Clarias gariepinus*, *Clarias ngamensis*, and *Serranochromis macrocephalus* from the monofilament gillnets sampled in November to December 2021. Different letters denote significant differences (ANOVA, p≤0.05)

	Kabweza	Sitwela	Makangala	Luhingi	Qhuqhumupa	**p-value**
Clarias gariepinus	0.412±0.12[a]	1.053±0.35[b]	0.158*[ab]	0.883±0.26[b]	0.416±0.22[a]	**<0.001**
Clarias ngamensis	0.177*[a]	0.397±0.37[a]	0.438±0.02[a]	0.780±0.26[ab]	0.513±0.09[a]	**0.001**
Serranochromis macrocephalus	0.315±0.16	0.177±0.18	0.340±0.14	0.280±0.10	-	**0. 967**

* - only one individual caught

4.4.1.2. Mean length of the three commercially important species in monofilament gillnets.

The mean length of *C. gariepinus* was significantly different among the reserves of the Zambezi and Kwando Rivers ($H_{(4)}$=25.850, p<0.0001) (Table 6). The highest mean length of this species was caught at Luhingi channel (486.8 ± 48.2 mm SD) on the Kwando River. and Sitwela (482.6 ± 56.0 mm SD) in the Zambezi River. Only one specimen was caught in Makangala and hence could not be considered for statistical comparisons. Turkey pairwise indicates that there was a difference between Kabweza and Luhingi (H =-23.936, p<0.0001), between Kabweza and Sitwela (H=-24.756, p=0.019), between Qhuqhumupa and Luhingi (H=15.658, p=0.048).

Similarly, there was a significant difference in the mean length of *C. ngamensis* collected from the fisheries reserves of the Zambezi and Kwando Rivers ($H_{(4)}$=13.179, p=0.010). Although the Kruskal–Wallis test showed a significant difference, the Tukey pairwise test indicated that there was no significant difference among the sampled reserves. However, there was no significant difference in the mean length of *S. macrocephalus* sampled from the fisheries reserves of the Zambezi and Kwando Rivers ($H_{(3)}$=0.779, p=0.885).

Table 6: Mean length (± standard deviation) and length range *Clarias gariepinus, Clarias ngamensis* and *Serranochromis macrocephalus* sampled in the Zambezi and Kwando Rivers using the monofilament gillnets in November to December 2021. Different letters denote significant differences (ANOVA, p≤0.05)

	Clarias gariepinus		***Clarias ngamensis***		***Serranochromis macrocephalus***	
	Mean Length (mm)	Length range (mm)	Mean Length (mm)	Length range mm)	Mean Length (mm)	Length range mm)
Qhuqhumupa	415.1±55.2[a]	355-522	420.6±51.9	380-556	-	-
Kabweza	372.0±35.0[a]	317-425	210.0*	210.0*	260.0±37.7	221-301
Luhingi	486.8±48.2[ab]	384-630	466.2±51.9	420-531	260.0±36.1	235-286
Makangala	560.0*[a]	560.0*	375.0*	375*	263.0±32.5	240-286
Sitwela	482.6±56.0[ab]	419-560	400.0*	357-510	240.0±45.0	188-310
p-value	**<0.0001**		**0.010**		**0.855**	

* - only one individual caught

4.5. Water temperature-catch per unit effort relationship

There was a significant difference between the temperatures recorded among the fisheries reserves ($H_{(4)}$= 175.188, p<0.0001) in the Zambezi and Kwando Rivers (Table 7). The highest temperature was recorded at Sitwela (26.66 ± 1.34 °C)

followed by Luhingi (25.69 ± 0.48°C), Makangala (25.48 ± 0.54°C), Qhuqhumupa (25.13 ± 0.41°C) and the lowest at Kabweza (24.75± 0.65°C).

