Assessing Small-Scale Inland Fishery Potential at Flag Boshielo and Glen Alpine Dams, Limpopo Province, South Africa

Report
to the Water Research Commission

by

HA Hlungwani[1,2,5], ML Magoro[2,3], L Mofu[2,3], PM Ndaleni[2], MS Thaela-Chimuka[6], D Khosa[4] and JR Sara[5]

[1]Department of Forestry, Fisheries and the Environment, Foretrust, Cape Town
[2] National Research Foundation-South African Institute for Aquatic Biodiversity, Makhanda
[3]Department of Ichthyology and Fisheries Science, Rhodes University, Makhanda
[4]Scientific Services, South African National Parks, Skukuza
[5]Department of Biodiversity, University of Limpopo, Turfloop
[6]Agricultural Research Council, Animal Production, Irene

WRC Report No. 3266/1/26
ISBN 978-0-6392-0807-7

July 2026

WATER
RESEARCH
COMMISSION

Obtainable from
Water Research Commission
Private Bag X03
Gezina, 0031
PRETORIA

Download from www.wrc.org.za

The publication of this report emanates from a project titled *Establishing the potential for a small-scale inland fishery at Flag Boshielo Dam and Glen Alpine Dam: A pilot project to inform the implementation plan of the National Freshwater (Inland) Wild Capture Fisheries Policy* (WRC Project No: C2023/2024-01310)

DISCLAIMER

This report has been reviewed by the Water Research Commission (WRC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

EXECUTIVE SUMMARY

This Water Research Commission (WRC) report presents the findings of a pilot project designed to evaluate the potential for small-scale inland fisheries at Flag Boshielo and Glen Alpine dams in Limpopo Province, South Africa. The report presents a comprehensive assessment of the fisheries resources, ecological status and socio-economic significance of Flag Boshielo Dam (FBD) and Glen Alpine Dam (GAD) in the province. The study responds to a longstanding national need for scientifically grounded evaluations of inland fishery potential to inform the implementation plan of the National Freshwater (Inland) Wild Capture Fisheries Policy (NFWCFP). Limpopo Province has been identified as one of the regions with the highest inland fisheries potential in South Africa, but evidence-based data gaps, weak governance and environmental degradation have hindered the sector's development, policy implementation and sustainable utilisation. This report offers the first integrated biological, socio-economic and environmental assessment of these two major dams in Limpopo, covering seasonal surveys from May 2024 to February 2025.

The findings of this study reveal severe declines in fish stocks, pronounced vulnerability to hydrological and management disturbances, and significant dependence of rural communities on these fisheries for food security and supplemental income. Taken together, these results demonstrate an urgent need for restoration-focused management, strengthened governance structures, and long-term monitoring to rebuild fish populations and enable sustainable exploitation. The overview below summarises key insights from each chapter and highlights the overarching implications for inland fisheries development in Limpopo.

Chapter 1 outlines the global and national context of inland fisheries, emphasising their importance for food security, livelihoods and poverty alleviation. Worldwide, inland fisheries contribute more than 11 million tonnes of fish annually, yet in South Africa, the sector remains informal, poorly recognised and poorly regulated despite growing dependence among rural communities. Limpopo Province, characterised by high unemployment and persistent food insecurity, hosts several dams with strong potential to support small-scale fisheries. However, systems such as FBD and GAD face mounting pressures from overfishing, illegal gear, pollution, habitat alteration and

water level instability, all of which compromise both ecological resilience and livelihood opportunities.

The chapter highlights the absence of enabling legislation, the fragmentation of provincial and national governance, and the shortage of biological data necessary for evidence-based management. Previous studies indicated potential fisheries development opportunities targeting *Labeo rosae* and *Oreochromis mossambicus,* which dominated catches both in abundance and biomass in earlier years, but subsequent ecological shifts and degradation demanded more updated, site-specific assessments. This study was commissioned to fill that critical gap, forming the empirical foundation for policy implementation.

Chapter 2 details the seasonal, multi-gear fishery surveys and environmental monitoring undertaken at both dams. Fieldwork included: physico-chemical profiling (temperature, dissolved oxygen, pH, total dissolved solids, conductivity, turbidity), standardised gill netting, fyke nets and cast nets, Species identification and biological sampling, Socio-economic surveys (demographics, motives, gear use and utilisation). The FBD is a larger and more intensively utilised dam with substantial recreational activity, noted for pollution and declining fish stocks. The GAD, by contrast, was poorly studied prior to this project, despite its importance to nearby villages such as Driekoppies and Mmankgodi.

Chapter 3 presents one of the study's most important findings: a fundamental shift in fish community structure compared to the composition recorded between 2016 and 2018. Historically dominant species, *Labeo rosae* and *Oreochromis mossambicus* have significantly declined, with *L. rosae* entirely absent from the current catches at FBD. Earlier assessments showed *L. rosae* contributing nearly 60% of biomass, whereas its disappearance now suggests long-term recruitment failure likely linked to drought-induced spawning disruption. Similarly, *O. mossambicus* has declined sharply, largely due to illegal monofilament gill nets, which selectively remove the large, mature individuals essential for sustaining population structure. In their place, *Coptodon rendalli* and *Micropterus nigricans* now dominate catches, representing an ecological transition with serious implications for fishery potential. At GAD, the situation is more severe. Following mismanaged water releases in spring 2024, the dam dropped from 52% to 2% capacity, causing a catastrophic mass fish kill that

eliminated almost all species except juvenile *Clarias gariepinus*. Thirteen species recorded in autumn and winter were wiped out, demonstrating the extreme vulnerability of this fishery to management failures.

The biological assessment reveals that fish populations in both dams have declined to an extent that basic biological parameters such as age structure, growth and maturity cannot be reliably estimated for historically targeted species. This absence of indicators is not a methodological issue but reflects near-collapse of key populations. Owing to the depleted abundance of *L. rosae* and *O. mossambicus*, recommendations made in earlier models (Hlungwani *et al.,* 2023; Marr *et al*., 2024), including piloting fisheries based on these species, were impossible to implement in FBD. Instead, the study focused on assessing whether *C. rendalli*, now dominant in catches, could serve as an alternative target species. Biological sampling was initiated to characterise its exploitation potential, but the low biomass and inconsistent recruitment limit immediate development prospects. The GAD's trajectory following the fish kill presents an urgent case for restoration-based management, as naïve re-establishing fish communities require careful monitoring to avoid irreversible ecological shifts.

Socio-economic assessment confirms that inland fisheries are central to the livelihood strategies of surrounding communities, particularly subsistence fishers, most of whom are unemployed rural residents relying on fishing for food security. Small-scale fishers were entirely African, whereas the majority of recreational users were white, reflecting persistent socio-economic and racial disparities in access and usage patterns. Subsistence fishers used rods, handlines and occasionally gill nets, while recreational anglers used modern gear and had vehicle access. These findings underscore the importance of fisheries for nutrition, micro-enterprise and local resilience, but also highlight issues of equity, enforcement and unregulated competition for depleted resources.

The final chapter synthesizes the ecological, biological and socio-economic evidence and concludes that both dam systems are in a state of ecological decline, with fish populations below viable thresholds for sustainable exploitation. Water quality instability, illegal gear use, poor dam management and lack of fisheries governance collectively undermine the recovery of fish populations. Key recommendations from the synthesis include:

- Immediate restoration measures: rehabilitating the habitat, reducing pollution, improving hydrological stability, and preventing future fish kills.
- Strict regulation of gill nets and revised gear and effort controls.
- Development of co-management structures involving fishers, communities, provincial authorities and dam managers.
- Long-term monitoring programmes coupling biological surveys with water quality and hydrological data.
- Strategic restocking of *L. rosae* and *O. mossambicus*, accompanied by genetic safeguards and controlled harvest regimes.

This report demonstrates that while inland fisheries in Limpopo Province hold significant potential for supporting livelihoods and contributing to rural economies, the current ecological and institutional conditions are insufficient to support sustainable exploitation. Fish stocks in FBD and GAD are severely depleted, governance frameworks remain fragmented, and socio-economic pressures continue to intensify extraction. Rebuilding these fisheries requires coordinated ecological restoration, strengthened regulation and inclusive management partnerships. The evidence presented here provides the crucial scientific foundation for implementing the NFWCFP, marking a significant step toward formalising and safeguarding the inland fisheries sector in South Africa.

ACKNOWLEDGEMENTS

The project team wishes to thank the following people for their contributions to the project.

Reference Group	Affiliation
Dr SM Hlophe-Ginindza	Water Research Commission (Project Manager)
Prof S Mpandeli	Water Research Commission
Dr L Nhamo	Water Research Commission
Dr EM Mbokane	University of Limpopo
Dr K. Salie	Stellenbosch University
Ms SA Joao	Stellenbosch University
Mr K Sankar	Department of Forestry, Fisheries and the Environment
Others	
Prof A. Chakona	National Research Foundation-South African Institute for Aquatic Biodiversity
Mr TJ Sebake	Department of Forestry, Fisheries and the Environment
Mr TR Nkhumeleni	University of Limpopo
Ms BG Machete	University of Limpopo
Mr CN Mashiloane	University of Limpopo
Ms A Mthombeni	Department of Forestry, Fisheries and the Environment
Mrs H Wells	Aloe Park Mmakatle (Flag Boshielo Accomodation)
Mr MM Masindi	Limpopo Department of Economic Development, Environment and Tourism
Mr A Njobeni	Department of Forestry, Fisheries and the Environment
Mr T Voyiya	Department of Forestry, Fisheries and the Environment

TABLE OF CONTENTS

EXECUTIVE SUMMARY i

ACKNOWLEDGEMENTS v

TABLE OF CONTENTS vi

LIST OF FIGURES ix

LIST OF TABLES x

CHAPTER 1: BACKGROUND 1

1. INTRODUCTION 1
1.1 Inland fisheries sector in South Africa 1
1.1.1 Small-scale fisheries 3
1.1.2 Recreational fisheries 4
1.1.3 Commercial fisheries 5
1.2 Knowledge requirements for inland fisheries development in South Africa 6
1.3 Fisheries potential in South Africa 6
1.4 Exploitation potential of inland fisheries resources in South Africa 8
1.5 Inland fisheries sector in Limpopo Province 9
1.6 Fisheries assessment methods 10
1.7 Productivity estimates of the resource 11
1.8 Fisheries harvest strategies 11
1.9 Resource utilisation practices 12
2. RATIONALE OF THE PROJECT 13
2.1 Scope and context of the project 14
2.2 Aims of the project 15
3. STRUCTURE OF THE REPORT 16

CHAPTER 2: GENERAL METHODS AND MATERIALS 19

1. DESCRIPTION OF THE STUDY SITES 19
1.1 The Olifants River System 19
1.2 The Mogalakwena River 21
2. SELECTED STUDY SITES 22
2.1 Flag Boshielo Dam 22
2.1.1 Physical characteristics of Flag Boshielo Dam 24
2.1.2 Fish fauna of Flag Boshielo Dam 25
2.2 Glen Alpine Dam 26
3. GENERAL SAMPLING METHODS 27
3.1 Ethical clearance and permits 27
3.2 Fish surveys 28
3.3 Socio-economic study 28

CHAPTER 3: SPECIES COMPOSITION AND CATCH RATES FROM THE FLAG BOSHIELO AND GLEN ALPINE FISHERIES RESOURCES, LIMPOPO PROVINCE, SOUTH AFRICA 29

1. INTRODUCTION **29**
2. METHODS AND MATERIALS **30**
2.1 Aims and Objectives of the Chapter 30
2.2 Physico-chemical parameters 31
2.3 Fish collection 31
2.4 Establishing the catch-per-unit effort (CPUE) 32
3. RESULTS **33**
3.1 FLAG BOSHIELO DAM 33
3.1.1 Physico-chemical properties 33
3.1.2 Species catch composition 33
3.1.3 Catch composition biomass per mesh size 34
3.1.4 Overall catch per unit effort (CPUE) per mesh size 35
3.1.5 Comparison of FBD historical and current fish stocks. 36
3.2 GLEN ALPINE DAM 38
3.2.1 Seasonal water levels and physico-chemical properties 38
3.2.2 Species catch composition 40
3.2.3 Catch composition biomass per mesh size 40
3.2.4 Overall catch per unit effort (CPUE) per mesh size 41
4. DISCUSSION **42**
5. CONCLUSION **43**

CHAPTER 4: A BIOLOGICAL ASSESSMENT OF THE FLAG BOSHIELO AND GLEN ALPINE FISHERIES **45**

1. INTRODUCTION **45**
1.1 Aim of the chapter 47
1.2 Objectives of the Chapter 47
2. METHODS AND MATERIALS **47**
2.1 Biological assessments 47
2.2 Age and growth 48
2.3 Maturity 49
2.4 Length/weight relationship 50
2.5 Data analysis 50
3. RESULTS **50**
3.1 Age and growth 50
3.2 Length-Weight relationship 51
3.3 Net selectivity 52
3.4 Maturity 53
4. DISCUSSION **53**
5. CONCLUSION **56**

CHAPTER 5: BASELINE ASSESSMENT OF UTILISATION PATTERNS IN THE FLAG BOSHIELO AND GLEN ALPINE FISHERIES **58**

1. INTRODUCTION **58**
1.1 Aim of the chapter 60
1.2 Objectives of the chapter 60
2. METHODS AND MATERIALS **60**
2.1 Questionnaire survey 60
2.2 User group classification 61
5.2.3 Data analysis 62

3. RESULTS **62**
3.1 Flag Boshielo Dam 62
3.1.1 Resource utilisation 62
3.1.2 User group's catch composition 66
3.1.3 Socio-economic Characteristics 67
3.2 Glen Alpine Dam 67
3.2.1 Area description 67
3.2.2 Socio-economic Characteristics 68
3.2.3 Glen Alpine Dam Fisheries 68
4. DISCUSSION **69**
5. CONCLUSION **71**

CHAPTER 6: GENERAL DISCUSSION AND RECOMMENDATIONS **72**

1. GENERAL DISCUSSION **72**
2. RECOMMENDATIONS **76**
3. CONCLUSION **79**

REFERENCES **81**

APPENDIX A (QUESTIONNAIRE) **94**

LIST OF FIGURES

Figure 1.1: Inland fisheries assessment framework (Hlungwani, 2021). 15

Figure 2.1: The location and profile of Flag Boshielo Dam in South Africa in relation to the Elands and Olifants rivers that flow into the impoundment (Dabrowski *et al.*, 2013). 20

Figure 2.2: Map of the Mogalakwena River System catchment showing locations of major towns, impoundments and tributaries. 22

Figure 2.3: The profile of Flag Boshielo Dam and the sites where fishing gears were set. 23

Figure 2.4: Glen Alpine Dam wall during January 2025, when the dam level was above full capacity. 26

Figure 3.1: Preparation for placing the nets, casting cast nets, and setting gill nets. 32

Figure 3.2: Seasonal dam water levels for Glen Alpine Dam. 38

Figure 3.3: Water channel in Glen Alpine Dam and fish kills caused by receding water levels during November 2024. 39

Figure 4.1: An otolith viewed under a light microscope showing the translucent (light) and opaque (dark) growth bands of a *Coptodon rendalli* caught in Flag Boshielo Dam. 48

Figure 4.2: Length-at-age relationship determined for *Coptodon rendalli* from specimens sampled during autumn survey conducted in Flag Boshielo Dam during May 2024 to February 2025 51

Figure 4.3: Length and weight relationship of the total number of *C. rendalli* (n = 42) caught using different fishing gear in FBD during the surveys 52

Figure 4.4: The CPUE (kg/100m-net/hour) of fish species caught in different gill-net mesh sizes. 53

Figure 5.1: Small-scale fishers (A and B) fishing at the FBD using fishing rods and (C) a fisher preparing his catch to take home from the FBD 61

Figure 5.2: Percentage of fishing gear usage by fishers to catch fish in FBD. 63

Figure 5.3: The distance, indicated as a percentage (%), travelled to Flag Boshielo Dam by various fishers. 63

Figure 5.4: Percentage of the mode of transport used by fishers to access the Flag Boshielo Dam from their point of origin. 64

Figure 5.5: Occupation/employment (as a percentage) of fishers who utilise the Flag Boshielo fishery. 65

Figure 5.6: Percentage of the fate of the catch of fishers who catch fish in Flag Boshielo Dam. 65

Figure 5.7: Proportional fish species composition recorded in both recreational and subsistence fishers catch at Flag Boshielo Dam. 66

Figure 6.1: A visual synthesis of the causal interactions among water-level decline, habitat loss, biological collapse, fishing pressure, governance gaps, and the necessary recovery actions. 73

LIST OF TABLES

Table 2.1: The composition of fish species captured in Flag Boshielo by Brits (2006), Sara *et al.* (2017) and Hlungwani *et al.* (2023). 25

Table 3.1: Mean values and standard deviation of physico-chemical parameters measured during surveys conducted in autumn, winter, spring of 2024 and summer 2025 at Flag Boshielo Dam. 33

Table 3.2: The total biomass and abundance, expressed as kilograms of all fish species collected in FBD using gill nets, fyke nets and cast nets during surveys conducted in May, August, November 2024 and February 2025. 34

Table 3.3: The total biomass of fish collected in FBD using gill nets with mesh sizes of 44, 60, 70, 100 and 144 mm during May, August, November 2024 and February 2025. (The biomass of a species is expressed as kilograms for each mesh size and the overall contribution (%) to the total mass collected). Values in bold indicate species that contributed >20% of the total catch. 35

Table 3.4: The catch-per-unit effort (CPUE) expressed as kg/100-m net/hr of all species caught using standardised gillnets from Flag Boshielo Dam during surveys conducted in May, August, November 2024 and February 2025. Values in bold indicate species that contributed > 20% of the total catch. . 35

Table 3.5: The abundance and biomass, expressed as a percentage (%), of fish species collected in FBD using standardised gill nets (44, 60, 70, 100 and 144 mm mesh size) during surveys conducted from February 2016 to April 2017. Values in bold indicate species that contributed > 20% of the total catch. 36

Table 3.6: The biomass of fish collected in FBD using gill nets with mesh sizes of 44, 60, 70, 100 and 144 mm from April 2016 to April 2017. (The biomass of a species is expressed as a percentage (%) of the total biomass for each mesh size and the overall contribution to the total mass collected.) Values in bold indicate species that contributed > 20% of the total catch. 37

Table 3.7: The catch-per-unit effort (CPUE) expressed as kg/100-m net/hr of all species caught using standardised gillnets from FBD during surveys conducted from April 2016 to April 2017. 38

Table 3.8: Means and standard deviation of physico-chemical parameters measured during surveys conducted in autumn, winter, spring 2024 and summer 2025 at Glen Alpine Dam. 39

Table 3.9: Abundance and biomass expressed as kilograms of fish species collected in GAD using gill nets, fyke nets and cast nets during surveys conducted in May, August, November 2024 and February 2025. Values in bold indicate species that contributed > 20% of the total catch. 40

Table 3.10: The biomass of fish collected in Glen Alpine Dam using gill nets with mesh sizes of 44, 60, 70, 100 and 144 mm during May, August, November 2024 and February 2025. (The biomass of a species is expressed as total biomass (kg) for each mesh size and the overall contribution (%) to the total mass collected.) Values in bold indicate species that contributed >20% of the total catch. 41

Table 3.11: The catch-per-unit effort (CPUE) expressed as kg/100-m net/hr of all species caught using standardised gillnets from Glen Alpine Dam. 41

Table 4.1: Macroscopic criteria used to stage the gonads of the most abundant species (adapted from Weyl & Hecht, 1998). 49

Table 4.2: Age-length key for *Coptodon rendalli* sampled between May 2024 and February 2025 in Flag Boshielo Dam. 51

Table 4.3: Maturity rating of male and female gonads of Coptodon rendalli sampled between May 2024 and February 2025 in Flag Boshielo Dam. 53

Table 5.1: Flag Boshielo Dam fisher demographics by user group. 66

ACRONYMS & ABBREVIATIONS

Abbreviation	Full Meaning
AMD	Acid Mine Drainage
CPUE	Catch-Per-Unit Effort
DAFF	Department of Agriculture, Forestry and Fisheries (former national department; now part of DFFE)
DFFE	Department of Forestry, Fisheries and the Environment
DO	Dissolved Oxygen
FAO	Food and Agriculture Organization of the United Nations
FBD	Flag Boshielo Dam
GAD	Glen Alpine Dam
GIS	Geographic Information System
MEI	Morpho-Edaphic Index (indicator used to estimate potential fish yield)
MLRA	Marine Living Resources Act
MUV	Marketed Use Value
NFWCFP	National Freshwater (Inland) Wild Capture Fisheries Policy
NTU	Nephelometric Turbidity Unit (unit of turbidity measurement)
RE	Random Effects
SBR	Spawner Biomass per Recruit (a fisheries stock-assessment metric)
SDG	Sustainable Development Goal (of the United Nations)
SL	Standard Length (measurement of fish length from snout to base of tail)
TDS	Total Dissolved Solids
TL	Total Length (full length of fish from snout to end of tail)
UL	University of Limpopo
WRC	Water Research Commission
YPR	Yield-Per-Recruit (a fisheries stock-assessment metric)

CHAPTER 1: BACKGROUND

1. INTRODUCTION

The estimated annual global inland fisheries production is reported to be 12.0 million tonnes (FAO, 2020) and accounts for 12.5% of the total global capture of fisheries production. This estimation makes the industry an important contributor towards ensuring food security, reducing poverty, and generating income (Hara & Backeberg, 2014; Funge-Smith, 2018). However, owing to the sector's informal status, its socio-economic impacts are frequently understated in many nations' financial figures, distorting their significance at the local or regional level (Hlungwani *et al.,* 2023). In many developing countries, the lack of policy to guide resource utilisation and allocation has been identified as one of the key drivers limiting the potential development of the inland fisheries sector (Weyl *et al*., 2007; Béné *et al.,* 2010; Hara & Backeburg, 2014; Britz *et al*., 2015; Cooke *et al*., 2016). Consequently, achieving the United Nations 2030 Sustainable Development Goals (SDGs), particularly No Poverty (SDG 1), Zero Hunger (SDG 2), Clean Water and Sanitation (SDG 6), and Responsible Consumption and Production (SDG 12), will not be feasible without ensuring a sustainable future for the inland fisheries sector (Lynch *et al*., 2020; Weyl *et al.,* 2020). The potential for the sector to redress poverty and hunger could be a potential pathway to developing new strategies to overcome poverty and increase food security, especially in developing African countries.