Turkey pairwise indicates that there was a significant difference in the temperature recorded between Qhuqhumupa and Kabweza (H =58.048, p<0.001); Kabweza and Luhingi (H =-80.194, p<0.001); Makangala and Kabweza (H =-115.286 p<0.001); Kabweza and Sitwela (H=-137.000, p<0.0001). However, there was no significant difference in between Luhingi and Makangala (H=-35.014, p=0.188), between Qhuqhumupa and Luhingi (H=-22.034, p=1.000), between Makangala and Sitwela (H=-21.361, p=1.000).

Table 7: Water temperature recorded among the fisheries reserves on the Zambezi and the Kwando River, sampled in November and December 2021 (mean ± SD). Different letters denote significant differences (ANOVA, p≤0.05).

	Zambezi River			**Kwando River**		
	Makangala	Sitwela	Kabweza	Qhuqhumupa	Luhingi	**p-value**
Temperature (°C)	25.48 ± 0.54[a]	26.66 ± 1.34[ab]	24.75± 0.65[c]	25.13 ± 0.41[d]	25.69 ± 0.48[ad]	**<0.0001**

4.5.1. Correlations between temperature and catch rates of all species caught in monofilament gillnets.

The results showed that there was no significant relationship between temperature and CPUE (F, (1, 198) = 0.011, P = 0.916) with R^2= 0.000. The fit relationship (R^2) is 0.000 which means that there is no influence of temperature on the significant changes in CPUE.

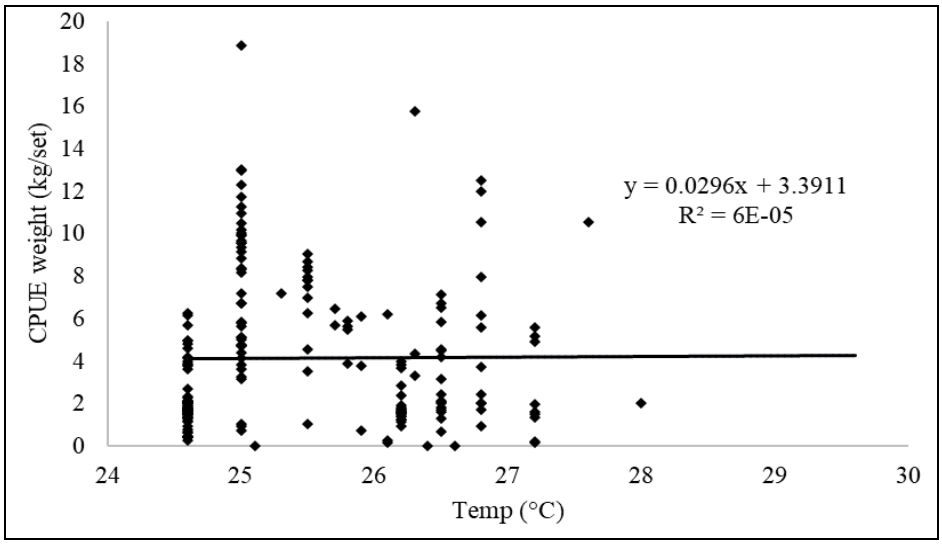

Figure 6: The relationship between catch per unit effort (kg/set) and temperature (°C) from data collected in five fisheries reserve(s) in the Kwando and Zambezi Rivers from November to December 2021.

4.6. Correlations between reserve size and catch rates of all species caught in monofilament gillnets

The results show that there is a significant relationship between reserve area (Table 2) and CPUE ($F, (1, 200) = 32.333, P < 0.001$) with $R^2 = 0.139$. The fit relationship (R^2) is 0.139 which means that there is a 14% influence of the reserve area on the significant changes in the CPUE.