1.1 Inland fisheries sector in South Africa

South Africa has historically lacked significant traditional small-scale inland fisheries, with notable exceptions being the fisheries on the Pongola Floodplain in northern Kwazulu-Natal and the Orange River in the Northern Cape (Britz *et al*., 2015). Unlike the typical global pattern in which inland fisheries evolve from small-scale to commercial to recreational use, South African inland fisheries began primarily with recreational use. Small-scale and commercial fishing activities emerged later due to factors such as the scarcity of natural water bodies, lack of traditional fishing culture

in some rural communities, exclusionary apartheid-era policies, and the absence of supportive developmental frameworks (Britz *et al*., 2015).

Inland fisheries development in South Africa began in earnest during the 19th century colonial period with the introduction of non-native fish species for recreational angling (McCafferty *et al*., 2012). The colonial government established hatcheries and implemented stocking programmes to promote trout fishing. This focus on recreational fishing led to the development of laws and policies that effectively recognised only recreational fisheries, overlooking small-scale fisheries (Britz *et al*., 2015). The apartheid regime further entrenched these disparities through policies that reinforced the exclusion of black fishers. While various homeland authorities promoted subsistence fishery projects in rivers and impoundments, these initiatives yielded mixed results due to administrative issues, lack of market access, and limited public sector capacity. The dam-building era in the 1960s and the 1970s saw an increasing focus on developing commercial fisheries; however, most failed due to the low productivity of dams and lack of a market for freshwater fish (McCafferty *et al*., 2012).

In post-apartheid era, a growing number of people were engaged in small-scale fishing activities across various inland water bodies in South Africa (Britz *et al*., 2015). With the advent of democracy in 1994, South Africa embarked on the process of transforming its fisheries governance structures to address inequities of the past. Significant progress was made in the marine fisheries sector with the introduction of the Marine Living Resources Act (MLRA) in 1998, which aimed to provide equitable access to marine resources. However, similar progress in the inland fisheries sector has lagged. Fisheries management was split between national and provincial authorities, with national bodies primarily focusing on marine issues and leaving inland fisheries under the provincial environmental departments. This division has resulted in inconsistent policies and enforcement across provinces. Importantly, governance frameworks have failed to address historical issues in legitimising the access rights of black small-scale fishers (Britz *et al*., 2015).

Following years of consultation, the development of the National Freshwater (Inland) Wild Capture Fisheries Policy in 2022 marked a significant milestone in recognising the importance of inland fisheries in South Africa and promoting their sustainable development and management. In general, South Africa’s inland fisheries sector is

poorly monitored, and there is a significant lack of data on the status of fish stocks, catch and effort, and social and economic values (Weyl *et al*., 2020). Broadly, the dominant users of inland fishery resources are recreational and small-scale fishers (Hara *et al*., 2021). These subsectors, as well as the largely dormant commercial subsector, are described in greater detail below.

1.1.1 Small-scale fisheries

Small-scale inland fishing in South Africa can be broadly defined as the full-time, part-time, or seasonal harvesting of fish for subsistence and/or income generation. Small-scale fishing has emerged as a significant activity in South Africa's inland waters, particularly in the post-apartheid era. However, it remains largely informal and poorly documented. No comprehensive studies have benchmarked the total number of inland small-scale fishers in South Africa or their total catch (Rouhani, 2004). Broader information is contained in various publications, notably in case studies conducted by Britz *et al*. (2015), Hara *et al.* (2021), and Rouhani (2001), which provide evidence that inland fisheries make an important contribution to food security, livelihoods, and income generation, especially in rural areas. Hara *et al*. (2021) estimated that the marketed use value (MUV) of small-scale inland fisheries in South Africa is approximately ZAR 444 million per year.

Small-scale fishing occurs in numerous reservoirs and rivers across South Africa, as well as in natural lakes, such as Lake Fundudzi (Britz *et al*., 2015). Some of the larger inland fisheries include FBD (Hlungwani *et al*., 2023) and Nandoni Dam in Limpopo Province (Fouche *et al.,* 2013), Loskop Dam in Mpumalanga Province (Hlungwani *et al.,* 2024), Pongola Dam (Pongolapoort Dam) in KwaZulu-Natal Province (Hlungwani, 2021), Voëlvlei Dam in Western Cape Province, Gariep Dam (Eastern Cape, Free State, Northern Cape) and Vanderkloof Dam (Britz *et al*., 2015). There are also established, albeit smaller, small-scale fisheries in numerous small impoundments across the country. However, the total catch of the sector is unknown. According to the FAO (2024) report, the total inland capture fisheries production in 2022 was 900 tonnes. However, given the informal nature of the sector, production is likely to be higher than that captured in these statistics.

Small-scale fishers target various native and non-native fish species. Some of the major target species include common carp, *Cyprinus carpio* (Linnaeus, 1758), African

sharptooth catfish *Clarias gariepinus* (Burchell, 1822), tilapia (*Oreochromis* spp.), cyprinids, for example, smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822), Orange River mudfish *Labeo capensis* (Smith, 1841), moggel *Labeo umbratus* (Smith, 1841) and other smaller indigenous species (Hlungwani *et al*., 2023). Common fishing gear includes gill nets, handlines, cast nets, fish traps, and rods and reels. The use of these gears varies depending on the water body, target species, and local regulations (where they exist and/or are enforced) (Britz *et al*., 2015).

Small-scale fishers primarily come from marginalised rural communities, with a significant proportion being black South Africans, a demographic pattern reflecting the historical socio-economic divide created by apartheid policies. Typically, small-scale fishers are middle-aged men and women aged between 30 and 50 years, although participation spans age groups. Gender roles are often distinct, with men predominantly engaged in fishing activities, and women more commonly involved in processing and selling fish. The sector is characterised by informal employment, with most fishers lacking formal contracts, social security, or access to financial services (Hara *et al*., 2021). Small-scale inland fisheries in South Africa are typically characterised by short value chains that cater primarily to local markets where small-scale fishers sell their catch as individuals. Fishers or local vendors, particularly women, often carry out basic processing tasks such as gutting, cleaning, drying, and smoking (Britz *et al*., 2015; Hara *et al*., 2021).

1.1.2 Recreational fisheries

Recreational angling is the dominant inland fisheries sector in terms of participation, involving approximately 1.5 million anglers (Britz *et al.*, 2015). This includes approximately 19,000 formal anglers affiliated with various associations and informal anglers who are not linked to any organised body. The total catch of the sector is difficult to monitor, given that activities are highly dispersed, and recreational angling is often non-consumptive, that is, catch and release is practised. However, the total recreational harvest is estimated to be approximately 1000 tonnes (Weyl *et al*., 2020). Recreational angling has a substantial economic impact in South Africa. A 2007 study by Leibold and van Zyl (2008) estimated that the average expenditure on angling-related equipment and activities was approximately ZAR 7500 per angler per year, which equated to a total contribution of ZAR 900 million per annum to the national

economy. This figure represents approximately 10% of the participants, suggesting that the overall economic contribution may be much higher than estimated.

Recreational angling occurs in several dams and rivers across South Africa, targeting a variety of species, including non-native carp, bass, trout, and native catfish and yellowfish (Ellender *et al.,* 2014). Common methods include bank angling, boat angling, fly fishing, artificial lure angling, and informal recreational and food fish angling (McCafferty *et al*., 2012).

1.1.3 Commercial fisheries

Commercial inland fisheries in South Africa can be defined as activities undertaken by private individuals who are granted provincial-level access to harvesting predetermined yields from dams. These enterprises aim to maximise efficiency and profit while minimising production costs (Britz *et al*., 2015). Historically, commercial fisheries have operated on a few impoundments, but their viability has been marginal despite studies on their potential. In South Africa, data compiled between 1979 and 2014 revealed that only 9036 tonnes of fish were harvested by commercial fishery enterprises operating sporadically across seven impoundments (Barkhuizen, 2015). The yields were dominated by the Bloemhof Dam (73%) and Kalkfontein Dam (23%), with only two ventures operating continuously for more than 32 years at the Bloemhof Dam. Attempts to develop formal small-scale commercial fisheries in rural communities have largely failed to remain operational after the initial project interventions (Britz *et al*., 2015). The underdevelopment of commercial inland fisheries has been attributed to various factors, including the low productivity of most inland water bodies and economic factors such as low fish prices and the absence of a formal marketing system (McCafferty *et al*., 2012).

Unlike South Africa's marine fisheries, there are no large-scale mechanised commercial fishing operations in inland waters because of low productivity. The few existing "commercial" operations are small-scale artisanal fisheries that use simple, manually operated gear (Britz *et al*., 2015). Despite their limited scope, these fisheries may provide some level of local economic benefit, although their overall impact remains minimal in the broader context of South Africa's fisheries sector (Hara *et al*., 2021). From a governance perspective, the institutional and policy framework for inland fisheries in South Africa is characterised by a multi-layered and somewhat

fragmented system that involves national, provincial, and local authorities. Consequently, the sector is currently managed through a combination of national and provincial regulations that primarily focus on conservation and biodiversity objectives.

1.2 Knowledge requirements for inland fisheries development in South Africa

Apart from the work done in the Free State (Ellender *et al.,* 2009, 2010; Barkhuizen *et al*., 2016; Swanepoel *et al*., 2025 (a)&(b)) and the Eastern Cape provinces (Richardson *et al*., 2019), descriptions of inland fisheries operating in South Africa are lacking. As already mentioned, the lack of catch rates and harvest data creates a major bottleneck in assessing the potential of inland fisheries as many impoundments are open to the public for both recreational and subsistence utilisation (Weyl *et al*., 2007). Therefore, studies aimed at providing catch and harvest data in South Africa are an immediate requirement to determine whether inland fisheries can be developed sustainably in many of the country's impoundments (Weyl *et al*., 2020).

In addition to the catch and harvest data, information on inland fisheries governance, licensing, and resource allocations is required (Britz *et al*., 2015). This data is essential to manage user conflicts, particularly between recreational and small-scale fishers as conflict is common and is mentioned in some publications (Weyl *et al*., 2007, 2010a). For example, an episode aired on 6 September 2020 on the *Carte Blanche* M-Net television show highlighted the need for South Africa to develop inland fisheries governance to avoid user conflict, as recreational anglers were shown to oppose the experimental gill net fishery aimed to develop a commercial fishery in Vanderkloof Dam in the Northern Cape Province. Understanding the causes underpinning user conflicts is essential for fisheries and fisheries policy development, to uphold South Africa's national policy objectives, such as the ecologically sustainable development and use of natural resources while promoting justifiable economic and social development as prescribed in Section 24 b (iii) of the South African Constitution.

1.3 Fisheries potential in South Africa

The primary function of most South African impoundments is to supplement urban and agricultural water supplies and provide hydropower during peak periods (Dabrowski

et al., 2014; Britz *et al*., 2015). As a result, approximately 3150 impoundments have been constructed countrywide (Britz *et al.*, 2015). These impoundments have created significant inland water resources, with a surface area of more than 3000 km^2. Based on currently available peer-reviewed and grey literature, surveys on the biology and management of fish populations in state-owned dams are limited to the Eastern Cape reservoirs: Xonxa (Richardson *et al*., 2019), Lubisi and Umtata (Schramm , 1993), five small impoundments (Potts, 2003; Potts *et al*., 2006) and Darlington Dam on the Sundays River system (Weyl *et al.,* 2010a); two impoundments on the Orange River system: Gariep Dam and Vanderkloof Dam (Hamman, 1981; Allanson & Jackson, 1983; Tómasson, 1983; Tómasson *et al*., 1985; Potts *et al.,* 2004; Ellender, 2008); Pongolapoort Dam in KwaZulu-Natal, and two impoundments at the Olifants River System: Loskop Dam and FBD (Hlungwani *et al*., 2023; Hlungwani *et al*., 2024). In each of these impoundments, the estimates were based on one-year assessments. Given the dire need for successful interventions to fight poverty and address food insecurity, especially in provinces such as Limpopo, Mpumalanga, and KwaZulu-Natal, South Africa cannot afford inefficiencies in the development of the inland fisheries sector, which has the potential to address poverty and food security. Hence, *post hoc* assessments of inland fisheries development interventions are important as South Africa has a history of failed attempts to develop formal small-scale fisheries (McCafferty *et al.*, 2012; Barkhuizen *et al*., 2016).

Cumulatively, the productivity of a study by Britz *et al*. (2015), using a Geographical Information System (GIS)-based assessment, estimated that South Africa's large impoundments collectively have a harvestable fish production potential of approximately 15 000 tonnes per year. This estimate was obtained from 425 dams ranging in size from 0.01 to 368 km^2, of which only 29 were likely to yield a sustained 100 t/yr necessary for the development of a small-scale commercial fishery (Weyl *et al*., 2007; Britz *et al.,* 2015). The analysis used dependent and independent catch data as a basis for weighting geographic (altitude, temperature and rainfall), morphometric (surface area, capacity and age), and edaphic (conductivity) variables that influence fish yield (Britz *et al*., 2015). However, since this estimate is derived from desktop predictions, many of these impoundments may not be able to support fisheries, pending locality-specific data. Therefore, a more scientifically defensible estimate based on locality-specific data is required, as most water bodies predicted to have

higher fisheries potential yields are in areas that are water-stressed and stretched to supply domestic, industrial, and agricultural water demands.

Britz *et al*. (2015) identified Limpopo, Mpumalanga, North West and KwaZulu-Natal provinces as having the highest potential for inland fisheries development. However, Britz *et al*. (2015) cautioned that the results should be treated as initial estimates, with baseline surveys to determine species composition, relative abundance, and basic biology of fish communities in these regions being an immediate requirement. Knowledge of life history characteristics, such as the rates of maturity, growth, and natural mortality of the fish species to be harvested is fundamental for informing sustainable development of a fishery (Booth & Khumalo, 2009; Weyl *et al*., 2020). Although there is a paucity of information on the catch and effort data of fish stocks in South African impoundments, there is relatively good information on the fish species present on a basin scale (Skelton, 2001; van Rensburg *et al*., 2011; Weyl & Cowley, 2015). For example, the Limpopo River System contains relatively large fish fauna (Abell *et al*., 2008), which include potential fisheries species such as large native cichlids, including *C. rendalli* and the *O. mossambicus* which inhabit large impoundments, such as the Flag Boshielo, Nandoni and Tzaneen dams (Brits, 2006; Fouché, 2009; Fouché *et al*., 2013). However, there are some concerns regarding impoundments within the Limpopo Province, especially those in the Olifants River System (ORS) as the river system has been systemically impaired by pollution over the years, with potential implications for the health of the fisheries resources (Dabrowski *et al*., 2014; Jooste *et al.,* 2015; Sara *et al*., 2020).

1.4 Exploitation potential of inland fisheries resources in South Africa

To achieve a sustainable inland fisheries sector in South Africa, it is essential to have a robust management strategy guided by scientifically generated fisheries data (Weyl *et al*., 2020). Previous attempts at developing inland fisheries in the country were unsuccessful due to unrealistic expectations and a lack of understanding of the capacity of inland fishery resources to provide fish stocks sustainably (Weyl *et al.*, 2007; McCafferty *et al*., 2012; Britz *et al*., 2015). Nevertheless, these past failures present an opportunity for South Africa to rectify its previous mistakes and create a thriving inland fisheries sector.

1.5 Inland fisheries sector in Limpopo Province

Limpopo is one of the provinces in South Africa where poverty and unemployment are among the many challenges that the youth face. To curtail these challenges, the South African government seeks alternative means to redress the effects of poverty and unemployment. In response, the government, through the Department of Forestry, Fisheries and the Environment (DFFE) has identified inland fisheries as a sector with the potential to contribute towards curbing poverty and ensuring food security, especially among rural communities that reside in close proximity to large freshwater bodies (Hara & Backerbeg, 2014). In Limpopo Province, there are large state-owned dams that have been built to supply water for domestic, mining, industrial, and agricultural purposes. Although not well documented, the capture of freshwater fish in Limpopo from impoundments such as FBD (Hlungwani *et al*., 2023) and GAD are envisaged to be of major importance to the livelihoods of most rural communities residing in their proximity. Hence, the knowledge, attitudes and practices of small-scale fishery users, and assessments of fishery resources should be prioritised if the envisaged implementation of the inland fisheries policy developed by the DFFE is to be achieved.

The current lack of legislation to govern inland fisheries in the Limpopo Province has resulted in the informal nature of the sector, where small-scale fisheries are often characterised as informal and subsistence-level activities (Tapela *et al.*, 2015). For these informal small-scale fisheries to become more formalised and sustainable, the harvesting potential of fishery resources should be informed by site-specific scientific evaluations. In the Limpopo Province, small-scale fisheries not only provide direct economic benefits through fish sales but are also crucial for providing food and a source of protein to rural households. Moreover, small-scale fisheries that are managed sustainably have the potential to contribute to local economies by creating income through fishing and related industries, such as eco-tourism (Britz *et al.*, 2015). In addition, inland fisheries undertaken by rural communities in landlocked provinces such as Limpopo present a practical alternative that can reduce the heavy reliance on marine fisheries (Weyl *et al*., 2007).

Inland fisheries resources in Limpopo Province are mainly used by small-scale fishers with limited knowledge of the sustainable use of the resources. The practices remain

largely uncontrolled and informal, and fishers continue to rely primarily on the uncontrolled harvesting of the fish. In addition, the absence of comprehensive, long-term data on fish stocks and fishing efforts constrains the development of evidence-based management strategies. A sustainable fishery in the province has the potential to contribute towards curbing food insecurity among communities residing close to the impoundments. However, the benefits of establishing a sustainable inland fisheries sector in the province currently face several challenges, such as overfishing, habitat degradation, pollution, mismanagement, and climate change (Marr *et al*. 2024). Overfishing and the lack of formal management structures dedicated to fisheries resources are amongst the major stressors threatening fish populations and biodiversity in Limpopo Province. Given the current trend, fishers will continue to catch fish unsustainably, with capture rates that are higher than the recruitment of the natural fish population (Marr *et al*., 2024).

1.6 Fisheries assessment methods

The morpho-edaphic index (MEI) is the basis for the present estimations of the potential yield attainable from South African inland water bodies; however, these MEIs have not been validated for South Africa water bodies (Weyl *et al*., 2020). If the sector is to be developed for economic benefits and long-term sustainability of fish stocks, the fish stock surveys that provide biological reference points for managing fishery target species based on life history characteristics and the selectivity of the harvesting gears should be a priority (Britz *et al*., 2015; Tweddle *et al*., 2015). Fish stock surveys are important not only to better understand the population dynamics of the fish stocks, but to provide input into the economic viability of establishing fisheries, especially in areas where the communities depend on the resources for livelihoods. Full stock assessments must be conducted in South African impoundments before a decision can be made on whether a fishery will be socially, economically, and biologically sustainable. Typically, as shown by Britz *et al.* (2015) such assessments should include comprehensive surveys to determine:

- the target species and initial productivity estimate of the resource (relative abundance and catch rates, catch per unit effort)

- the best harvest strategy to ensure sustainable fishing practices (predictive modelling)
- how a fishery is likely to impact non-target species that are of conservation concern (gear suitability, exploitation potential, and species population dynamics).

1.7 Productivity estimates of the resource

In fisheries studies, relative abundance and catch rates are determined using the Catch Per-Unit Effort (CPUE). The CPUE is an indirect measure of the abundance of a target species (Puertas & Bodmer, 2004), and changes in the CPUE indicate changes to the target species' initial or determined abundance in a fishery. For example, a decreasing CPUE indicates unsustainable exploitation, while an unchanging CPUE indicates sustainable harvesting (Puertas & Bodmer, 2004). The CPUE has several advantages over other methods of measuring abundance because it does not interfere with routine harvesting operations, and the data can be collected easily (Kantoussan *et al.*, 2014). The data is easy to analyse, even for non-specialists, in contrast to methods based on transects (Puertas & Bodmer, 2004) which means that decisions about stock management can be made by the fishers doing the harvesting themselves, rather than by specialists. The best practice when using CPUE is to standardise the effort employed (the duration of fishing using a specific gear), which controls for the reduction in catch size that often results from subsequent efforts. However, a disadvantage of using the CPUE is that many users find it difficult to define the unit of the effort (Puertas & Bodmer, 2004). Although this may be the case, the CPUE remains a good index to use especially in South Africa where many impoundments lack the catch rates data. Therefore, employing CPUE, which can be obtained independent of the history of the fishery is the best way to determine initial abundances of targeted fishery species.