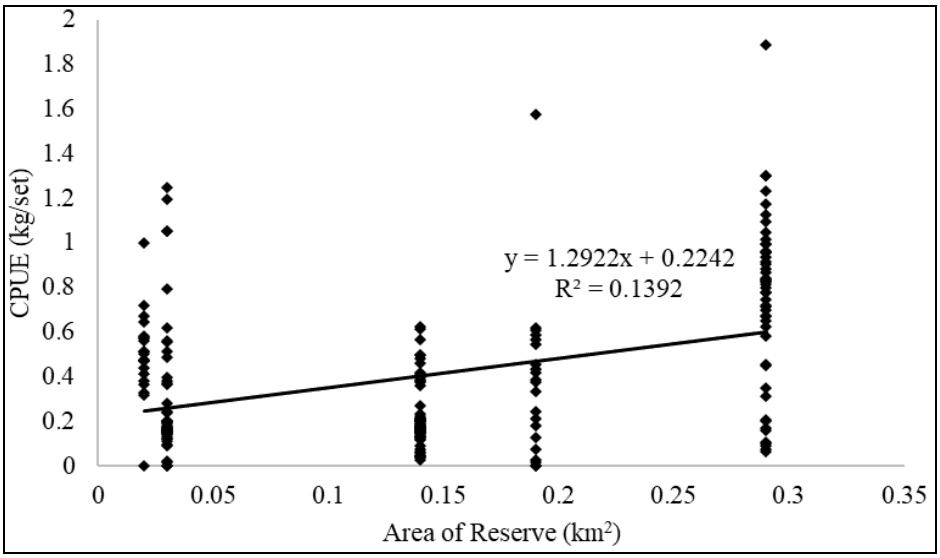

Figure 7: The relationship between catch per unit effort (kg/set) and area of reserve (km^2) from data collected in five fisheries reserve(s) in the Kwando and Zambezi Rivers from November to December 2021.

5. Discussion

5.1. Species Diversity and Community Assemblages by Sampling Sites

In the present study, no statistically significant differences in species diversity were observed among the fisheries reserves of the Zambezi and Kwando Rivers when data collected from all fishing gears were analyzed collectively. This finding suggests a relative uniformity in the composition of fish species across the sampled reserves, regardless of geographic location or gear type used. One possible explanation for this consistency is the ecological similarity observed across the reserves, particularly in terms of their macrophyte communities. Although not quantitatively assessed, qualitative observations indicated that the aquatic plant species present in both river systems were broadly similar in structure and composition, especially within the boundaries of the protected reserves.

These similarities in macrophyte communities are ecologically significant, as aquatic vegetation plays a critical role in supporting freshwater biodiversity. Macrophytes serve multiple functions within aquatic ecosystems—they provide food resources for herbivorous and omnivorous species, create shelter and refuge from predators, and offer suitable substrates for spawning. Such uniform vegetation structure likely contributes to the observed consistency in fish species diversity across different reserves. This inference is supported by existing literature, which emphasizes the essential role of macrophytes in maintaining ecological stability and enhancing species richness in freshwater systems (Junk *et al.*, 1989; Gaylord *et al.*, 2005). These plants can act as ecological engineers, shaping the physical environment and influencing the distribution and abundance of aquatic organisms.

Despite these insights, there remains a need for further research to better understand the specific influence of macrophyte communities on fish biodiversity in these systems. Future studies should aim to quantify the types, density, biomass, and spatial coverage of aquatic vegetation within and around the reserves. Moreover, assessing the relationship between macrophyte diversity and fish community structure would help identify key drivers of species distribution and inform habitat-based management strategies within these protected areas.

Similarly, fish community assemblages showed minimal variation across the different sampling sites. This observed homogeneity in fish composition can likely be attributed to the seasonal hydrological connectivity that occurs between the Zambezi and Kwando Rivers during periods of flooding. During such high-water events, the rivers and their surrounding floodplains become interconnected, creating a dynamic and expansive aquatic network. This seasonal connection allows fish to move freely between areas that are otherwise isolated during low-water periods, including side channels, oxbow lakes, and even between adjacent river systems.