1.8 Fisheries harvest strategies

Gill nets are one of the fishing gears widely used for commercial fisheries and research purposes (Hamley & Regier, 1973; Doll *et al.,* 2014). Gill nets are the preferred sampling method because they are selective, and when used appropriately, the fish

population structure and fish abundance can be estimated with high confidence (Hamley & Regier, 1973; Doll *et al.,* 2014) which is important because accurate estimations of fish stocks have implications for fisheries management. Therefore, quantifying gill net selectivity is crucial, especially for open-access fisheries in South Africa, such as the FBD, where the use of monofilament gill nets has been reported to be on the rise in recent years (Sara *et al*., 2017).

Methods of estimating gill net selectivity vary and depend on factors such as mesh size, elastic stretching of the net, inelastic stretching of the net, hanging coefficient of the net and the shape of the fish (Clark, 1960; Potts, 2003). The most used methods for determining gill net selectivity are direct and indirect methods (Smith *et al*., 2017). Direct estimates compute the length-frequency distributions of the fish population using gill net catches and compare these size distributions with a known standard, such as the size distribution of the fish population (Borgström, 1989; Yokota *et al*., 2001). Since South Africa lacks catch and effort data, the indirect method is the most suitable method to determine gill net selectivity. This method makes assumptions using catch frequencies from different mesh sizes and statistical software to estimate the selectivity parameters (Tanaka, 2002). It requires no knowledge of the size distribution of the fish population, instead it relies on suitable assumptions about the nature of the selectivity curves. In addition, the indirect method typically requires less experimental time and expense than direct methods. As a result, indirect methods have been applied to a large range of data-limited fisheries (Gulland & Harding, 1961; Doll *et al*., 2014; Smith *et al*., 2017).

1.9 Resource utilisation practices

The potential for inland fisheries to increase food security and provide livelihoods is often compromised by the effects of intense fishing pressure, which can depress catch rates and affect socio-economic benefits for fishers by depleting larger, more valuable species in the fishery (Tweddle *et al.,* 2015; Irvine *et al*., 2019). The quantification of harvests in relation to estimates of the potential yield from inland fisheries is essential for developing a coherent management strategy (Weyl *et al*., 2020). In South Africa, the available assessments of current fishing efforts and harvests are limited to isolated case studies. These include estimates of the fishing effort and catch rates based on roving creel surveys of anglers at Gariep Dam (Ellender *et al*., 2010a), harvests from

formal catch returns from commercial fisheries (Barkhuizen *et al.*, 2016), and participation from the enumeration of angling license sales in the Free State Province (Barkhuizen *et al*., 2017). As the information on current harvests is important not only from a management perspective, but also for national-level assessments of food security, developing a monitoring system to determine current participation and harvests is an urgent requirement (Weyl *et al*., 2020). Such monitoring systems for small-scale fisheries are relatively well developed in African Great Lakes, where inland fisheries are highly organised and concentrated in large water bodies (Irvine *et al*., 2019).

2. RATIONALE OF THE PROJECT

The DFFE developed the National Freshwater (Inland) Wild Capture Fisheries Policy (NFWCFP) which was gazetted for implementation in February 2022. Currently, the policy needs an Implementation Plan, and to support this process, a properly focused research strategy is essential to guide its development (Weyl *et al*., 2020; Hlungwani *et al*., 2023; Marr *et al*., 2024). However, the lack of locality-specific fisheries data in South Africa remains a major constraint towards such development. To support the implementation plan of the policy, a pilot case in the Limpopo Province was chosen on the basis that Hlungwani *et al*. (2023) and Marr *et al*. (2024) provided the locality-specific fisheries data and biological sustainable harvest reference points for *O. mossambicus* and *L. rosae* Steindachner, 1894 which were identified as candidate species from 2016 to 2018 assessments in the impoundment. Using Hlungwani *et al.* (2023) and Marr *et al*. (2024)'s recommendations, a pilot fisheries project in FBD was deemed necessary to explore the possible means of developing a fishery to support much-needed food security for the rural communities surrounding the fishery.

In addition to using the FBD as a pilot case study, more locality-specific data for potential fisheries species was investigated in other impoundments, such as the GAD. This was deemed necessary to inform the Implementation Plan of the policy through providing the biological data that forms the basis of sustainable development of the inland fisheries sector (Britz *et al*., 2015; Weyl *et al*., 2021), especially in a province predicted to have a high inland fisheries potential.

2.1 Scope and context of the project

The utilisation of freshwater fish resources as an important source of food and protein in Limpopo Province continues to increase, particularly for the rural communities (Hlungwani *et al.*, 2023; Marr *et al*., 2024). However, for sustainable inland fisheries development in South Africa, it is highly recommended that the policy is informed by biological research to provide management advice on the sustainability of the sector. As is in many parts of South Africa, inland fisheries in Limpopo Province are currently not formally developed or regulated. As it stands, there is no categorisation or recognition of the users and the sector itself. As shown in other parts of southern Africa, uncontrolled and unregulated fisheries often lead to overexploitation and unsustainable harvesting (Tweddle *et al*., 2015).

Initial research efforts to determine the exploitation potential of fisheries, and the evaluation of the current use of the fisheries, should be a priority for the South African government to inform the sustainable development of the sector. This project adopted the strategy outlined in Figure 1.1 to inform the sustainable utilisation of the Flag Boshielo and Glen Alpine fisheries, in which stock assessment surveys were the first step towards determining fish stocks, target species, exploitation potential and the application of predictive modelling to inform a management strategy.

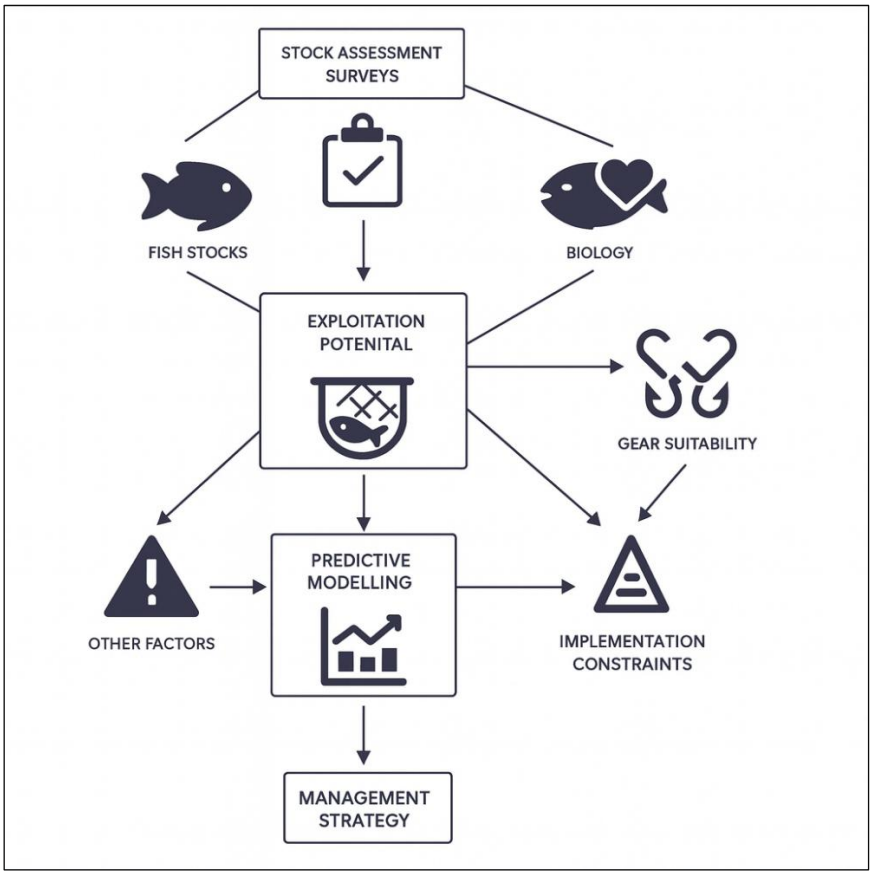


Figure 1.1: Inland fisheries assessment framework (Hlungwani, 2021).

Hlungwani *et al*. (2023) determined the fish stocks, target species and exploitation potential for FBD. However, there is a need to test the sustainability of harvesting the identified target species as a pilot study. Determining fish stocks, target species and the exploitation potential of GAD is a requirement to benchmark the fisheries potential of the province. In addition, attention was focused on the provision of the utilisation patterns of the fisheries and the contribution of these fisheries was related to the livelihoods associated with harvesting fish from the FBD as a contribution towards the implementation strategy. Using these two impoundments as test cases to explore the exploitation potential for a fishery was seen as an immediate knowledge requirement to validate the predictions of Hlungwani *et al.* (2023) and add to the sustainable development of inland fisheries in Limpopo Province, as outlined by Marr *et al.* (2024).

2.2 Aims of the project

The sustainable development of South Africa's inland fisheries sector offers a viable pathway for advancing key policy objectives, including food security and poverty alleviation. However, the provision of locally specific fisheries-associated data to guide

this development remains critical, as failures in other southern African countries have shown that the absence of such information can contribute to the collapse or underperformance of the inland fisheries sector. Hence this project aimed to:

- determine the exploitation potential of South Africa's inland fisheries resources using FBD and GAD as case studies;
- determine the impacts of water level fluctuations on catch rates and fish production in FBD;
- outline the options for fisheries enhancement in FBD and GAD;
- establish the utilisation patterns of FBD and GAD;
- pilot a fisheries project in Flag Boshielo Dam to support the implementation of the NFWCFP.

3. STRUCTURE OF THE REPORT

This report is presented in five chapters. Each chapter addresses specific components of the scope of work outlined for this project. Here, an outline of each chapter is presented to provide the reader a quick overview of the content of the respective chapters and their contribution to the report:

Chapter 1 establishes the broader context of inland fisheries globally and within South Africa. It highlights the essential role inland fisheries play in food security, nutrition, livelihoods, and rural poverty alleviation, particularly in regions with high unemployment such as Limpopo Province. Despite their importance, South Africa's inland fisheries remain largely informal and lack appropriate recognition, governance, and scientific support. The chapter motivates the need for structured, evidence-based development of inland fisheries and identifies critical gaps in biological, ecological, and socio-economic data, especially for systems such as FBD and GAD. These gaps form the rationale for the current study, which aims to generate the empirical knowledge required to guide emerging national inland fisheries policy and sustainable utilisation frameworks.

Chapter 2 outlines the research design adopted to assess the ecological and socio-economic dimensions of fisheries at FBD and GAD. It describes the seasonal sampling

framework, the gears employed, and the environmental variables monitored. Methods enabled comprehensive characterisation of fish communities, stock structure, and basic biological traits while capturing user-group dynamics through socio-economic surveys. By detailing procedures for biological sampling, physico-chemical profiling, and household-level data collection, the chapter establishes the methodological foundation required to evaluate exploitation potential and livelihood dependencies at both dams.

Chapter 3 sets out to document the current fish assemblages in both impoundments, quantify relative abundance, and assess catch rates using standardised sampling gears. The aim is to determine which species presently dominate the system, which species show potential for supporting fisheries, and how current stock structures compare to historical baselines. The chapter further seeks to understand how fishing effort, water level dynamics, and environmental conditions are shaping fish community composition, with the goal of evaluating the feasibility of fisheries development under present ecological conditions.

Chapter 4 examines the biological characteristics of key species identified as potentially important for fisheries development. These characteristics include growth patterns, age composition, maturity stages, and recruitment traits. The purpose of the chapter is to evaluate whether these species possess life-history strategies compatible with sustainable exploitation and to determine what biological indicators are necessary to support future fisheries modelling. The chapter outlines an assessment of whether alternative species may serve as viable targets in the event of shifts in dominance within the fish community.

Chapter 5 investigates the human dimensions of inland fisheries at the two study sites. It documents patterns of resource use by subsistence fishers, recreational anglers, and local households, and explores the motivations, economic constraints, and livelihood functions associated with fishing activities. The chapter aims to clarify how different user groups interact with the resource, what barriers and inequalities shape access, and how fishing contributes to household economies and food systems. This socio-economic insight is essential for designing equitable and realistic management strategies.

Chapter 6 integrates ecological, biological, and socio-economic insights to form a holistic interpretation of the current state of inland fisheries at FBD and GAD. The chapter presents an assessment of whether conditions at the two systems align with the requirements for sustainable small-scale fisheries development and identifies key areas where governance, restoration, monitoring, and capacity building will be essential. The chapter's purpose is to outline a practical pathway toward sustainable inland fisheries, including strategic governance reforms, biological recovery measures, community-centred management, and long-term scientific monitoring. These recommendations contribute directly to national policy development and the broader objective of establishing formal, sustainable inland fisheries in South Africa.

CHAPTER 2: GENERAL METHODS AND MATERIALS

1. DESCRIPTION OF THE STUDY SITES

1.1 The Olifants River System

Historically, the Olifants River was a strong-flowing perennial river, but it has shifted into a weak perennial river that increasingly experiences periods of no flow in some sections of the river length (Ashton *et al.,* 2001; Sara *et al.,* 2017). This degradation is driven by increased water abstractions for mining and agricultural activities, land-use change compounded by weak governance, inadequate regulation, and poor enforcement of regulations (Dabrowski *et al.,* 2014). When combined with the escalating threats of climate change, persistent rural poverty, and food insecurity, these pressures heighten livelihood vulnerability, accelerate environmental degradation, and increase the potential for intensified conflict over scarce water resources within the Olifants River Catchment (ORC).The upper ORC comprises Witbank, Middleburg, Bronkhorstspruit and Premiere dams upstream of Loskop Dam (Dabrowski *et al.,* 2014), where the middle reach of the catchment comprises the FBD (Figure 2.1), with the lower reaches beginning downstream of location of the Phalaborwa Barrage (Heath *et al*., 2010). Major tributaries in the middle catchment of Olifants River are the Selons, Moses, Bloed, and Elands rivers (Heath *et al*., 2010). The lower catchment comprises the areas below the confluence where the Letaba and Olifants rivers meet and cross the Kruger National Park into Mozambique.

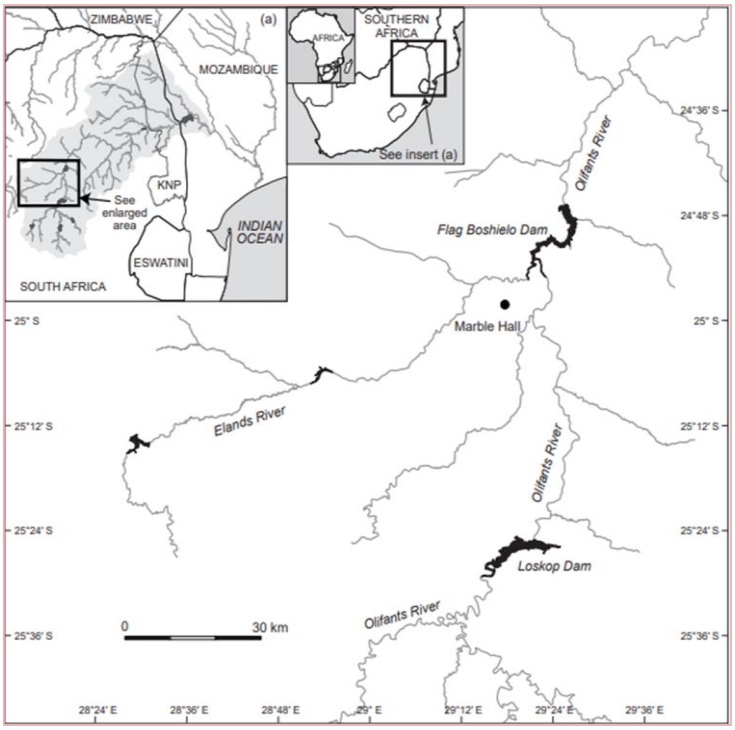


Figure 2.1: The location and profile of Flag Boshielo Dam in South Africa in relation to the Elands and Olifants rivers that flow into the impoundment (Dabrowski *et al*., 2013).

The geographic position of the ORC means that prevailing winds, and the landfall of tropical cyclones from the Indian Ocean influence its climate (Ashton *et al.,* 2001). Air temperatures across the basin show a marked seasonal cycle, with the hottest temperatures occurring during early summer and the lowest temperatures during cool, dry winter months (Dabrowski *et al*., 2014). Within the highveld, rainfall is highly seasonal, falling predominantly during warmer summer months. The climate in the ORC is described as semi-arid and hot with an annual average rainfall of 400 mm but can be as high as 800 to 900 mm annually on the Mpumalanga Highveld (Ashton 2010).

Land-use activities along the Olifants River include mining, industry, coal-fired electric power generation with chrome and steel smelters occurring close to the cities of Witbank and Middleburg in the upper catchment (Dabrowski *et al*., 2014). In the middle catchment there is intense irrigated agriculture and rural development, while land use in the lower catchment is dominated by mining and nature conservation (Heath *et al.,* 2010). Acid Mine Drainage (AMD) (Hobbs *et al.,* 2008), acid rain, the discharge of industrial effluents, and nutrient enrichment from domestic sources (De Villiers and

Thiart, 2007), habitat destruction, and soil erosion have polluted and degraded the water quality in this system. Consequently, the system has received considerable media and scientific attention due to episodic deaths of fish and crocodiles (Ashton, 2010; Sara *et al*., 2020), raising concerns about various anthropogenic factors influencing water quality in the system's upper catchment.

The Olifants River is one of the main river systems threatened by pollution (Heath *et al.,* 2010; Lebepe *et al*., 2016) and is characterised by elevated levels of metals, nutrients and sulphate (De Villiers & Mkwelo, 2009; Oberholster *et al.,* 2010; Dabrowski *et al*., 2014). The effluents emanating from abandoned mines in the upper catchment were found to contribute heavily to the pollution of the ORC (Dabrowski *et al.,* 2013) with the result that the AMD is increasing concentrations of sulphates, dissolved salts, metal ions and, in some instances, radionuclides to the already stressed river and impoundments (De Villiers & Mkwelo, 2009). Flag Boshielo and Loskop dams have also been reported to be alkaline, with high sediment metal concentrations over the past few years (Oberholster *et al*., 2010; Lebepe *et al*., 2016). Given the on-going coal mining activities in the upper ORC (Hodgson & Krantz, 1998), the AMD from abandoned mines may result in a drop in pH, which may remobilise metals back into the water column.

1.2 The Mogalakwena River

The Mogalakwena River is a 250 km long river (Tooth *et al*., 2002; Greenfield *et al*., 2007) that flows into the main stem of the Limpopo River near Limpokwena Nature Reserve in the Limpopo Province (Figure 2.2). The river's source is located at the downstream portion of the Nyl River floodplain near the town of Mokopane. The GAD is the only major impoundment within the main stem of the Mogalakwena River, with the Nyl Dam (located upstream in the Nyl River in Mokopane) and the Doorndraai Dam (located on the Sterkrivier on the outskirts of Mokopane) representing major impoundments on the Mogalakwena's tributaries. Several small farm dams are located downstream of GAD (Figure 2.2). The upstream section of the river catchment, which falls within the Nyl River floodplain, is exposed to metal contamination emanating from some settlements located within the vicinity. The catchment is characterised by

various activities, including farming (crops and livestock) and mining, as well as the presence of various urban and rural settlements (Hecht, 1980).

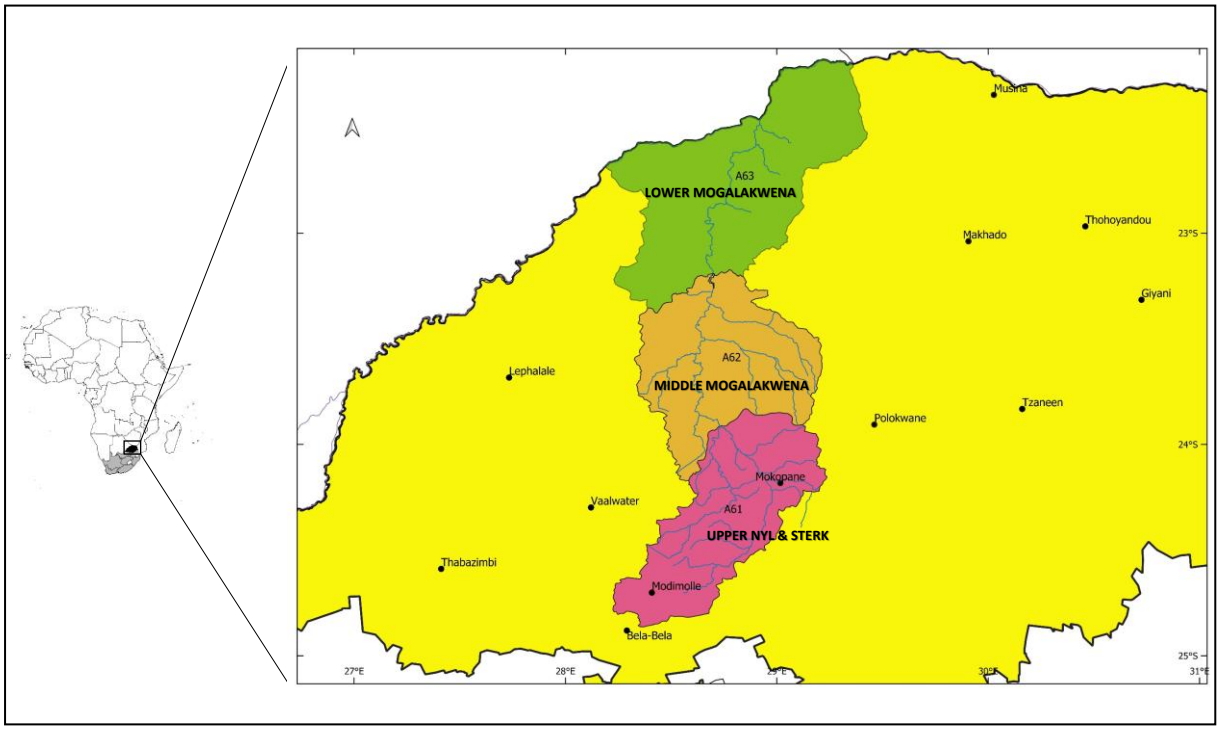


Figure 2.2: Map of the Mogalakwena River System catchment showing locations of major towns, impoundments and tributaries.

2. SELECTED STUDY SITES

2.1 Flag Boshielo Dam

The FBD (24°47′0″S: 029°25′40″E), previously known as Arabie Dam, was constructed in 1987, and the wall raised by a further 5 metres to a height of 30 m in 2005 (Ashton, 2010). This impoundment is located downstream of the confluence of the Olifants and Elands rivers (Figure 2.3). The reservoir is situated about 85 km downstream of Loskop Dam and approximately 25 km north-east from the town of Marble Hall in the extreme north-western corner of the Limpopo Province (Madanire-Moyo *et al.,* 2012a). With a mean depth of 8,15 m, the catchment area of the dam covers 4213 km^2 (Dabrowski *et al.,* 2014) and provides water to neighbouring municipal and rural districts for domestic, agriculture, and mining purposes (Ashton *et al*., 2001). The Schuinsdraai Nature Reserve covers a large portion of the FBD western shore where public access is limited to recreational anglers and wildlife enthusiasts. Recreational

angling activities are designated to a region of shoreline that stretches 1 km adjacent to the reserve's main gate. Conservation officers and park rangers often patrol the shoreline of the reserve. In contrast, besides the state-run Tompi Seleka Agricultural College and the privately-owned Aloe Park Holiday and Fishing Resort, public access to the eastern shore of the impoundment is unrestricted, and small-scale fishers can be seen along the bank.

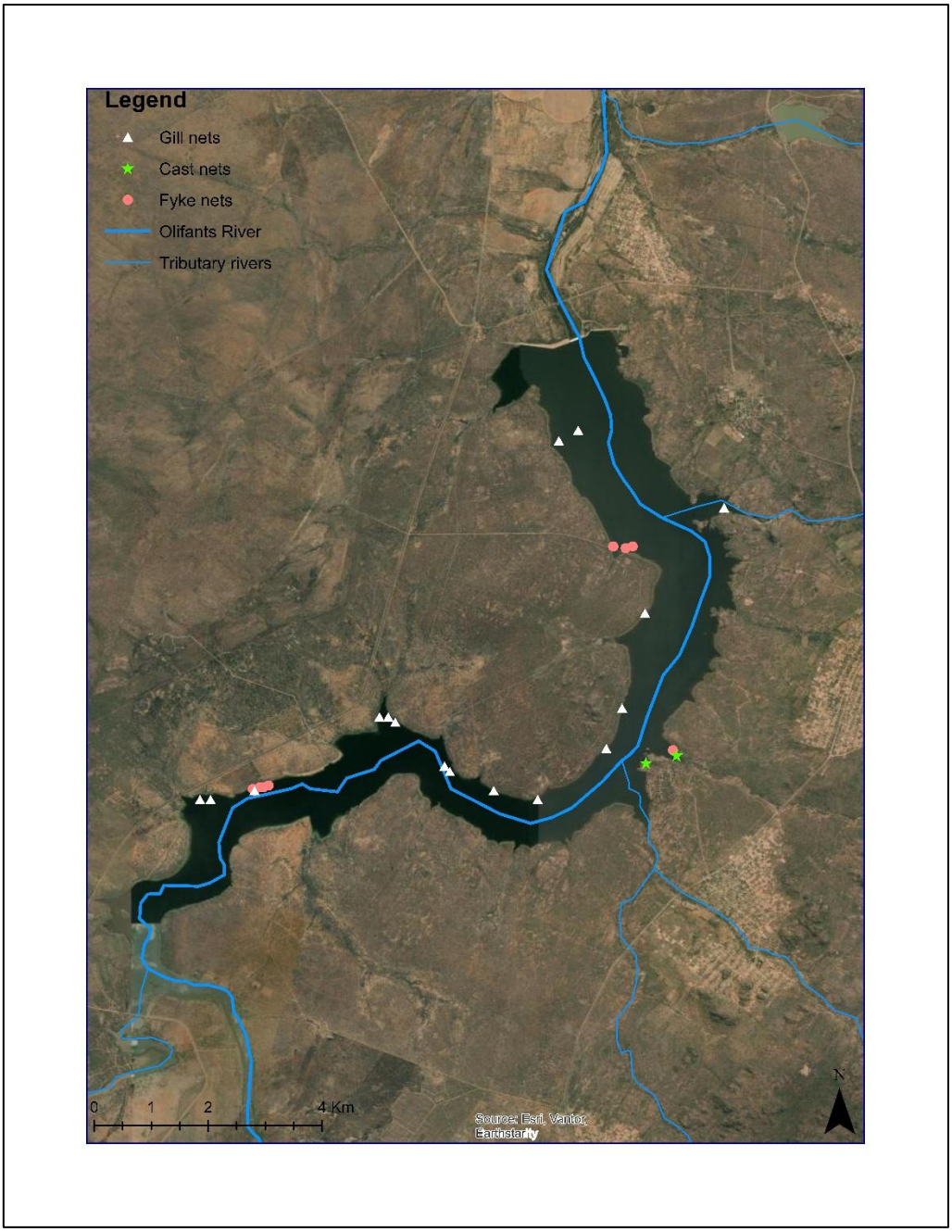


Figure 2.3: The profile of Flag Boshielo Dam and the sites where fishing gears were set.

Over the past four years (2019 to 2022), an increase in the use of illegal monofilament gill nets has been observed in waters along the eastern and western shorelines (Sara *et al*., 2017). The FBD has become an important recreational fishing venue over the years, hosting regular angling competitions for species such as the indigenous *O. mossambicus* and invasive alien sport-fishes such as the largemouth bass *Micropterus negricans* (Lacepède, 1802), the common carp *Cyprinus carpio* (Linnaeus, 1758) and the silver carp *Hypophthalmichthys molitrix* (Valenciennes, 1844). The latter species has become a major drawcard for coarse and recreational anglers after it was accidentally introduced into the impoundment in the early 1990s from an aquaculture research facility that was situated on the riverbanks adjacent the Olifants-Elands river confluence (Sara *et al*., 2017).

2.1.1 Physical characteristics of Flag Boshielo Dam

Flag Boshielo Dam and its tributaries fall within the southern temperate highveld freshwater eco-region (Abell *et al*., 2008). Ecologically, the dam is surrounded by typical savannah and bushveld vegetation with many partly and fully submerged dead trees providing habitat for piscivorous birds like darters, herons, cormorants and fish eagles (Jooste *et al*., 2015). The reservoir also hosts a considerable, albeit declining, population of Nile crocodiles (Botha *et al*., 2011). The impoundment supports a subsistence fishery that is important to the surrounding rural communities (Dabrowski *et al*., 2013; Tapela *et al*., 2015).

Over the past few decades, pollution associated with various land-use activities, AMD, and effluent from anthropogenic sources within the watershed of Olifants River has resulted in the impoundment becoming one of the most threatened and polluted (Heath *et al*., 2010; Ashton and Dabrowski, 2011; Huchzermeyer *et al.*, 2011; Jooste *et al*., 2015; Marr *et al*., 2015; Azeez *et al*., 2017; Oberholster *et al*., 2017). As a result, many studies in the impoundment have investigated the metal and metalloid content in *O. mossambicus* (Addo-Bediako *et al*., 2014a); butter catfish *Schilbe depressirostris* (Peters, 1852) (Addo-Bediako *et al*., 2014b, Marr *et al*., 2015); *L. rosae* (Jooste *et al*., 2014; Lebepe *et al*., 2016; Marr *et al*., 2017); the *C. gariepinus* (Jooste *et al*., 2015; Marr *et al*., 2015), the brown squeaker *Synodontis zambezensis* (Peters, 1852) (Sara *et al*., 2017) and the silver carp *H. molitrix* (Sara *et al*., 2018).

2.1.2 Fish fauna of Flag Boshielo Dam

Brits (2006), Sara *et al.* (2017) and Hlungwani *et al.* (2023) have reviewed the composition and status of the ichthyofauna in FBD. Their research into the fish composition and fish abundance involved monthly surveys and the use of gill nets, seine nets, mosquito nets, and electro-fishing equipment. The catch composition consisted of species such as *L. rosae* and *O. mossambicus* (Table 2.1). Hlungwani *et al.* (2023) corroborated the findings of Sara *et al*. (2017) in FBD recording *M. negricans*, *S. zambezensis*, threespot barb *Enteromius trimaculatus* (Peters, 1852) and the largescale yellowfish *Labeobarbus marequensis* (A. Smith, 1841).

Table 2.1: The composition of fish species captured in Flag Boshielo by Brits (2006), Sara *et al.* (2017) and Hlungwani *et al.* (2023).

Species	Common name	Conservation status
Enteromius paludinosus (Peters, 1852)	Straightfin Barb	Least concern
Enteromius rapax (Guimarães, 1884)	Papermouth	Least concern
Enteromius trimaculatus (Peters, 1852)	Threespot Barb	Least concern
Enteromius unitaeniatus Günther, 1866	Slender Barb	Least concern
Clarias gariepinus (Burchell, 1822)	Sharptooth Catfish	Least concern
Coptodon rendalli (Boulenger, 1896)	Redbreast Tilapia	Least concern
Ctenopharyngodon idella (Valenciennes, 1844)	Grass Carp	Invasive alien
Cyprinus carpio Linnaeus, 1758	Common Carp	Invasive alien
Hypophthalmicthys molitrix (Valenciennes, 1844)	Silver Carp	Invasive alien
Labeo cylindricus Peters, 1852	Redeye Labeo	Least concern
Labeo molybdinus Du Plessis, 1963	Leaden Labeo	Least concern
Labeo rosae Steindachner, 1894	Rednose Labeo	Least concern
Labeobarbus marequensis (A. Smith, 1841)	Largescale Yellowfish	Least concern
Labeobarbus polylepis (Boulenger, 1907)	Smallscale Yellowfish	Least concern
Marcusenius krameri Maake, Gon & Swartz, 2014	Limpopo Bulldog	Least concern
Engraulicypris brevianalis (Boulenger, 1908)	River Sardine	Least concern
Micralestes acutidens (Peters, 1852)	Silver robber	Least concern
Micropterus nigricans (Lacepède, 1802)	Largemouth Bass	Invasive alien
Oreochromis mossambicus (Peters, 1852)	Mozambique Tilapia	Vulnerable
Pseudocrenilabrus philander (Weber, 1897)	Southern Mouthbrooder	Least concern
Schilbe depressirostris (Peters, 1852)	Butter Catfish	Least concern
Synodontis zambezensis Peters, 1852	Brown Squeaker	Least concern
Tilapia sparrmanii Smith, 1840	Banded Tilapia	Least concern

2.2 Glen Alpine Dam

The Glen Alpine Dam (23°14″S:28°42″E) is a gravity and earth-fill dam (Figure 2.4) located south of the Zoutpansberg mountain range and has a total surface area of 500 hectares (Hecht, 1980). The dam was primarily constructed to supply water for the cultivation of tobacco and maize and is located on the main channel of the Mogalakwena River, where it forms the eastern boundary of the Wonderkop Nature Reserve near Bochum in Limpopo Province. The Driekoppies, Mmankgodi and Papegaai villages are located on the eastern side of GAD, providing public access points to the waterbody. However, information on the physio-characteristics of the dam is relatively scant, and no studies have focussed on the potential of fisheries in the dam. This project presents the first record of species composition, limnology and biology of the species as an opportunity to describe an otherwise 'neglected' waterbody, with the potential for the development of a sustainable fishery for the benefit of local communities.



Figure 2.4: Glen Alpine Dam wall during January 2025, when the dam level was above full capacity.

3. GENERAL SAMPLING METHODS

The main aim of fishery assessments is to determine the status of fish stocks and establish safe harvest levels for sustainable exploitation (Weyl *et al*., 2020). As shown in Hlungwani *et al*. (2024) and Marr *et al.* (2024), catch and effort data give a good indication of the site-specific potential of a fishery. However, it is as important to determine the utilisation patterns of the fishery by fishermen as it is to determine how the fish stocks respond to fishing pressure. The main motivation for fishermen to fish, together with their social and economic status, are key elements to understanding the impacts that resource utilisation may have on the targeted fish stocks (FAO, 2020). The actions of fishermen are at the centre of understanding fisheries resources (Ellender *et al*., 2010a), especially for open-access fisheries such as FBD and GAD. Sustainable development of inland fisheries in South Africa requires balancing food production with aquatic biodiversity conservation, as past examples such as the collapse of river fisheries in the Zambezi have shown how uncontrolled harvesting can rapidly deplete fish stocks (Tweddle *et al.*, 2015). Where dams contain rare or threatened species, their protection must be integrated into management plans before fisheries are established. In addition, scientific assessments are needed to determine the safety and suitability of fish for human consumption, and regulations must clearly identify any health hazards associated with consuming fish from inland fisheries.

3.1 Ethical clearance and permits

All research activities followed the regulations stipulated in the ethical clearance and research permit approved for this specific project. An animal research (AREC-290914-017) and human ethics (REC-0310111-031) committee ethical clearance to carry out scientific research on aquatic biota and humans was obtained from the University of Limpopo (UL). Co-approval for the research was also obtained from the NRF-SAIAB Animal Ethics Committee (REF No. 2024-09). A permit to do scientific work in Limpopo Province was obtained from the Limpopo Department of Economic Development, Environment and Tourism (Permit number 1182281).

3.2 Fish surveys

During surveys, sampling sites were selected to be representative of the riverine, transition and main basin zones in the dams. To include seasonal trends, the dams were surveyed between May 2024 and February 2025. During each survey, each dam was mapped according to its depth profile, its substrate, aquatic macrophytes, tributaries and any other factors that could influence fish distribution. Water quality parameters were measured at each site using multi-parameter water quality meters. The following fishing gears were used during the surveys: 1) experimental gill nets with different standardised mesh sizes (44, 60, 70, 100 and 144 mm) were used to collect fish. All fish captured were identified to species level following the identification keys in Skelton (2001), measured to the nearest millimetre (FL) and weighed to the nearest 0.1 g; 2) a set of four fyke nets were deployed on the shallow habitats, and 3) cast nets were used to sample the shoreline.

3.3 Socio-economic study

An assessment of the current use and socio-economic contribution of small-scale fisheries at FBD and GAD was conducted through comprehensive surveys of participation, catch and utilisation (e.g. food or income) patterns. A questionnaire (see Appendix A) was used to determine factors such as the origin of the fishery users, fishery user demographics (race/gender/age), primary motivation for fishing (sale, recreation, or subsistence), means of transport used to get to the dam (walk, bicycle, lift, own vehicle), occupation (unemployed, permanent, part-time, pensioner, student/scholar), gear types (hand line, fishing rod or gill net) and catch size as outlined by Ellender *et al*. (2009). The socio-economic data collected throughout the course of the project was also used to assess the current knowledge of, attitudes to and practices of small-scale fishers using the resource to determine whether participation (and competition for the fish resource) is related to food security and poverty alleviation. The project further identified individuals with local knowledge and expertise in inland fisheries and developed a concept for the dissemination of this knowledge to communities where fishing is less prevalent.

CHAPTER 3: SPECIES COMPOSITION AND CATCH RATES FROM THE FLAG BOSHIELO AND GLEN ALPINE FISHERIES RESOURCES, LIMPOPO PROVINCE, SOUTH AFRICA

[1,2,5]Hlungwani HA, [2]Magoro ML, [2,3]Mofu L, [2]Ndaleni PM, and [4]Khosa D

[1]Department of Forestry, Fisheries and the Environment
[2]National Research Foundation- South African Institute for Aquatic Biodiversity
[3]Department of Ichthyology and Fisheries Science, Rhodes University, Grahamstown,
[4]Scientific Services, South African National Parks, Skukuza
[5]Department of Biodiversity, University of Limpopo, Turfloop.

1. INTRODUCTION

Limpopo is one of the provinces in South Africa where poverty, food insecurity, and unemployment remain significant challenges, particularly affecting the youth (Hara & Backeberg, 2014). To address these challenges, the South African government continues to explore sustainable livelihood opportunities to improve socio-economic conditions in rural communities. In this regard, the DFFE has identified inland fisheries as a sector with the potential to support poverty alleviation and enhance food security, especially for rural households living near major freshwater systems (Hlungwani, 2021).

In Limpopo Province, large state-owned dams have been built to supply water for domestic, mining, industrial, and agricultural purposes (Marr *et al*., 2024). Although not well documented, the capture of freshwater fish in Limpopo Province from dams such as FBD and GAD is envisaged to be of major importance to the livelihoods of most rural communities residing in proximity to these waterbodies. Thus, the knowledge, attitudes and practices of small-scale fishery users and assessments of fishery resources should be prioritised if the envisaged implementation of the NFWCFP developed by the DFFE is to be realised.

The current lack of legislation to govern and recognise inland fisheries in Limpopo, Province, as in many parts of South Africa, has resulted in the informal nature of the sector where small-scale fisheries are characterised as informal and subsistence-level

activities (Tapela *et al.*, 2015). For these informal small-scale fisheries to become more formalised and sustainable, the harvesting potential of fishery resources should be informed by scientific evaluations that are site specific (Hlungwani *et al*., 2024). In Limpopo Province, small-scale fisheries do not only provide direct economic benefits through the sale of fish but are crucial at providing food and a source of protein to rural households (Mokhaukhau *et al.*, 2020; Hara *et al*., 2021). Moreover, small-scale fisheries managed sustainably have the potential to contribute to local economies by creating income through fishing and related industries such as eco-tourism (Britz *et al.*, 2015).

Hlungwani *et al.* (2023) described the biological parameters of exploitable species at the FBD to inform the sustainable harvest limits targeting *L. rosae* and *O. mossambicus* if a formal fishery was to be established. In addition, Marr *et al*. (2024) showed the yield-per-recruit (YPR) and spawner biomass per recruit (SBR) for both *L. rosae* and *O. mossambicus*, indicating biological sustainable harvest reference points for FBD. However, given that the study by Hlungwani *et al*. (2023) was conducted between 2016 and 2018 when water levels in FBD had decreased to the lows of 17% capacity in 2017, a follow-up study was recommended to institute evidence-based sustainable harvest levels and to test the effects that water level fluctuations have on fish catches in the FBD.

The GAD was also selected as a possible fishery site to determine its fishery potential and its influence on the livelihoods of rural communities residing closer to the dam. Currently, there is no published information on the fish composition and potential fish yields for this system (GAD). This information is prerequisite to the formation of management strategies that are key building blocks towards the development of the implementation plan of the NFWCFP.

2. METHODS AND MATERIALS

2.1 Aims and Objectives of the Chapter

This chapter aims to determine the patterns observed during fishery resource assessments at FBD and GAD.

The objectives of this chapter were to:

- Determine the physico-chemical parameters by undertaking seasonal water surveys in FBD and GAD.
- Establish the fish composition and diversity using different fishing gear in FBD and GAD.
- Determine the catch-per-unit effort (CPUE) of fish species in FBD and GAD.
- Highlight the impacts of water fluctuations on fish catches and composition in FBD and GAD.

2.2 Physico-chemical parameters

Triplicate physico-chemical parameters were measured at three randomly selected sites in both FBD and GAD representing the inflow, middle and dam wall regions. A handheld YSI Professional Plus Multiparameter meter (Model: YSI 554 Datalogger and multiprobe) was used to measure parameters such as temperature (°C), dissolved oxygen (mg/l), pH, total dissolved solids (TDS) (mg/l), and conductivity (mS/cm). Turbidity (NTU) was measured with a WTW turbidity meter (Model: Turb 430 IR/T). Water depth was measured using a measuring tape fitted with a metal weight.

2.3 Fish collection

Fish were collected during surveys of one week at each dam undertaken in May, August, November 2024, and February 2025 using gillnets (a fleet of four nets comprising panels 5 m long by 2 m deep with stretch mesh sizes of 44, 60, 70, 100 and 144 mm), fyke and cast nets (used to sample shallow habitats and the fringes of the banks) (Figure 3.1). Fyke and cast nets were used to enhance catches for gathering biological data (including reproduction, diet and age). Captured fish were identified using field identification keys in Skelton (2001). Fish caught using gill nets were placed in marked holding tanks containing dam water that was oxygenated using portable battery-operated aerators. Fishes extracted from a specific mesh size were placed into separate holding tanks.