The ecological consequences of this seasonal connectivity are profound. It facilitates the dispersal of fish species across a broader landscape, enabling individuals to exploit new habitats, access additional resources, and avoid localized disturbances or predation. As a result, species composition across sites becomes more similar, contributing to the homogenization of fish communities. Moreover, the temporary expansion of aquatic habitats during flood seasons supports an increase in both the number and diversity of fish, particularly benefiting generalist species that can adapt to a wide range of environmental conditions.

Floodwaters also play an important role in reproductive processes and genetic exchange. They can transport eggs, larvae, or juvenile fish between different habitats and river systems, enhancing gene flow and contributing to the mixing of populations. This genetic exchange not only increases resilience within fish populations but also promotes ecological stability at the landscape scale. Therefore, the regular occurrence of seasonal flooding in these river systems is likely a major factor driving the observed similarities in both species diversity and community assemblages among the fisheries reserves of the Zambezi and Kwando Rivers.

5.2. Effect of water parameters on species composition

Among all sites, Qhuqhumupa and Luhingi exhibited the highest recorded water temperatures, which may have influenced the composition of fish communities in these areas. In both reserves, the fish assemblages were dominated by catfish species—organisms well known for their ability to tolerate harsh and variable environmental conditions (Bruton, 1979; Manomi, 2024). The predominance of catfish, which are typically resilient to environmental stressors such as low oxygen levels and high temperatures, may be indicative of habitat degradation or ecosystem imbalance.

This pattern highlights the potential impact of abiotic factors, especially temperature, on species composition in riverine ecosystems. It also reinforces the importance of monitoring water quality parameters when assessing the ecological health of fisheries reserves. The findings suggest a need for more detailed and systematic investigations into the environmental dynamics of the Kwando River and its associated reserves.

Future research should focus on habitat classification, seasonal fluctuations, and how variations in environmental parameters—such as temperature, dissolved oxygen, and nutrient levels—affect fish diversity and community structure over time.

5.3. Effect of fish reserve size and habitat complexity on species composition

The findings of this study indicate that the reserves along the Kwando River exhibited lower species richness compared to those along the Zambezi River. This disparity can be attributed to differences in catchment size and hydrological characteristics between the two river systems (refer to Table 2 and Figure 7). These results are consistent with those reported by Taylor *et al.* (2017), who documented up to 44 fish species in the Zambezi River and 41 in the Kwando River.

A key factor contributing to this difference is the nature of the flooding regimes. The Kwando River is characterized by shorter, less consistent, and lower-magnitude flood events compared to the Zambezi. Such limited and irregular flooding reduces water exchange and restricts the movement of fish into the floodplains, thereby decreasing opportunities for colonization and population mixing (Taylor *et al.,* 2017). As noted by Neiff, Neiff, and Verón (2009), rivers with highly variable flood seasons tend to experience reduced transfer of both nutrients and aquatic organisms between the main channel and adjacent wetlands or water bodies—factors which can negatively affect species richness.

Furthermore, specific locations such as the Qhuqhumupa Reserve become hydrologically isolated from the main river channels during low-water periods. This isolation, combined with the brevity of the flood season, likely hinders the

recruitment of new species into the reserve. Bornette *et al.* (1998) support this notion, highlighting that poor hydrological connectivity can lead to the loss of less competitive species due to limited opportunities for recolonization.

In addition, nutrient dynamics play a crucial role in shaping biodiversity patterns. Ecosystems with extremely low or excessively high nutrient levels tend to support fewer species, often favoring specialists that can tolerate such conditions. In contrast, environments with intermediate nutrient availability tend to support higher species richness by accommodating a broader range of ecological niches and nutrient requirements.

However, in river systems characterized by stable and predictable flooding regimes, the consistent movement of water enhances nutrient cycling and overall productivity, which in turn supports greater fish species richness. The Zambezi River and its floodplains exemplify such a system, where regular inundation promotes ecological processes that sustain diverse aquatic communities (Power *et al.,* 1995; Simasiku, 2019; Hay *et al.,* 2020). Conversely, rivers like the Kwando—where floods are shorter in duration and less predictable—often experience reduced nutrient availability. This limitation constrains primary productivity and diminishes the abundance and variety of food sources available to aquatic organisms (Junk *et al.,* 1989; Taylor *et al.,* 2017). Infrequent or restricted flooding also impedes the distribution of nutrient-rich sediments throughout the river system, further limiting aquatic productivity (Junk *et al.,* 1989; Tockner *et al.,* 2000).