At a makeshift field laboratory situated on the banks of the dam, fish were individually removed from the holding tanks and the standard length (SL:mm), total length (TL:mm) and live mass (grams) were recorded using a measuring board and a RADWAG weighing balance (Model: WTB 2000) respectively. The fish were euthanised using

clove oil, and once unconscious, they were sacrificed and dissected to collect biological data such as age and growth. The otoliths were stored dry in individually labelled Eppendorf tubes, for use in fish age determination.

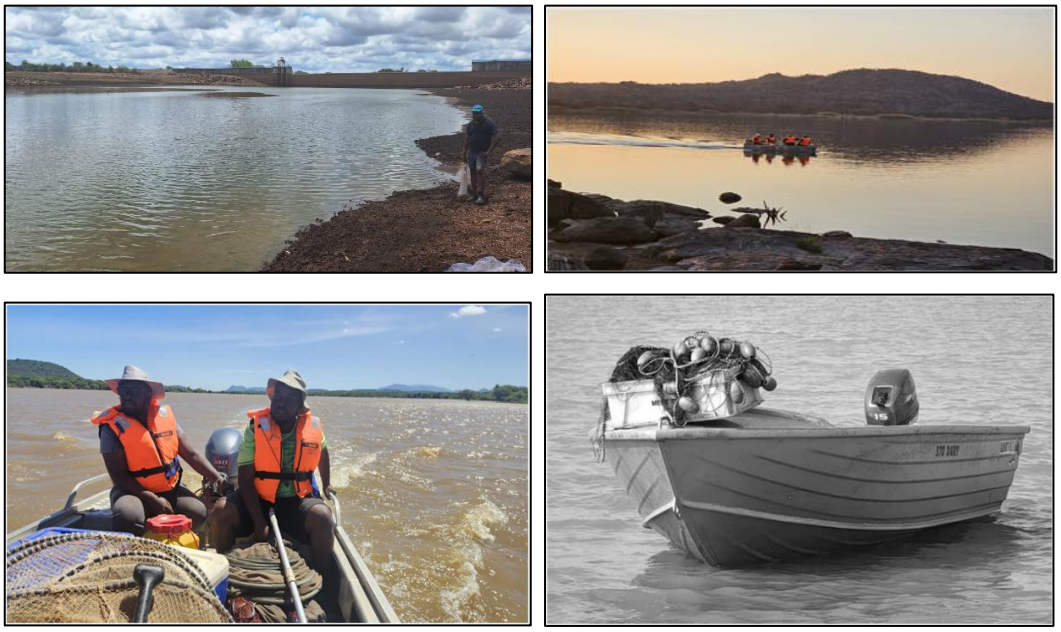


Figure 3.1: Preparation for placing the nets, casting cast nets, and setting gill nets.

2.4 Establishing the catch-per-unit effort (CPUE)

Catch-per-unit-effort (CPUE) was calculated for all the species caught in gill nets as the biomass of a species collected per hour e.g. g/100-m net/hr. Procedures outlined by Pollock (1994) were used to provide estimates of CPUE with the mean CPUE calculated as:

$$\overline{CPUE} = \frac{\sum_{i=1}^{n} \left({}^{C_i}/_{E_i} \right)}{n}$$

where C_i is the catch size (either in the number or mass of fish caught) per gear *i*, and E_i is fishing effort on day *i* (Pollock, 1994).

Species contributing > 20% of the total catch in terms of abundance and biomass were considered as potential candidate species for the fishery in GAD. For FBD the CPUE recorded was compared to the CPUE of the dominant species reported by Hlungwani

et al. (2023) to determine whether a gill net fishery could be developed sustainably as per the reference points given by Marr *et al*. (2024).

3. RESULTS

3.1 FLAG BOSHIELO DAM

3.1.1 Physico-chemical properties

Seasonal fluctuations in water temperature showed the expected low winter and high spring temperatures indicative of cold and warm periods respectively (Table 3.1). Dissolved oxygen (DO) concentrations (mg/l) showed a distinct trend, with mean values recorded in May 2024 lower than those recorded during the other months surveyed. Throughout the study, alkaline conditions persisted (pH 7.83 – 8.34). Total dissolved solids (TDS) and electrical conductivity (EC) were higher in autumn with the lowest TDS recorded in spring. Turbidity was uniform in autumn and winter with the highest level recorded during the spring survey (Table 3.1).

Table 3.1: Mean values and standard deviation of physico-chemical parameters measured during surveys conducted in autumn, winter, spring of 2024 and summer 2025 at Flag Boshielo Dam.

Variable	Season			
	Autumn	Winter	Spring	Summer
Temperature (°C)	31.63±14.08	18.05±0.06	29.36±0.04	30.38±0.34
Dissolved oxygen (mg/l)	8.07±2.97	6.26±1.29	8,97±0.28	7.79±3.41
pH	7.83–8.12	8.25 –8.34	8.08 – 8.19	7.67 – 8.86
Total Dissolved Solids (mg/l)	50.86±26.75	48.45±24.43	47.33±23.44	23.83±0.02
Electrical Conductivity (mS/cm)	86.38±42.74	83.23±35.66	84.34±36.25	82.24±33.4
Turbidity (NTU)	6.01±0.34	6.78±1.22	7.22±0.16	5.88±0.18

3.1.2 Species catch composition

The total catch composition from FBD consisted of seven species (Table 3.2). Fish retained by gillnets were *C. rendalli, M. nigricans, O. mossambicus, H. molitrix* and *C. gariepinus. Coptodon rendalli* was the most dominant species in all gears used in

terms of abundance (*n* = 68) and total biomass (6.81 kg). Only two (2) *Marcusenius krameri* (Gill, 1862) were recorded when using fyke nets.

Table 3.2: The total biomass and abundance, expressed as kilograms of all fish species collected in FBD using gill nets, fyke nets and cast nets during surveys conducted in May, August, November 2024 and February 2025.

Species	Gear					
	Gill nets		Fyke nets		Cast nets	
	Biomass (kg)	*n*	Biomass (kg)	*n*	Biomass (kg)	*n*
Coptodon rendalli	6.81	68	1.57	33	1.78	43
Oreochromis mossambicus	1.35	6	0.26	22	0	0
Micropterus nigricans	3.22	16	0.20	2	0.09	1
Clarias gariepinus	0.06	3	1.61	1	0	0
Hypophthalmichthys molitrix	0.76	1	0	0	0	0
Synodontis zambezensis	0.75	12	0.37	7	0	0
Marcusenius krameri	0	0	0.19	2	0	0
Total	12.95	106	4.21	67	1.88	44

3.1.3 Catch composition biomass per mesh size

The overall gill net catch in terms of biomass in all mesh sizes was dominated by *C. rendalli* and *M. nigricans,* with the 60 and 70 mm mesh size recording the highest biomass at 9.06 and 5.44 kg, respectively (Table 3.3). The 44 and 144 mm mesh sizes recorded similar biomass at 3.84 kg, while the 100-mm mesh size recorded the lowest biomass at 0.62 kg (Table 3.3). Overall, *C. rendalli* was the dominant species, contributing 26.6% of the total catch composition, followed by *M. nigricans* (24.1%) in terms of biomass across all mesh sizes.

Table 3.3: The total biomass of fish collected in FBD using gill nets with mesh sizes of 44, 60, 70, 100 and 144 mm during May, August, November 2024 and February 2025. (The biomass of a species is expressed as kilograms for each mesh size and the overall contribution (%) to the total mass collected). Values in bold indicate species that contributed >20% of the total catch.

Species	Mesh size (biomass kg)					Overall contribution	
	44	60	70	100	144	Total	%
Coptodon rendalli	1.76	2.94	0.57	0.15	0.65	6.07	**26.6**
Micropterus nigricans	0.89	2.10	1.11	0	1.39	5.49	**24.1**
Clarias gariepinus	1.18	0.37	0.37	0	1.18	3.10	13.6
Oreochromis mossambicus	0	1.09	2.70	0.47	0	4.26	18.7
Hypophthalmichthys molitrix	0	2.57	0	0	0.61	3.18	13.9
Synodontis zambezensis	0	0	0.69	0	0	0.69	3
Total	3.84	9.06	5.44	0.62	3.84	22.79	100

3.1.4 Overall catch per unit effort (CPUE) per mesh size

The CPUE expressed as mean biomass (kg/100 m net/hr) for all the species caught in standardised gill nets per mesh size during the surveys is presented in Table 3.4. The overall CPUE was higher for the 70 mm mesh size than the other mesh sizes. Overall, the 60 and 70 mm mesh sizes dominated the CPUE at 0.57 and 0.25 kg/100-m net/hr for *M. nigricans,* followed by *C. rendalli* recorded at 0.24 kg/100-m net/hr. *Oreochromis mossambicus* was retained by the 60, 70 and 100 mm mesh sizes with the 70 mm mesh dominating the CPUE at 0.17 kg/100-m net/hr (Table 3.4).

Table 3.4: The catch-per-unit effort (CPUE) expressed as kg/100-m net/hr of all species caught using standardised gillnets from Flag Boshielo Dam during surveys conducted in May, August, November 2024 and February 2025. Values in bold indicate species that contributed > 20% of the total catch.

Species	Mesh size					Overall contribution	
	44	60	70	100	144	Total	%
Coptodon rendalli	0,17	0,24	0,25	0.02	0,08	0,74	**24,24**
Micropterus nigricans	0,05	0,57	0,25	0	0,36	1,23	**40,41**
Clarias gariepinus	0,16	0,05	0,05	0	0,12	0,38	12,55
Oreochromis mossambicus	0	0,07	0,17	0,05	0	0,29	9,41
Hypophthalmichthys molitrix	0	0,24	0	0	0,08	0,33	10,76
Synodontis zambezensis	0	0	0,08	0	0	0,08	2,63
Total	0,38	1,17	0,78	0,07	0,65	3,03	100

3.1.5 Comparison of FBD historical and current fish stocks.

3.1.5.1 Species catch composition

The total catch composition reported by Hlungwani (2021) consisted of 11 species with 1376 specimens caught as opposed to the seven species and 106 specimens recorded in this project using the same standardised gill nets. Historically, species composition in FBD was dominated by four cyprinids; *L. rosae,* southern papermouth *Enteromius rapax* (Steindachner, 1894), *C. carpio* and *L. marequensis*, followed by two cichlids, *O. mossambicus* and *C. rendalli* (Table 3.5). The catch included two invasive alien species, *C. carpio* and *M. nigricans* (Hlungwani 2021). About 3% of the catch was damaged by crocodile activity on the nets. The total biomass of all the fish species caught from the standardised gill nets was 247.6 kg compared to the 12.9 kg recorded during the current project.

Table 3.5: The abundance and biomass, expressed as a percentage (%), of fish species collected in FBD using standardised gill nets (44, 60, 70, 100 and 144 mm mesh size) during surveys conducted from February 2016 to April 2017. Values in bold indicate species that contributed > 20% of the total catch.

Species	Abundance (%) (*n* = 1376 fish)	Biomass (%) (Total = 247.6 kg)
Micropterus nigricans	0.44	1.60
Oreochromis mossambicus	21.15	**22.05**
Coptodon rendalli	0.29	0.19
Clarias gariepinus	0.65	6.00
Enteromius rapax	0.65	0.41
Cyprinus carpio	0.44	0.44
Labeo rosae	58.72	**58.69**
Labeobarbus marequensis	0.44	0.24
Synodontis zambezensis	12.35	6.07
Marcusenius krameri	0.87	0.48
Schilbe depressirostris	1.09	0.53
Total	100	100

3.1.5.2 Catch composition biomass per mesh size

During the current project the overall gill net catch in terms of biomass in all mesh sizes was dominated by *C. rendalli* and *M. nigricans* with the 60 and 70 mm mesh size recording the highest biomass. However, the overall catch in terms of biomass in all mesh sizes recorded by Hlungwani (2021) was dominated by *L. rosae*, *O. mossambicus*, *C. gariepinus* and *S. zambezensis* (Table 3.6). *Labeo rosae* and *O. mossambicus* dominated the 70 mm mesh size, whereas *C. gariepinus* dominated

the 144 mm mesh size. *Synodontis zambezensis* dominated the 44 mm mesh size whilst no *C. gariepinus* and *M. nigricans* biomass were recorded at the 44 mm mesh size. *Labeo rosae* and *O. mossambicus* also dominated the 60 and 100 mm mesh sizes (Table 3.6). The biomass caught typically increased with an increase in mesh size, with four of the eleven species caught in the 144 mm mesh size net, that is, *C. carpio*, *C. gariepinus*, *L. rosae* and *O. mossambicus,* contributing 2.01, 74.83, 5.09 and 18.07% of the catch, respectively (Table 3.6). Overall, *L. rosae* and *O. mossambicus* were the dominant species, contributing 40.75% and 23.91% of the total catch composition in terms of biomass across all mesh sizes. In contrast, no *L. rosae* were recorded during the current project, and *C. rendalli* replaced both *O. mossambicus* and *L. rosae* as the dominant species.

Table 3.6: The biomass of fish collected in FBD using gill nets with mesh sizes of 44, 60, 70, 100 and 144 mm from April 2016 to April 2017. (The biomass of a species is expressed as a percentage (%) of the total biomass for each mesh size and the overall contribution to the total mass collected.) Values in bold indicate species that contributed > 20% of the total catch.

Species	Mesh size (mm)					Overall contribution (%)
	44	60	70	100	144	
Cyprinus carpio	0.00	0.25	0.61	0.00	2.01	0.57
Clarias gariepinus	0.00	0.79	1.45	7.23	74.8	16.86
Coptodon rendalli	0.52	0.00	0.55	0.00	0.00	0.21
Enteromius rapax	0.55	0.91	0.00	0.00	0.00	0.29
Labeobarbus marequensis	2.11	0.14	0.24	0.00	0.00	0.49
Labeo rosae	23.68	74.9	62.4	37.61	5.09	**40.75**
Marcusenius krameri	5.44	0.42	0.06	0.00	0.00	1.185
Micropterus nigricans	0.00	0.25	1.80	15.03	0.00	3.42
Oreochromis mossambicus	18.91	17.7	26.7	38.07	18.0	**23.91**
Schilbe depressirostris	4.06	0.55	0.08	0.00	0.00	0.94
Synodontis zambezensis	44.72	3.90	6.12	2.06	0.00	11.36
Total	55.27	99.8	100	100	100	100

3.1.5.3 Overall catch per unit effort (CPUE) per mesh size

The overall CPUE for the current project was dominated by *M. nigricans* and retained by the 60 and 70 mm mesh sizes. Compared to Hlungwani's (2021) observations, the overall CPUE was higher for the 144 mm mesh size than the other mesh sizes, while the biomass increased with mesh size from 0.1±0.1 (kg/100-m net/hr) in the 44 mm mesh to a maximum of 0.20±0.38 (kg/100-m net/hr) in the 144 mm mesh (Table 3.7).

Table 3.7: The catch-per-unit effort (CPUE) expressed as kg/100-m net/hr of all species caught using standardised gillnets from FBD during surveys conducted from April 2016 to April 2017.

Mesh size	Mean±SD	*n*
44	0.10±0.01	194
60	0.20±0.02	699
70	0.30±0.02	384
100	0.40±0.03	83
144	2.00±0.38	16

3.2 GLEN ALPINE DAM

3.2.1 Seasonal water levels and physico-chemical properties

In autumn 2024, the water level in GAD was at 52%, decreasing to 2% in November 2024 (Figure 3.2) (data obtained from the Department of Water and Sanitation via https:// https://www.dws.gov.za/hydrology/Weekly/Province.aspx). The lowest water levels occurred during Spring 2024 when water depth was less than 0.5 metres, causing severe habitat loss that resulted in a major fish kill event reported during the November 2024 survey (Figure 3.3).

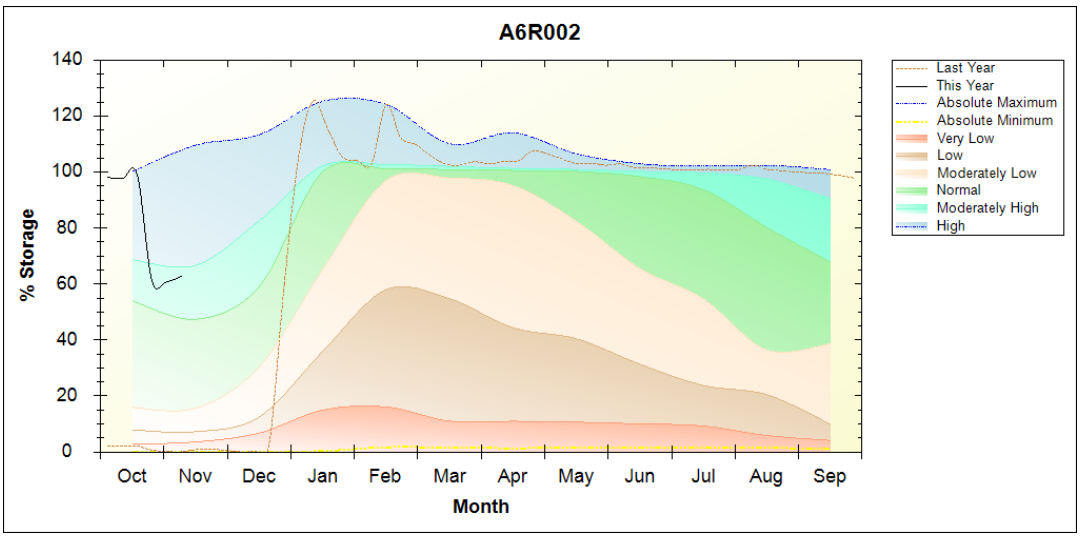


Figure 3.2: Seasonal dam water levels for Glen Alpine Dam.



Figure 3.3: Water channel in Glen Alpine Dam and fish kills caused by receding water levels during November 2024.

Dissolved oxygen (DO) concentrations declined from 6.78±0.13 to 3.08 mg/l in May and August 2024, respectively. Throughout the study, alkaline conditions persisted (pH 7.89 – 8.85). During the water loss event, turbidity levels increased from 3.68 NTU in winter to 46.97 NTU, the highest level recorded throughout the current study (Table 3.9). Total dissolved solids and electrical conductivity also increased from 74.80 mg/l and 82.76 mS/cm in winter to 144.5 mg/l and 98.67 mS/cm in spring, respectively (Table 3.8). However, during the summer survey, the dam was at 100% capacity due to the heavy rains experienced during December 2024 and January 2025 in the Mogalakwena area.

Table 3.8: Means and standard deviation of physico-chemical parameters measured during surveys conducted in autumn, winter, spring 2024 and summer 2025 at Glen Alpine Dam.

Variable	Autumn	Winter	Spring	Summer
Temperature (°C)	26.03±0.15	18.22±0.25	24.03±0.04	28±1.07
Dissolved Oxygen (mg/l)	6.78±0.13	3.08±1.17	4.66±0.47	4.91±0.63
pH	7.89 – 8.85	8.03 – 8.89	8.21 – 8.42	7.74 – 8.26
Total Dissolved Solids (mg/l)	148.6±31.38	74.80±1.21	144.5±28.31	175.1±o.03
Electrical Conductivity (mS/cm)	124.9±3.21	82.76±1.67	98.67±2.12	117.2±0.02
Turbidity (NTU)	3.94±0.66	3.68±0.53	46.97±0.47	101.9±53.35

3.2.2 Species catch composition

The total catch composition consisted of twelve native species: fish retained in gill nets were *S. depressirostris* (Peters, 1852)*, O. mossambicus* and *S. zambezensis*. *Schilbe depressirostris* was the dominant species in terms of biomass in all gears used (2.69 kg). Redeye labeo *Labeo cylindricus*, African longfin eel *Anguilla mossambica*, threespot barb *Enteromius trimaculatus*, bowstripe barb *Enteromius viviparus*, and *L. marequensis* were recorded using fyke nets. Fish caught using cast nets were dominated by *O. mossambicus* in terms of both abundance and biomass (Table 3.9).

Table 3.9: Abundance and biomass expressed as kilograms of fish species collected in GAD using gill nets, fyke nets and cast nets during surveys conducted in May, August, November 2024 and February 2025. Values in bold indicate species that contributed > 20% of the total catch.

Species	gill nets		Fyke nets		Cast nets		Total	(%)
	n	Biomass(kg)	*n*	Biomass(kg)	*n*	Biomass(kg)		
Coptodon rendalli	0	0	0	0	5	0,18	0,18	2,05
Oreochromis mossambicus	4	0,46	1	0,02	32	0,63	1,11	12,69
Synodontis zambezensis	2	0,14	1	0,04	0		0,18	2,08
Marcusenius krameri	2	0,10	50	2,11	0		2,21	**25,21**
Schilbe depressirostris	32	2,35	3	0,24	5	0,09	2,69	**30,66**
Engraulicypris brevianalis	1	0,00	6	0,00	2	0,00	0,00	0,05
Labeo cylindricus	1	0,04	0	0	0	0	0,04	0,48
Anguilla mossambica	0	0	1	0,33	0	0	0,33	3,73
Petrocephalus wesselsi	0	0	23	0,27	0	0	0,27	3,09
Enteromius trimaculatus	0	0	5	0,01	0	0	0,01	0,08
Enteromius viviparous	0	0	310	0,10	2	0,00	0,11	1,19
Labeobarbus marequensis	0	0	0	0	1	0,03	0,03	0,28
Clarias gariepinus	17	1,61	0	0	0	0	1,61	**18,38**
Total	49	4,72	400	3,13	47	0,94	8,78	100

3.2.3 Catch composition biomass per mesh size

The overall catch in terms of biomass in all mesh sizes was dominated by *S. depressirostris* and *O. mossambicus* (Table 3.10). The 60 and 70 mm mesh sizes retained the most biomass whilst the 100 and 144 mm mesh sizes retained no fish. Overall, *S. depressirostris* was the dominant species, contributing 78% of the total catch composition in terms of biomass across all mesh sizes (Table 3.10).