Additionally, the higher species richness observed in the Zambezi River reserves compared to those of the Kwando may be partly attributed to the larger size of the Zambezi reserves, both in terms of area and perimeter (see Table 2). These results are consistent with Halpern (2003), who found that the ecological effectiveness of protected areas generally increases with their size. Therefore, the Zambezi River reserves, given their scale and ecological connectivity, hold considerable potential for delivering positive conservation outcomes—particularly when supported by active and adaptive management strategies.

5.4. Catch rates (CPUE) by sampling sites

The results revealed significant differences in catch per unit effort (CPUE) across the five sampled channels, both in terms of total weight (kg) and mean individual length (mm). The highest CPUE values were recorded in the two reserves located on the Kwando River, while the lowest were observed in the three sampling sites along the Zambezi River. The elevated catch rates in the Kwando River reserves can be largely attributed to the dominance of large-sized Clariidae specimens, which were more frequently captured in this system compared to the smaller-sized individuals commonly recorded in the Zambezi River reserves.

One likely explanation for this trend is the relatively pristine condition of the Kwando River, which experiences minimal anthropogenic pressure. As noted by Naesje *et al.* (2004), reduced human disturbance can create favorable conditions for fish populations to grow to their full potential size, contributing to higher biomass and, consequently, increased CPUE. This suggests that environmental quality and

protection status play key roles in shaping fish population structure and productivity within riverine reserves.

Alternatively, the positive outcomes observed in the Kwando River reserves may be influenced by the governance structures and protective designations associated with the surrounding areas. The Kwando River flows through two national parks that have been under formal protection since their gazettement in 1990. This longstanding protection likely contributes to a spillover effect of larger fish species into nearby reserves such as Luhingi and Qhuqhumupa. Notably, both reserves are located within national parks and well-established community conservancies. Specifically, the Luhingi Reserve is situated within the Mayuni Conservancy, inside the boundaries of the Mudumu National Park and near the Bwabwata National Park, while the Qhuqhumupa Reserve lies within the Balyerwa Conservancy, close to Nkasa Rupara National Park.

The integration of fisheries reserves within these existing wildlife conservancy frameworks, which are co-managed by traditional authorities and the Ministry of Environment, Forestry and Tourism, provides a strong governance foundation rooted in community-based conservation. Local communities are already accustomed to the principles of conservation and co-management through long-standing wildlife initiatives. This familiarity enhances the likelihood that similar strategies applied to fisheries management will yield comparable ecological and social benefits.

Moreover, the proximity of these reserves to ecotourism lodges—key stakeholders in the region—has played an important role in the successful establishment and

implementation of fisheries reserves. These lodges have shown strong support for conservation initiatives, helping to reduce conflicts with local fishers and encouraging compliance with reserve regulations. This collaborative approach ensures that the benefits of fisheries protection—such as fish stock recovery—are shared among conservancies, tourism operators, and local communities alike (Simasiku and Hay, 2023).

The notably lower catch rates observed for all fish species combined, as well as for the three key commercially important species at the Makangala reserve on the Zambezi River, when compared to those in the Kwando River reserves, may be strongly influenced by the reserve's proximity to the Namibia-Zambia transboundary area. This geographical positioning creates unique management challenges, as it potentially facilitates unregulated and illegal fishing activities by migrant fishers crossing borders. These unauthorized fishing efforts are often difficult to monitor and control, leading to overexploitation and disruption of fish population dynamics within the channel (Tweddle *et al.*, 2015; Imbwae *et al.*, 2023). The impact of such unregulated fishing is compounded by the fact that transboundary water bodies commonly suffer from overlapping jurisdictions, conflicting management policies, and limited enforcement capacity, making consistent regulation and protection difficult to achieve (Abbott *et al.*, 2007; Imbwae *et al.*, 2023). These governance challenges undermine conservation efforts and contribute to the depletion of valuable fish stocks in areas like Makangala.