Table 3.10: The biomass of fish collected in Glen Alpine Dam using gill nets with mesh sizes of 44, 60, 70, 100 and 144 mm during May, August, November 2024 and February 2025. (The biomass of a species is expressed as total biomass (kg) for each mesh size and the overall contribution (%) to the total mass collected.) Values in bold indicate species that contributed >20% of the total catch.

Species	Mesh size (mm)					Overall contribution	
	44	60	70	100	144	Total	%
Oreochromis mossambicus	0	0.39	0.07	0	0	0.46	13.1
Schilbe depressirostris	2.43	0.33	0	0	0	2.77	**78.7**
Marcusenius krameri	0.10	0	0	0	0	0.10	2.9
Engraulicypris brevianalis	0.00	0	0	0	0	0.00	0.02
Labeo cylindricus	0.04	0	0	0	0	0.04	1.2
Synodontis zambezensis	0.14	0	0	0	0	0.14	4.0
Total	2.73	0.72	0.07	0	0	3.52	100

3.2.4 Overall catch per unit effort (CPUE) per mesh size

The CPUE results expressed as mean biomass (kg/100-m net/hr) for all the species caught in standardised gill nets per mesh size during the surveys are presented in Table 3.11. The highest CPUE was recorded on the 44 mm mesh size with *S. depressirostris* dominating the biomass at 1.08 kg/100-m net/hr.

Table 3.11: The catch-per-unit effort (CPUE) expressed as kg/100-m net/hr of all species caught using standardised gillnets from Glen Alpine Dam.

Species	Mesh size (mm)					Overall contribution	
	44	60	70	100	144	Total	%
Oreochromis mossambicus	0	0.04	0.01	0	0	0.05	3.9
Schilbe depressirostris	1.06	0.03	0	0	0	1.08	92.9
Marcusenius krameri	0.01	0	0	0	0	0.01	1.1
Engraulicypris brevianalis	0.00	0	0	0	0	0.00	0.01
Labeo cylindricus	0.00	0	0	0	0	0.01	0.4
Synodontis zambezensis	0.02	0	0	0	0	0.02	1.5
Total	1.09	0.07	0.01	0	0	1.17	100

4. DISCUSSION

The current study reveals a substantial decline in fish diversity, abundance, and ecological integrity within both FBD and GAD, demonstrating a trajectory of deterioration more severe than previously reported by Hlungwani *et al*. (2023) for FBD. The sharp drop in water levels at GAD, falling from 52% in May 2024 to only 2% by November 2024 was not driven by natural hydrological cycles, but by misinformed and poorly coordinated water management decisions. This rapid recession eliminated biotopes for fish assemblages, riparian shading, and left substrate and bank structures in a degraded state, forcing fish populations into the remaining shallow pool near the dam wall. The resulting crowding, low dissolved oxygen, and habitat compression contributed directly to the large-scale fish mortality observed. These findings highlight a critical shortcoming: ecological thresholds and fishery considerations were not incorporated into dam operation strategies, illustrating the vulnerability of impoundments managed without adaptive or evidence-based water release protocols.

In the FBD, the biological consequences of these management failures are evident in the observed decline in species richness. Where previous studies recorded 23 species (Brits, 2006) and 16 species (Sara *et al*., 2017), the present study documented only 12 species in May 2024, collapsing further to seven species by November 2024. The near absence of species such as *L. rosae* and *O. mossambicus*, previously abundant (Hlungwani *et al.,* 2023), points to pronounced population declines. These reductions coincide with increased reports of intensive monofilament gill-netting targeting *O. mossambicus* and other large-bodied species. Such unregulated fishing practices, coupled with an apparent rise in organised illegal harvesting syndicates, demonstrate the detrimental impact of weak enforcement, poor compliance monitoring, and inadequate fisheries governance. The combination of habitat degradation and intense extraction pressure indicates that current management frameworks are insufficient to maintain ecological resilience or support sustainable fishery productivity in these fisheries.

Similarly, in Flag Boshielo Dam, declines in CPUE biomass compared to findings recorded by Sara *et al*. (2017) and Hlungwani *et al*. (2023) confirm an overarching downward trend in stock abundance. The shift in species dominance toward *C. rendalli*, a species more tolerant of fishing pressure and habitat disturbance, is

consistent with symptoms of overexploitation observed in many African inland fisheries (Weyl & Hectht, 1999, Tweddle *et al*., 2015). The depletion of high-value species and reduced CPUE reflect the lack of harvest regulations, gear restrictions, or scientifically informed management controls. This pattern of decline underscores a broader systemic issue: the long-standing absence of an effectively implemented inland fisheries policy. Although the NFWCFP (2022) provides a necessary legislative foundation, progress toward operationalising the policy remains limited. Many provincial authorities responsible for dam management lack the financial resources, scientific expertise, and institutional capacity required to regulate fishing pressures, collect long-term ecological data, or address illegal harvesting.

These institutional and operational gaps have created conditions where fisheries are increasingly vulnerable to multiple stressors, including water abstraction, poor water quality, and anthropogenic pressures. Without comprehensive catchment-level management, the ecological stability of both dams continues to erode. The fish kill event at GAD exemplifies the consequences of prioritizing water extraction needs without considering the ecological requirements necessary to sustain aquatic biodiversity and fishery productivity. As such, the findings of this study not only provide evidence of the current degraded state of these fisheries but also illustrate the urgent need for integrated, evidence-based, and enforceable management approaches designed to restore ecosystem function and ensure long-term sustainability.

5. CONCLUSION

This study demonstrates that both FBD and GAD fisheries are experiencing significant declines driven by a combination of hydrological mismanagement, inadequate enforcement of fishing regulations, and insufficient institutional capacity. To reverse these trends, comprehensive management interventions are required that address ecological, social, and governance dimensions of inland fisheries. The rehabilitation of both fisheries should be prioritised, including restocking programmes for depleted species such as *L. rosae* and *O. mossambicus*, alongside habitat restoration initiatives and improved environmental flow management to maintain ecological integrity during periods of water abstraction.

Furthermore, sustainable fisheries development must be guided by scientific evidence and implemented through strong co-management structures. These structures should empower dam managers, involve local communities, and ensure legal compliance through routine monitoring and enforcement. Key actions include establishing gear restrictions (especially prohibiting monofilament gill nets), setting harvest limits, implementing locality-specific monitoring programmes, and improving surveillance to combat illegal fishing syndicates. Strengthening institutional capacity within provincial departments will be critical, enabling them to collect long-term fishery data, monitor water quality, react to ecological disturbances, and effectively enforce fisheries legislation.

Without these interventions, the continued decline of fish populations and degradation of freshwater ecosystems will undermine both the ecological stability and socio-economic potential of inland fisheries in the Limpopo Province. However, with coordinated management, evidence-based policy implementation, and collaborative governance, FBD and GAD can be restored as resilient and productive fisheries capable of supporting biodiversity conservation, local livelihoods, and sustainable resource utilisation.

CHAPTER 4: A BIOLOGICAL ASSESSMENT OF THE FLAG BOSHIELO AND GLEN ALPINE FISHERIES

[1,2,5]Hlungwani HA, [2,3]Magoro ML, [2]Ndaleni P, [1,5]Nkhumeleni TR, and [4]Khosa D

[1]Department of Forestry, Fisheries and the Environment
[2] National Research Foundation-South African Institute for Aquatic Biodiversity
[3]Department of Ichthyology and Fisheries Science, Rhodes University, Grahamstown,
[4]Scientific Services, South African National Parks, Skukuza
[5]Department of Biodiversity, University of Limpopo, Turfloop.

1. INTRODUCTION

The observed decline in both *L. rosae* and *O. mossambicus* relative to previous assessments indicates a potential shift in the species composition and fishery dynamics of FBD. Historically, *L. rosae* contributed substantially to biomass yields (Hlungwani *et al.*, 2023), and its absence in the current catches suggests a disruption in the fish stock structure consistent with observations by Marr *et al*. (2024), who reported that in spite of the high CPUE, the specimens exhibited mature gonads but could not spread due to the drought-induced environmental conditions. The persistence of the drought conditions may have resulted in prolonged recruitment failure, leading to a population bottleneck currently reflected in low CPUE values.

For *O. mossambicus*, the decline appears to be driven more by increased exploitation pressure than by reproductive failure. The illegal use of monofilament gill nets observed during this study is particularly concerning, as such gear selectively targets larger, mature individuals that are critical to sustaining population structure and long-term yield. Removal of these key size classes can lead to truncated age distributions, reduced fecundity at the population level, and diminished resilience to environmental variability. Collectively, these observations point to a system under stress from both environmental and anthropogenic pressures. The reduced availability of historically dominant and economically important species may have cascading implications for local livelihoods, food security, and the feasibility of establishing or sustaining a viable inland fishery. These trends underscore the urgency of implementing adaptive

monitoring, enforcing gear regulations, and improving habitat conditions to support recovery and long-term sustainability.

Given the reduced abundance of both *L. rosae* and *O. mossambicus* in the current study, it was not feasible to pilot the fishery development recommendations proposed by Hlungwani *et al.* (2023) and Marr *et al*. (2024), which were based on sustainably targeting these species as primary fishery resources. In contrast, the present study recorded *M. nigricans* and *C. rendalli* as the dominant species in the catch, despite contributing less than 5% of total CPUE during the earlier study period reported by Hlungwani (2021). This notable shift in species dominance raises the question of whether *C. rendalli* could serve as an alternative target species should a formal fishery be established. To assess this possibility, biological sampling was undertaken to determine age and growth patterns, maturity structure, and associated life history characteristics of *C. rendalli* to evaluate the species' capacity to sustain targeted exploitation.

The need for such baseline stock assessment monitoring is further emphasised by recent events at the GAD fishery, where the absence of stock assessment and monitoring systems hindered effective management. During spring 2024, the dam was flushed to zero percent storage, resulting in substantial losses of fish biomass, biodiversity, and associated livelihoods. While thirteen species were recorded at GAD during autumn and winter sampling, only *C. gariepinus* persisted following the mass fish kills, and juvenile *C. gariepinus* dominated the catches during the subsequent recovery period. This pattern illustrates how anthropogenic disturbance can rapidly transform species assemblages, effectively creating a new fishery whose recovery trajectory must be monitored and modelled in real time to ensure sustainable utilisation. To date, no comprehensive data exist on the life-history characteristics of species re-establishing in either FBD or GAD. The life history characteristics provides critical lessons from the collapse and recovery of the GAD fishery, underscoring the importance of site-specific, continuous monitoring and adaptive management to support long-term fishery sustainability.

1.1 Aim of the chapter

The main aim of this chapter is to assess the life-history characteristics of *C. rendalli* in FBD in order to evaluate its potential to sustain a targeted inland fishery and to derive lessons for sustainable fishery management in the context of recent shifts in fish community composition and environmental disturbance in GAD.

1.2 Objectives of the Chapter

The objectives of this chapter are to:

- determine key life-history parameters of *C. rendalli*, including age and growth, size-at-maturity, and maturity structure;
- evaluate the potential of *C. rendalli* to function as a sustainable target species in the event of reduced availability of historically targeted species;
- draw lessons from the collapse and recovery trajectory of the GAD fishery, particularly in relation to the consequences of inadequate stock assessment and environmental variability;
- provide evidence-based recommendations for the development of a site-specific and adaptive management plan that supports sustainable inland fisheries in Flag Boshielo Dam and comparable systems.

2. METHODS AND MATERIALS

2.1 Biological assessments

Although *M. nigricans* and *C. rendalli* were the dominant species recorded during the current study, the number of *C. rendalli* specimens collected was limited. While the small sample size does not allow for definitive conclusions regarding the capacity of existing *C. rendalli* stocks to support a targeted fishery, it provides an important preliminary baseline. This dataset contributes initial insight into the species population structure and life history traits, and highlights the need and opportunity for future, more comprehensive sampling to inform sustainable fishery development. All *C. rendalli* specimens retained for biological assessment were dissected and assigned a maturity stage following the criteria presented in Table 4.1 (Section 2.3 below). Sagittal otoliths were removed and preserved for age estimation. For sectioning, otoliths were

embedded in clear casting resin and transversely sectioned through the nucleus at a thickness of 0.3 mm using a double-bladed diamond-edged saw. Sections were mounted on microscope slides with DPX mountant. Age determination was undertaken by counting alternating translucent (light) and opaque (dark) growth bands (Figure 4.1), following established methodologies described by Richardson *et al*. (2009), and Winker *et al*. (2010).



Figure 4.1: An otolith viewed under a light microscope showing the translucent (light) and opaque (dark) growth bands of a *Coptodon rendalli* caught in Flag Boshielo Dam.

2.2 Age and growth

Otoliths taken from the *C. rendalli* were sectioned and viewed using a dissecting microscope under transmitted light at various magnifications (10–40x). Counts were done two weeks apart. If reading one and two were the same, then the age estimation was accepted, if the readings differed, a third reading was done. After the third reading, those readings that were the same as either reading one or two were accepted. Those readings that differed by up to two were averaged over the three readings and the mean age taken. The readings that differed by more than two were rejected. The age and growth data were fitted with the von Bertalanffy growth model (VBGF) where:

$$L_a = L_\infty\left(1 - e^{-k(a-a_0)}\right)$$

a_o is the age at "zero" length; L_∞ is the predicted asymptotic length and K is the Brody growth co-efficient, and L_a is the length at age (a).

2.3 Maturity

All the *C. rendalli* caught were sacrificed, dissected and assigned a maturity stage (Table 13). The proportion of sexually mature individuals (ψ) by length (L) were then fitted to the logistic curve:

$$\psi = \frac{1}{1 + e^{-(L - L_{m50})/\delta}}$$

where L_{m50} is the mean length-at-50%-sexual maturity and δ is the width of the logistic ogive.

Table 4.1: Macroscopic criteria used to stage the gonads of the most abundant species (adapted from Weyl & Hecht, 1998).

Stage	Characteristics
J-Juvenile	Gonads are a thin band, unable to be accurately sexed.
1-Immature	Gonads able to be sexed, very thin white band in testes and translucent band in ovary.
2-Resting	Gonads were able to be distinguished by sex, in males a thin white band and females a thicker transparent ovary.
3-Developing	Both ovaries and testis are better developed, ovary loses total transparency, and the first signs of pale yellow/green oocytes appear. The testis is creamy-white and enlarging.
4-Ripe/Running	The ovaries are large and rigid, the oocytes are bright yellow in colour, the testes are pure white and rigid, if any pressure is applied to either the testes or ovary eggs or semen may ooze out.
5-Spent	The ovary and testes appear flaccid and reddish in colour; the remaining eggs in the ovary appear dull grey/yellow.

2.4 Length/weight relationship

Studies have used the length and weight relationship to assess the growth patterns of fish; the relationship has shown its use in distinguishing positive and negative allometric growth in fish (Ellender, 2008), thus, the length-weight relationship for *C. rendalli* was established to determine the growth patterns in FBD. The relationship between length and weight was described by the power relationship as:

$$W = aL^b$$

where *W* is the total weight (g), and *L* is the length (cm), and *a* and *b* parameters were estimated using linear regression analysis of the natural logarithm-transformed dependent and independent variables.

2.5 Data analysis

Having recorded fewer samples of *C. rendalli* and 90% of the sample were juveniles caught with fyke and cast nets, the maturity logistic ogive and mortality estimates could not be produced. Variance estimates for age and growth data, the (conditioned) parametric bootstrap resampling method (Efron, 1982) with 1000 bootstrap iterations were used, where standard errors and 95% confidence intervals were constructed from the bootstrap data using the percentile method (Buckland, 1984). To include ageing error into the VBGF, the Random Effects (RE) methods as proposed by Cope and Punt (2007) was used.

3. RESULTS

3.1 Age and growth

The observed length-age keys for *C. rendalli* are presented in Table 4.2. Among the *C. rendalli* caught and aged, specimens aged two (2) that were 80 to 200 mm in length (TL) dominated. Only one individual was found to be four years old. Forty-six otoliths were selected for age processing from male and female *C. rendalli*, of which 15 (32.6%) were considered unreadable and were rejected. When plotting length over age using the von Bertalanffy growth equation, a maximum age and asymptotic total

length of four years and 350 mm were observed, respectively, with the growth function (*K*) of 0.45 and t_0 of 0.3 determined (Figure 4.2).

Table 4.2: Age-length key for *Coptodon rendalli* sampled between May 2024 and February 2025 in Flag Boshielo Dam.

Length (mm)	Age (Years)				
	1	2	3	4	5
80-110	1	5	2		
110-140	1	4	3		
140-170			4		
170-200		5	2		
200-230		2			
230>			1	1	
n	2	16	12	1	

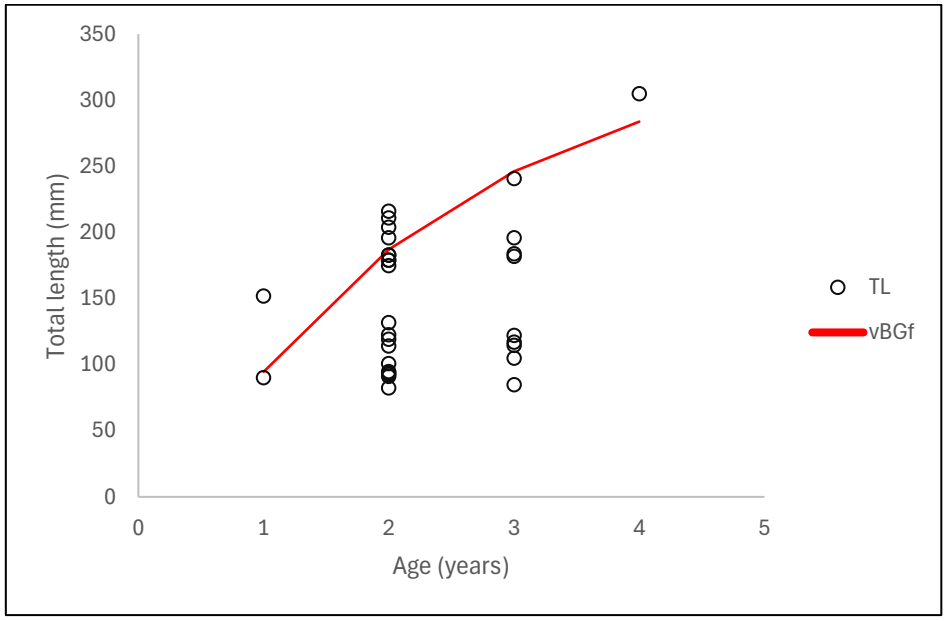


Figure 4.2: Length-at-age relationship determined for *Coptodon rendalli* from specimens sampled during autumn survey conducted in Flag Boshielo Dam during May 2024 to February 2025

3.2 Length-Weight relationship

The length and weight relationships of *C. rendalli* are shown in Figure 4.3. The length-weight relationship observed for both male and female was $W = 0.0050 \times TL^{3.2276}$(cm)

(r^2 = 0.93). The male population showed negative allometric growth (b<3), with females exhibiting positive allometric growth (b>3).

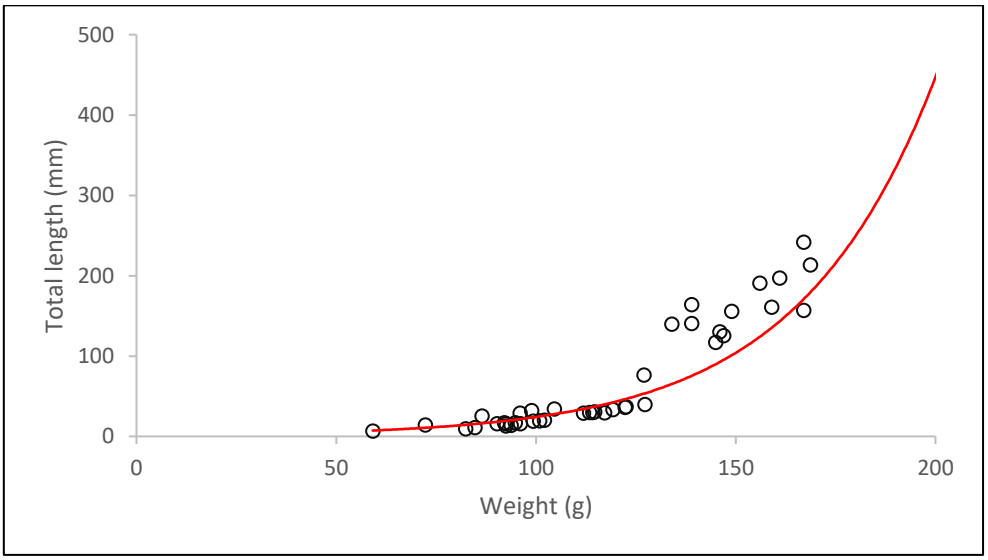


Figure 4.3: Length and weight relationship of the total number of *C. rendalli* (n = 42) caught using different fishing gear in FBD during the surveys

3.3 Net selectivity

Five *M. nigricans* were recorded by the 44 mm mesh size, while 14 *C. rendalli* were retained by the 100 mm mesh size (Figure 4.4). The catch per unit effort (CPUE) in a 100 m-net per hour, indicated that the mesh size of 44 mm yielded a catch of 0.04 kg per 100 m-net per hour for *M. nigricans,* while the mesh size of 114 mm revealed a yield of 0.12kg 100 m-net per hour for *C. gariepinus* and the mesh size of 70 mm yielded 0.21 kg 100 m-net per hour for *C. rendalli*. The most species caught with the gill nets were *M. nigricans* (*n* = 34) and *C. rendalli* (*n* = 30) retained by mesh sizes 44, 60 and 70 mm (Figure 4.4).