Furthermore, the Zambezi River floodplains surrounding the Kabweza and Sitwela reserves are subject to heavy fishing pressure from local communities who rely

heavily on these waters for subsistence and livelihood. At the time of the study, the conservancies tasked with managing these areas were still in the initial stages of establishment and formal gazettement, which meant that effective regulatory frameworks for sustainable resource use were either not fully in place or not widely enforced. This transitional phase often results in gaps in compliance and enforcement, with traditional fishing practices continuing without sufficient management oversight. Consequently, fishing pressure in these floodplains likely intensified, leading to overexploitation characterized by the removal of large, mature, and reproductively important fish. The depletion of these mature individuals can lead to skewed population structures dominated by juveniles, which may hinder the recovery and long-term sustainability of fish populations in these ecosystems. Without timely intervention and strengthened governance, these areas risk continued decline in fish biodiversity and productivity, ultimately affecting both ecological integrity and community livelihoods dependent on these fisheries.

5.5. Catch rates and mean sizes of the commercially important species

Although the economically important species have been mentioned and partially discussed earlier, the catfish species *Clarias gariepinus* and *Clarias ngamensis*, along with *Serranochromis macrocephalus*, were consistently present at all sampled stations due to their relative abundance compared to other species. These three species were therefore selected as key commercially important fish for further analysis. Examination of the CPUE (catch per unit effort) for these species revealed significant differences in catch rates of *C. gariepinus* and *C. ngamensis* across the reserves, likely reflecting variations in habitat quality and fishing pressure within

these protected areas. For instance, the highest CPUE of *C. gariepinus* was recorded at Sitwela on the Zambezi River, which may be attributed to favorable conditions such as regular water flow promoting high productivity and less dense vegetation. Conversely, Qhuqhumupa in the Kwando River exhibited the lowest catch rates, possibly due to less suitable habitat conditions related to inconsistent flooding regimes, as noted by Taylor *et al.* (2017). Mora and Sale (2002) emphasized that increased environmental complexity enhances habitat suitability and indirectly boosts productivity within reserves.

In contrast, *Serranochromis macrocephalus* showed relatively uniform catch rates across all reserves, indicating either stable populations or evenly distributed fishing pressures throughout these sites. Among the reserves, Luhingi demonstrated notably high productivity, underscoring its importance as a priority site for conservation efforts. These results are consistent with findings by Murray *et al.* (1999) and Gaylord *et al.* (2005), who highlighted the role of reserves in increasing fish biomass and catch rates due to reduced exploitation. Furthermore, Jennings *et al.* (2009) underscored CPUE as a valuable indicator for assessing fishing effort and resource abundance, reinforcing its relevance in this study.

Additionally, the average size of commercially important species varied among the reserves. *C. gariepinus* showed the largest mean size at Luhingi, suggesting favorable growth conditions such as abundant prey or lower fishing pressure (Riha *et al.,* 2024). In contrast, smaller average sizes at Kabweza may reflect higher fishing intensity or limited recruitment. Similarly, *C. ngamensis* individuals were largest at Luhingi, while smaller sizes at Kabweza could indicate selective harvesting or

environmental stressors. Meanwhile, *S. macrocephalus* maintained consistent mean sizes across reserves, implying stable habitat conditions or uniform fishing pressure. This observation aligns with Russ *et al.* (2008), who found that long-term protection within reserves often leads to increased mean fish sizes and healthier population structure

6. Conclusion

This study provides a baseline assessment of fish assemblages within the established fisheries reserves of the Zambezi and Kwando Rivers in Namibia. Overall, the two reserves on the Kwando River supported higher catch rates and larger individuals of commercially important species compared to those on the Zambezi River. These differences are likely linked to variations in reserve size and the degree of protection afforded. The Kwando River sampling sites benefit from strict monitoring due to their proximity to Bwabwata, Nkasa Rupara, and Mudumu National Parks. Consequently, these reserves benefit from the broader terrestrial protection and management under the Ministry of Environment, Forestry and Tourism.