The catches for both species were dominated by the 60 mm mesh size. Fewer *O. mossambicus* (*n* = 12) individuals were retained by the 70 mm mesh size while mesh size 144 mm retained only *S. zambezensis* (*n* = 8). *Micropterus nigricans* dominated the mesh sizes as retained by the 44 mm (*n* = 6), 60- (*n* = 9) and 70 mm (*n* = 19) mesh sizes. The low numbers in sample size did not provide a normal common spread model for the best fit for either *C. rendalli* or *M. nigricans*, therefore, no fitted

selectivity curves and deviance residuals were produced to indicate which mesh size had the highest retention for size classes.

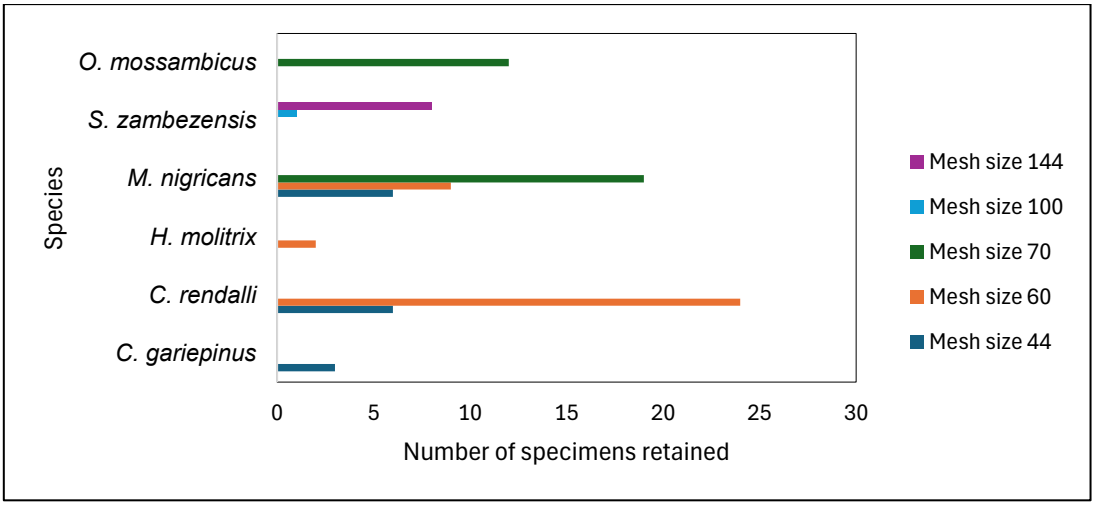


Figure 4.4: The CPUE (kg/100m-net/hour) of fish species caught in different gill-net mesh sizes.

3.4 Maturity

A total of 36 male and 7 female *C. rendalli* were sexed and the gonadal developmental categorised showed that 90% of the samples were in maturity Stage 1 (Juvenile); only four females showed developing gonads, and only one male had developing gonads (Table 4.3). The limited nature of the data did not allow for the determination of the length-at-50% sexual maturity (Lm_{50}).

Table 4.3: Maturity rating of male and female gonads of Coptodon rendalli sampled between May 2024 and February 2025 in Flag Boshielo Dam.

Sex	Juvenile	Resting	Developing	Ripe	Spent
Male	34	1	1	0	0
Female	3	0	4	0	0
Total	37	1	5	0	0

4. DISCUSSION

Aquatic ecosystems in Limpopo Province have undergone substantial ecological pressure over the past two decades as a result of altered hydrological regimes, water

abstraction, extreme climatic events, catchment degradation, and increasing competition for water resources (Sara *et al*., 2017). These pressures have had measurable consequences for fish populations and the sustainability of inland fisheries, particularly in multi-use impoundments such as FBD and GAD. Recent assessments conducted during the present study were aimed at determining fish population structures, biological attributes, and long-term viability of key species of fisheries importance. However, the findings reveal severe declines in abundance, diversity, and size structure, especially for *O. mossambicus* and *L. rosae,* and highlight broader ecological instability across the system. The combined evidence indicates that environmental disturbances, recurring fish kills, and poor recruitment have resulted in depleted stocks to such an extent that basic biological parameters could not be derived from the current samples. This chapter synthesises the ecological changes observed, evaluates the implications of diminished catch rates, and discusses the consequences for fisheries management and future development within Limpopo Province.

Recent fish kills recorded in the GAD point toward periods of acute environmental stress driven by deteriorating water quantity and quality. Drivers likely include eutrophication, low dissolved oxygen, rapid temperature fluctuations, and high organic loading conditions consistent with poor catchment management and increased anthropogenic pressure. Such events do not operate in isolation; they represent symptoms of chronic environmental decline capable of suppressing fish survival, disrupting recruitment, and skewing population structures. The current state of the dam ecosystems reflects the legacy of these stressors. Degraded littoral zones, unstable water levels, and siltation have further reduced available habitat for spawning, feeding, and juvenile refuge. Collectively, these shifts undermine the ecological integrity required to support sustainable fish populations and fisheries-oriented resource use. Currently, the flow regulation, abstraction for agriculture and domestic use, and increasingly frequent drought cycles have altered natural hydrological patterns. These changes limit connectivity and reduce the availability of nursery habitats, directly affecting recruitment success of native species. Particularly susceptible are riverine species such as *L. cylindricus*, which depend on seasonal flows to trigger spawning migrations and support early life stages.

Across all sampling events in the current project, captures of *O. mossambicus* and *L. rosae* were extremely low, with some sampling sessions failing to record any individuals at all. This pattern contrasts sharply with historical reports that documented relatively abundant populations of both species within Limpopo's impoundments. The near-absence of these species in the present study signals a major decline in abundance and suggests a broader collapse of once-functioning fish communities. Biological sampling requires a minimum threshold of individuals to reliably estimate growth parameters, body condition, size-at-age, maturity stages, and recruitment patterns. Because the catches for these two species fell far below this threshold, no biological reference points or population parameters could be derived.

The scarcity of individuals has far-reaching implications such as biological uncertainty: without length frequency distributions, age structures, or reproductive data, the current study cannot generate the baseline information typically used for fisheries stock assessments. And in the absence of reliable biological parameters (e.g., mortality rates, growth constants, recruitment estimates), managers cannot set sustainable harvest rules or predict stock response to exploitation. Therefore, a fishery cannot be developed or expanded when foundational metrics are missing. Attempts to do so would risk further collapse of already fragile populations. Also, these low catches may reflect functional collapse of breeding populations, disrupted recruitment cycles, or alteration of trophic dynamics. These constraints highlight the seriousness of the ecological decline, where the biological limitations themselves become key indicators of ecosystem dysfunction. The declines observed diminish the prospects for establishing viable inland fisheries in Limpopo Province. *Oreochromis mossambicus*, once an important species for subsistence and small-scale commercial interest, no longer occurs at densities capable of supporting harvest. Likewise, *L. rosae*, which contributes culturally and ecologically to riverine systems, cannot sustain fishing pressure under current conditions.

In communities where inland fish resources provide supplementary protein, cultural value, and economic opportunity, stock depletion reduces resilience and heightens vulnerability. Without a clear understanding of biological productivity, efforts to promote fisheries for rural development become constrained, potentially exacerbating poverty and reducing local participation in resource stewardship. The combined

evidence from environmental assessments and biological sampling indicates that Limpopo's inland aquatic systems are experiencing significant ecological degradation. Fish kills reflect acute environmental stress, while persistent low catches reveal chronic population-level decline. The inability to derive biological parameters from the present dataset is not merely a methodological limitation, it is a direct consequence of ecological collapse in key species of fisheries importance. These outcomes underscore a critical point as the biological data necessary to inform fisheries management and development cannot currently be generated due to the severely depleted state of fish stocks. Robust management frameworks depend on accurate biological inputs; without them, sustainable use cannot be planned, implemented, or evaluated. Therefore, reversing degradation and rebuilding populations must precede any fisheries development initiatives in Limpopo Province.

5. CONCLUSION

The present study demonstrates that fish populations in FBD, GAD and associated systems are undergoing significant decline, with *O. mossambicus* and *L. rosae* showing particularly severe reductions in abundance. The degraded ecological condition, influenced by environmental stressors such as fish kills, poor water quality, and hydrological instability, has restricted catches to levels insufficient to generate fundamental biological metrics. As a result, no concrete biological conclusions can be drawn from the current dataset, and key parameters required for stock assessment remain undetermined. This limitation reflects not a shortcoming of sampling effort, but the reality that the fish populations have fallen below levels necessary for reliable scientific analysis. Consequently, the biological information needed to support fisheries management cannot yet be produced, creating a barrier to sustainable fisheries development in the province. A structured monitoring programme should be implemented to track population recovery, water quality changes, recruitment patterns, and environmental fluctuations. This programme must include seasonal sampling, improved gear diversity, and integration of hydrological and limnological data.

Given the critically low abundance of key species, strategic restocking, supported by hatchery production and genetic management should be considered to rebuild

O. mossambicus and *L. rosae* populations. Restocking must be accompanied by habitat rehabilitation and strict controls on fishing pressure. Efforts should focus on reducing nutrient loading, controlling pollution, rehabilitating riparian zones, and improving flow regulation. Protecting ecosystem integrity is essential for preventing further fish kills and enabling recovery of natural recruitment cycles.

Fisheries development should not proceed in isolation. Any future fishery initiatives must be part of broader ecosystem restoration frameworks that address water quality, habitat health, and community involvement. Engaging local communities, fishers, and water users strengthens stewardship and encourages compliance with management measures. Training and education will support long-term sustainability and enhance local benefits from restored fisheries resources. Until fish populations recover sufficiently to generate reliable biological data, fisheries managers in FBD and GAD must prioritise ecological restoration, stock rebuilding, and long-term monitoring. Only through these actions can the scientific foundation needed for sustainable inland fisheries development be established.

CHAPTER 5: BASELINE ASSESSMENT OF UTILISATION PATTERNS IN THE FLAG BOSHIELO AND GLEN ALPINE FISHERIES

[1,2,5]Hlungwani HA, [2]Magoro ML, [3]Bova CS., [1]Mthombeni A, [1,5]Nkhumeleni TR, and [4]Khosa D

[1]Department of Forestry, Fisheries and the Environment
[2] South African Institute for Aquatic Biodiversity
[3]Department of Ichthyology and Fisheries Science, Rhodes University, Grahamstown,
[4]Scientific Services, South African National Parks, Skukuza
[5]Department of Biodiversity, University of Limpopo, Turfloop.

1. INTRODUCTION

In Africa, inland fisheries provide livelihoods for at least 4.8 million people and contribute approximately 28% of the global inland fisheries catch (FAO, 2020). Despite their socio-economic importance, these fisheries remain poorly regulated, with fragmented and unreliable catch data (Thorpe & Van Anrooy, 2010; Fluet-Chouinard *et al*., 2018; Hlungwani *et al*., 2023). For instance, the most recent FAO report (2022) highlighted that 25 African countries failed to report inland fish catches, underscoring the urgent need for coordinated monitoring to obtain accurate and comparable data.

In southern Africa, inland fisheries face multiple pressures, including overfishing, habitat degradation, pollution, invasive species, and climate change, which have led to declines in catch rates, reduced food security, and loss of income for dependent communities (Tweddle *et al*., 2015; Utete *et al*., 2018; Weyl *et al*., 2020). Collapse of fisheries in the Zambezi River System and African Great Lakes demonstrates that recovery is unlikely without fundamental changes to exploitation patterns and habitat restoration (Tweddle *et al*., 2015).

In South Africa, inland fisheries development offers a strategic pathway to alleviate poverty and create employment in line with the National Development Plan 2030 (National Planning Commission of South Africa, 2012). Central to this is the application of the FAO's Ecosystem Approach to Fisheries, which ensures that natural resource use is ecologically sustainable while supporting social and economic development (FAO, 2003; Weyl *et al*., 2020). Generating evidence on fish community composition, life-history traits, and patterns of resource utilisation is essential to guide informed

management decisions, optimise resource use, and safeguard the livelihoods of communities that are dependent on inland fisheries, particularly in Limpopo Province (Weyl *et al*., 2007; Ellender *et al*., 2010; Hlungwani *et al*., 2023).

Recent studies in FBD illustrate the consequences of limited data and shifting species dynamics. Historically, *L. rosae* and *O. mossambicus* dominated the catch and were considered primary fishery targets (Hlungwani *et al*., 2023; Marr *et al.*, 2024). However, current assessments show that these species contribute less than 10% of the catch in both abundance and biomass, indicating recruitment failure and possible overexploitation. Reduced catches of *L. rosae* align with prior observations that mature individuals were unable to spawn due to drought-induced environmental stress (Hlungwani, 2021), while declines in *O. mossambicus* are likely exacerbated by illegal fishing practices, such as monofilament gill nets targeting larger individuals. These findings highlight the importance of understanding species-specific population dynamics to inform sustainable exploitation strategies.

In contrast, *M. nigricans* and *C. rendalli* have emerged as the dominant species in the catch, despite previously contributing less than 5% of total CPUE (Hlungwani *et al*., 2023). Assessing the life-history traits of *C. rendalli* including age, growth, and maturity is therefore essential to evaluate its potential as an alternative fishery species and to guide sustainable management should a formal fishery be established.

The GAD fishery further underscores the consequences of inadequate monitoring and management. During spring 2024, the dam was effectively flushed, resulting in complete loss of fish biomass, biodiversity, and livelihoods dependent on the fishery. Although thirteen species were recorded during autumn and winter, only *C. gariepinus* survived the fish kill, with juveniles dominating catches during the subsequent recovery period. This event emphasises the vulnerability of inland fisheries to environmental perturbations and the need for continuous, site-specific monitoring to ensure sustainable utilization.

Together, the challenges observed at FBD and GAD highlight a broader issue: inland fisheries in Limpopo Province remain under-monitored, underutilised, and vulnerable to both anthropogenic and environmental pressures. Understanding current species composition, life-history traits, and utilisation patterns is critical to map the impact of

fisheries on livelihoods, guide sustainable exploitation, and inform adaptive management strategies.

1.1 Aim of the chapter

This chapter aims to assess inland fisheries utilisation patterns in FBD and GAD, with a focus on the resource exploitation status in order to evaluate the fisheries impacts on livelihoods and provide recommendations for sustainable management.

1.2 Objectives of the chapter

The objectives of this chapter are to:

- investigate fisheries utilisation patterns, including harvesting methods, effort, and socio-economic dependence of local communities;
- evaluate the impacts of fisheries exploitation on livelihoods, food security, and income, particularly in communities reliant on FBD and GAD;
- provide evidence-based recommendations for sustainable management, integrating ecological, social, and economic considerations to optimize inland fisheries development in Limpopo.

2. METHODS AND MATERIALS

2.1 Questionnaire survey

An assessment of the current use and socio-economic contribution of small-scale fisheries at Flag Boshielo and Glen Alpine fisheries from May 2024 to February 2025 was conducted through a comprehensive survey of participation, catch and utilisation (e.g., food or income) patterns using a questionnaire (Appendix A). During these interviews the following socio-economic information was recorded:

- Origin of the fisher/fishers.
- Demographics (race, gender and age).
- Primary motivation for fishing (sale, recreation or subsistence).
- Means of transport used to get to the fishery.
- Employment status.

2.2 User group classification

The fishers utilising the fisheries were grouped into two user groups: small-scale fishers (inclusive of subsistence) and recreational anglers. The socio-economic information obtained from the interviews, the type of employment of the fisher, the motivation or reason for fishing, mode of transport to the dam, distance travelled to the dam, and type of fishing gear used was used to define the user groups. Small-scale fishers were grouped as individuals that live on or near the Flag Boshielo and Glen Alpine fisheries and use basic transport methods to the dam, such as walking, cycling, or catching a lift. Fishers who travelled long distances by vehicle but whose primary motivation to fish was for food security and economic benefits were also classified as small-scale fishers. Recreational anglers were classified as the fishers who utilised the fishery for leisure purposes but may consume or sell a portion of their catch. They accessed the resource exclusively by vehicle, are permanently employed, and use fishing gear such as a boat and a fibreglass or graphite rod with a multiplying or spinning reel (Figure 5.1).



Figure 5.1: Small-scale fishers (A and B) fishing at the FBD using fishing rods and (C) a fisher preparing his catch to take home from the FBD

5.2.3 Data analysis

The water loss event that resulted in fish kills in GAD, and the low catches of the target species in FBD (*HA pers. comm with lodge owner*) resulted in a decline in fishing activities in the impoundments and fewer fishermen in both FBD and GAD. Therefore, no statistical analyses were performed. However, using the socio-economic information obtained from the interviews, exploratory and descriptive statistics were used to classify and define the user groups in both fisheries. The relative abundance of the species in user group catches was calculated as the percentage of the total catch composition for each species by length (cm) and weight (kg).

3. RESULTS

3.1 Flag Boshielo Dam

3.1.1 Resource utilisation

Eighty-five (85) interviews using questionnaires were conducted during the study in FBD. The majority of the users interviewed were small-scale fishers, whilst the remainder were recreational anglers. Also, the majority of the small-scale fishers originated from villages such as Phetwane, Sevenstart and Mokgalajana which are within 50 km from the FBD. A large percentage of rod and line usage at 93% whilst a portion of small-scale fishers using monofilament gill nets and seine nets accounted for 6% (Figure 5.2).

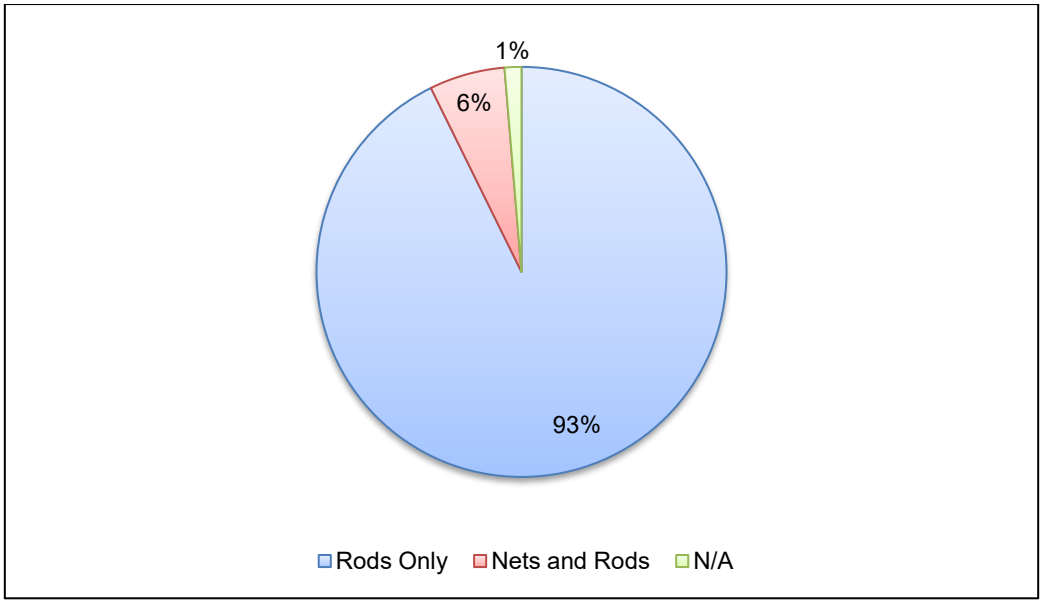


Figure 5.2: Percentage of fishing gear usage by fishers to catch fish in FBD.

A large percentage of the small-scale fishers were locals who resided ≤10 km from the dam. All recreational anglers originated from areas >10 km (Figure 5.3).