In contrast, reserves such as Kabweza and Makangala on the Zambezi River exhibited lower catch rates and smaller specimens of key commercial species, highlighting the urgent need for habitat restoration and stronger protection measures. Nevertheless, Makangala shows potential; its limited accessibility may have provided some protection against overfishing, helping to preserve species that are otherwise heavily targeted in adjacent areas.

The presence of smaller commercially important fish in the Zambezi reserves underscores the necessity for ongoing monitoring, enforcement of regulations, and adaptive management to ensure these areas continue to serve their ecological function in fish conservation. Therefore, comprehensive management and regular assessment of all reserves are essential to track progress and provide early warnings for necessary interventions. Finally, the implementation of regulations regarding gear restrictions and catch limits is recommended to safeguard larger, reproductive fish and promote sustainable fish populations.

7. Management recommendations for fisheries

- There is a need to prioritise monitoring efforts along the Kabweza and Makangala fish reserves, where high species richness and yet low catch rates were reported.

- The dominance of catfish in the monofilament gillnet catches in Kwando reserves, requires further investigation as the lack of presence of other species is concerning.
- The two sampling gears used may have limited data collection. To enhance the robustness of future studies, we recommend using a wider range of gears and extending the sampling period. Support from the Ministry of Fisheries and Marine Resources would be valuable in facilitating this.

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9. Appendices

Appendix 1: Ethical Clearance Certificate obtained from the University of Namibia

UNAM
UNIVERSITY OF NAMIBIA

ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SOS-0033 Date: 04 March 2022

This Ethical Clearance Certificate is issued by the University of Namibia Ethics Committee (REC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the ethics committee.

Title of Project: A COMPARATIVE STUDY OF FISH ASSEMBLAGES BETWEEN THE ZAMBEZI/CHOBE AND KWANDO RIVERS, ZAMBEZI REGION, NAMIBIA

Student: NAMITAA TUKELO LAVINIA

Student Number: 201506965

Supervisor(s): DR. CLINTON HAY (UNAM); DR. EVANS SIMASIKU

Centre for Research Services

Take note of the following:

1. Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the ethics committee. An application to make amendments may be necessary.
2. Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the ethics committee
3. The Principal Researcher must report issues of ethical compliance to the ethics committee (through the Chairperson) at the end of the Project or as may be requested by the ethics committee
4. The ethics committee retains the right to:

i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected, ii) Request for an ethical compliance report at any point during the course of the research.

The ethics committee wishes you the best in your research.

Appendix 2: Authorization for the Research Purposes granted by NCRST

NCRST
NATIONAL COMMISSION ON RESEARCH SCIENCE & TECHNOLOGY

AUTHORIZATION OF RESEARCH PROJECTS

Authorization is hereby granted in terms of Section 21 of the RST Act No. 23 of 2004, to:

Name: Tukelo L. Namitaa

Address: P. O. Box 1598, Ngweze,
Namibia

Coworkers: N/A

Certificate Number (if applicable): RCIV00022018 **Authorization No:** 202209010

Type of Research:
Non- Commercial research and the use of resources be limited to what is in the proposal.

Title of Research Authorized:
A Comparative Study of Fish Assemblage between the Zambezi/ Chobe and Kwando Rivers, Zambezi Region, Namibia.

Locality:
Kwando River, Zambezi River and Chobe River.

Duration: 20 September 2022 - 30 September 2023

Research / Sample Collection Conditions:
Refer to research conditions on the next page.

Yours sincerely,

National Commission on Research Science & Technology
22 SEP 2022
P/Bag 13253
Windhoek, Namibia

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