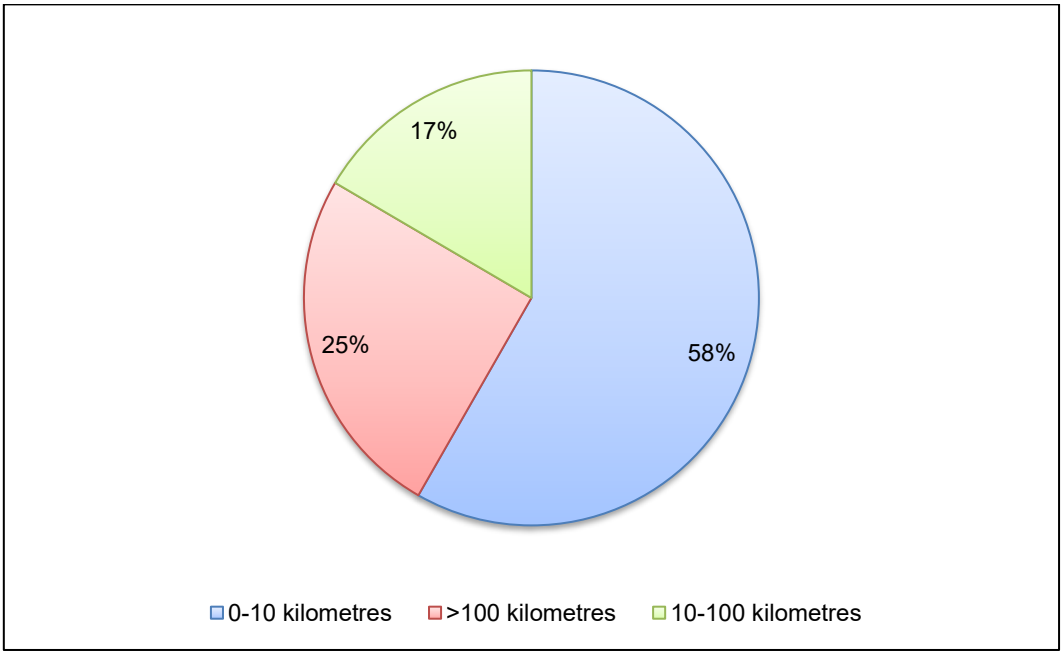


Figure 5.3: The distance, indicated as a percentage (%), travelled to Flag Boshielo Dam by various fishers.

Vehicles made up a substantial portion (50%) as the mode of transport for the users of the FBD fishery. Only 6% of the fishers used a bicycle, whilst catching a lift and

walking were the most frequent modes of transport for small-scale fishers who lived in close proximity to FBD (Figure 5.4).

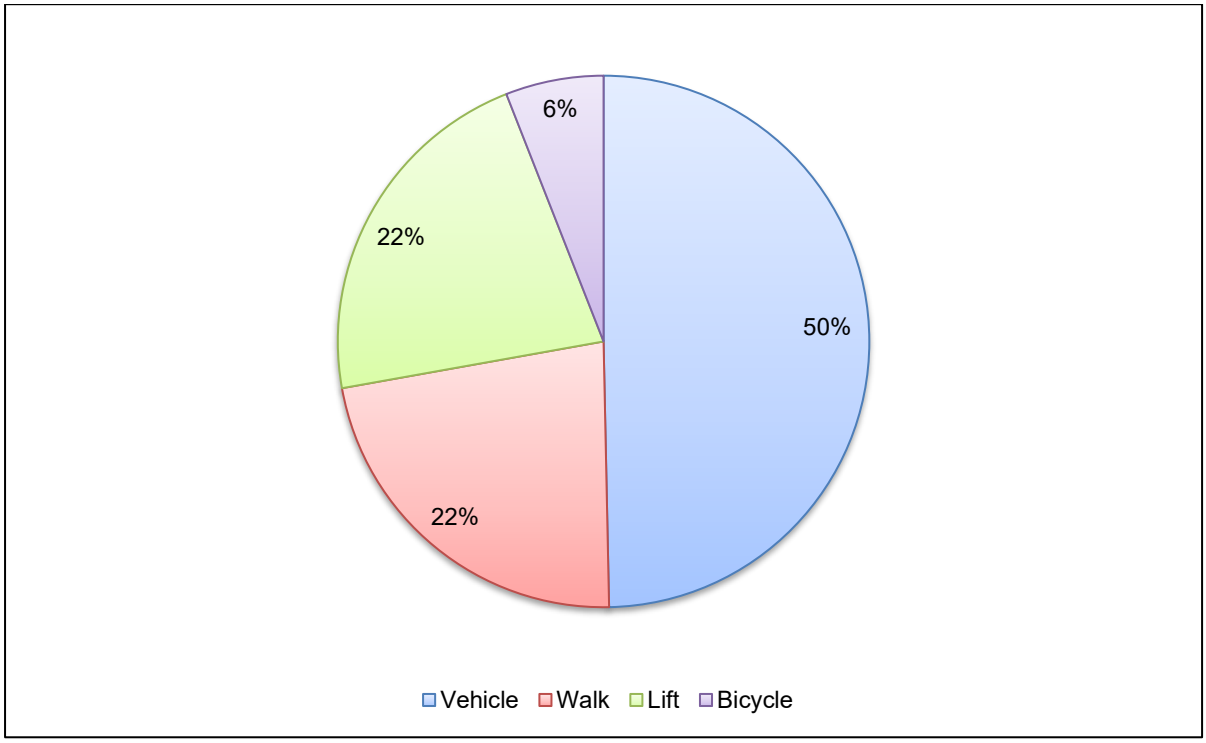


Figure 5.4: Percentage of the mode of transport used by fishers to access the Flag Boshielo Dam from their point of origin.

A large percentage of the users, whom were mostly small-scale fishers were unemployed, while only 5% had a permanent job. Pensioners (who receive the government grant for the elderly) and retired (former professional) fisher folk who fished for subsistence and recreational reasons contributed 9% and 4%, respectively, whilst small-scale fishers who have casual work contributed 10% of the survey (Figure 5.5).

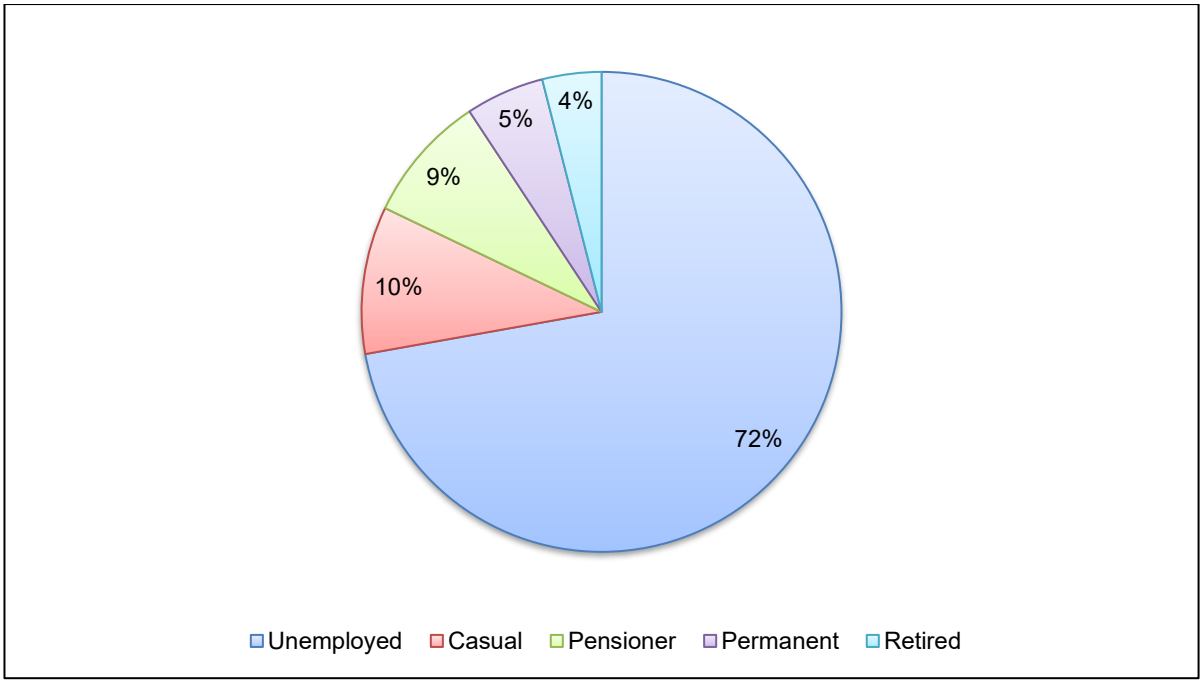


Figure 5.5: Occupation/employment (as a percentage) of fishers who utilise the Flag Boshielo fishery.

Of the group classified as small-scale fishers, none released or gave away their catches, amongst those interviewed 39% caught purely for their own consumption while 37.7% of those interviewed sold all their catch. The remaining 22.5% sold and consumed some of their catch. A large percentage of recreational anglers released their catch, while some consumed the fish they caught (Figure 5.6).

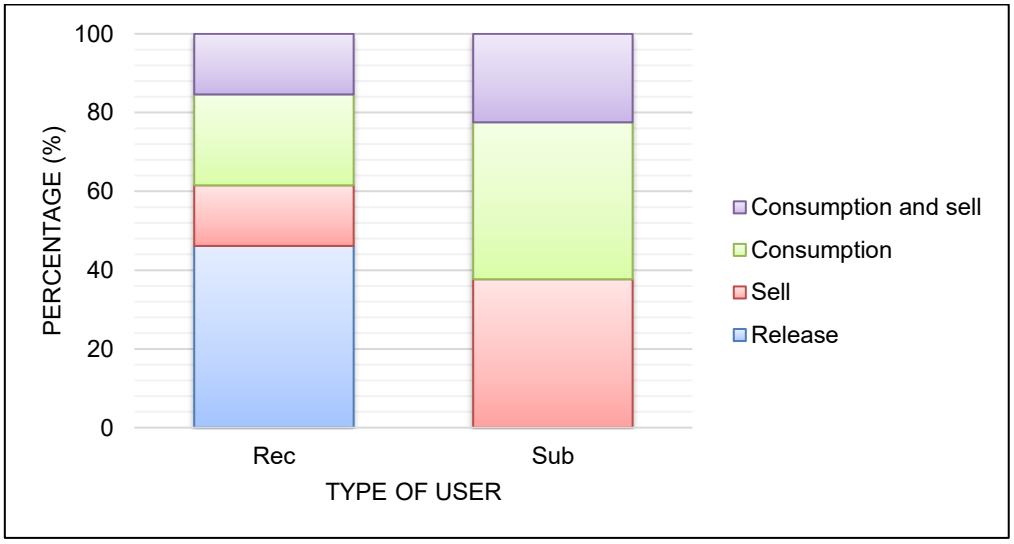


Figure 5.6: Percentage of the fate of the catch of fishers who catch fish in Flag Boshielo Dam.

Whites dominated the recreational user group, while Africans dominated the subsistence/small-scale users (Table 5.1). The majority of subsistence/small-scale fishers were males of between 20 and 40 years.

Table 5.1: Flag Boshielo Dam fisher demographics by user group.

Characteristic		Recreational	Small-scale
Race (%)	White	100	0
	African	0	100
Gender (%)	Male	100	88.9
	Female	0	11.1
Age (%)	18-20 years	0	11.1
	20-40 years	66.6	44.4
	40-60 years	0	33.3
	>60 years	33.3	11.11

3.1.2 User group's catch composition

Three species were recorded in both the small-scale fishers' and recreational anglers' catches: the redbreast tilapia *Coptodon rendalli,* largemouth bass *Micropterus nigricans*, and the brown squeaker *Synodontis zambezensis*. *Coptodon rendalli* dominated the catch composition in terms of abundance followed by *M. nigricans* and *S. zambezensis* (Figure 5.7).

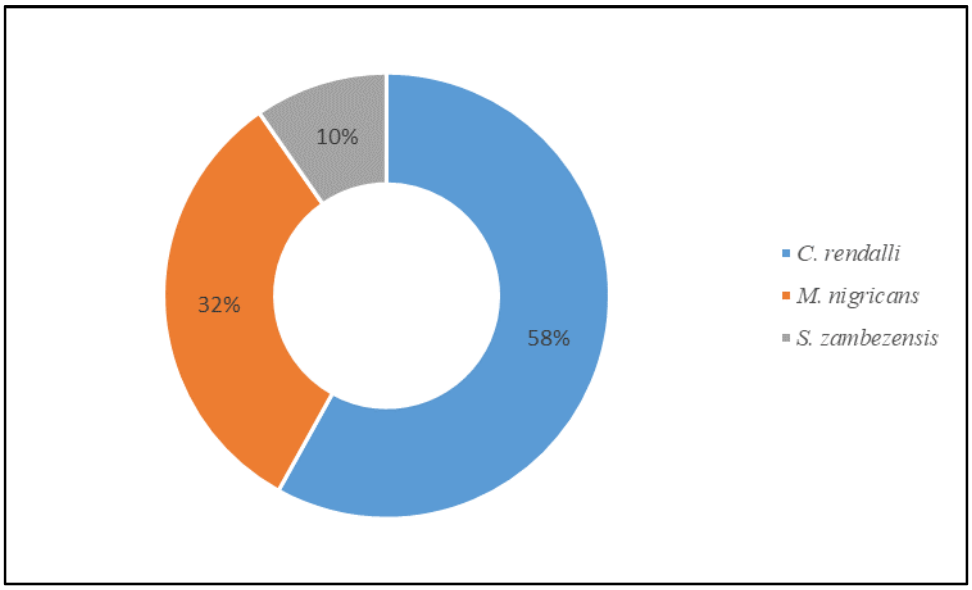


Figure 5.7: Proportional fish species composition recorded in both recreational and subsistence fishers catch at Flag Boshielo Dam.

3.1.3 Socio-economic Characteristics

The FBD is located in a local municipality which is grant-dependant, where the largely unskilled population has low levels of education, and opportunities for skill development in the area are poor. The dependence on grants is a negative characteristic, highlighting the need for initiatives to improve the livelihoods in the area. The FBD and surrounding sites, such as the Schuinsdraai Nature Reserve (SNR), present opportunities for tourism development. The SNR covers a large portion of the Flag Boshielo Dam's western shore where public access is limited to recreational anglers and wildlife enthusiasts, and the development of a formal fishery in the area would help to redress the socio-economic problems through tourism associated with the recreational angling activities.

In contrast, besides the state-run Tompi Seleka Agricultural College and the privately owned Aloe Park Holiday and Fishing Resort, public access to the eastern shore of the impoundment is unrestricted and small-scale fishers can operate along the bank. As a result of the uncontrolled activities over the past four years, an increase in the use of illegal monofilament gill nets has been noted in waters along the eastern and western shorelines, which has resulted in the reduction of the Mozambique Tilapia that was shown to have fisheries potential by Hlungwani *et al*. (2023).

3.2 Glen Alpine Dam

3.2.1 Area description

The GAD presently supplies water to emerging farmers, who have not yet taken up their fully allocated quota and who are expected to supply the growing domestic requirements in future. The Blouberg area is rural in character, with a relative absence of large towns and burgeoning economic activity, and with a gradually shrinking population, due in part to rural-urban migration. The conjecture that the municipality is characterised by significant rural-urban migration of its population is supported by the fact that women outnumber men and that more than half of households are headed by females (Statistics South Africa, 2012). Education levels in Blouberg are significantly lower than in Mogalakwena, with more than one-quarter of persons over twenty years of age having had no schooling. In addition, access to water and

sanitation services in Blouberg is significantly lower than in Mogalakwena, and the municipality suffers from significant backlogs in other services, such as roads, education, health and recreational facilities (IDP, 2011- 2016).

3.2.2 Socio-economic Characteristics

As suggested by the statistics presented above, the Blouberg area, as a rural municipality, experiences economic challenges in terms of high unemployment levels, low education levels, skills mismatch, and insufficient infrastructure to support job creation initiatives. Its relative lack of development is partially due to the fact that it is a mountainous area, with large parts of the municipal area being unsuited for development. The main economic sector in the local municipal area is agriculture which consists of two economies: established and commercial (mostly White) farming community, and less established, subsistence-orientated traditional African farming community. Livestock and game farming are the pillars of the agricultural sector, especially that practised in areas around Alldays and the surrounding farms. Livestock farming is practised by participants in both the commercial and subsistence levels of the economy, although at varying degrees of intensity. Game farming is mainly practised in the northern and south-western parts of the municipality, including the Alldays, Vivo, Tolwe, Maastroom and Baltimore areas.

3.2.3 Glen Alpine Dam Fisheries

The small-scale fishing sector at GAD is important for local livelihoods. However, no solid conclusions could be drawn from the project as only eight interviews were conducted, and no quantitative data are available on the total catch, effort, or socio-economic value. Detailed information on the status of recreational angling at GAD is limited. There is no known popular recreational fishery for the dam with social media posts citing safety and water quality of the dam as one of the reasons for its lack of popularity. During the autumn and winter surveys, many gill nets were observed and there seems to be limited (if any) control of public access on the reserve side of the dam. As with the FBD fishery, there is a portion of the dam comprising a nature reserve where public access is considered to be limited, and a large portion where there is public access. Moreover, in GAD, the public has easy access to the dam wall on the

reserve side, whereas at FBD, public access is prohibited. The current lack of effective regulations and enforcement allows gill netting practices to persist, which may lead to overfishing. The absence of comprehensive and recent data on fish populations, catch rates, and socio-economic impacts in GAD hinders effective management and conservation efforts.

4. DISCUSSION

The sustainability of inland fisheries depends heavily on healthy fish stocks, effective governance, and responsible utilisation by resource users. At FBD and GAD, the current state of the fish communities, combined with the patterns of utilisation observed during the study, raise critical concerns regarding the feasibility of any formalised fisheries development in the near future. Although these systems show potential for future fisheries, the present conditions characterised by low catch rates, poor enforcement, widespread illegal gill-netting, and inadequate biological data make the establishment of a formal fishery highly premature. This chapter provides an integrated discussion of these constraints and examines whether future fisheries development remains a feasible long-term goal.

The most significant form of utilisation at these dams is widespread, illegal gill-netting using monofilament gill nets. Gill nets are size-selective and highly efficient, removing both breeding adults and juvenile cohorts, thus creating persistent recruitment bottlenecks, which are particularly damaging in multi-species systems where sensitive taxa (e.g., *L. rosae*, *O. mossambicus*) require stable age structures and unimpeded spawning cycles. The involvement of recreational anglers and casual subsistence fishers contributes comparatively minor pressure to the use of monofilament gill nets. Hook-and-line captures represent a lower-impact activity and form only a fraction of total removals. The dominance of monofilament unregulated nets means that removals are poorly documented, largely unreported, and occur in ways that are incompatible with sustainable stock replenishment.

Furthermore, fisheries governance around the two dams is inconsistent and largely ineffective. Limited patrols, insufficient staff, and weak institutional coordination between environmental and policing authorities allow illegal fishing activities to continue with little deterrence. This vacuum encourages resource users to operate

without accountability and undermines any potential fisheries management initiatives. Moreover, local communities often lack clear communication regarding regulations, contributing to misunderstandings about allowable gear types and access rights. Combined with limited engagement from authorities, this reduces compliance and fuels resource over-exploitation. As a result of the low catches of important species such as *Oreochromis mossambicus* and *Labeo rosae* which were shown to have potential to be the targeted species for a fishery in FBD by Marr *et al*. (2024). The current state could be an indication of the ecological imbalance, yet the low representation of *O. mossambicus* and *L. rosae* suggests severe population decline or displacement. Such low numbers also mean that standard biological metrics such as length-at-maturity, growth patterns, and population structure could not be determined reliably.

Based on the current conditions, recommending a formal fishery at Flag Boshielo or Glen Alpine would be irresponsible. As formalisation requires predictable and sustainable fish stocks, accurate biological and catch-effort data, functional governance systems, long-term community compliance, and mechanisms to control effort and prevent over-exploitation. None of these prerequisites are currently met. Introducing a formal fishery under these conditions could legitimise increased harvesting pressure, accelerate depletion of sensitive species, legitimise gill-netting through loopholes or misinterpretation, and undermine any future restoration efforts.

Despite the current shortcomings, a formal fishery may still be feasible in the long term if specific conditions are met. A balanced and forward-looking assessment suggests that fisheries development could remain a strategic goal only if stocks recover to stable reproductive levels; illegal gill-netting is brought under control; systematic monitoring programmes generate reliable biological data; governance, enforcement, and community co-management structures are strengthened, and habitat quality and water levels remain stable or improve. Thus, while immediate formalisation is not advisable, long-term feasibility remains possible, conditional on strategic ecological and governance interventions.

5. CONCLUSION

The current utilisation patterns at Flag Boshielo and Glen Alpine Dams are characterised by harmful and unsustainable practices dominated by illegal gill-netting. Combined with severely depleted stocks of key species and the absence of critical biological information, these factors make the development of a formal small-scale fishery unviable in the present context. The limited and unreliable biological data generated in this study cannot be used to inform management, and any fisheries development recommendations based on such incomplete information would be misguided. Nevertheless, a balanced assessment acknowledges that future fisheries development is not impossible. If stock status improves, illegal harvesting is curbed, and governance capacity is strengthened, a sustainable formal fishery may become feasible over time. Hence there is need to strengthen enforcement and governance to prioritize anti-gill-netting patrols, improve coordination between environmental and policing authorities, enhance community awareness of regulations.

Further recommendations would include establishing long-term monitoring programmes to regular catch assessments, dedicated sampling for key species, water quality and habitat monitoring. Stock recovery plans to protect spawning areas should be implemented, taking into consideration scientifically guided restocking programmes for depleted species, and catch-and-release for sensitive taxa should be promoted. A phased approach to fisheries formalisation should be developed that will consider formalisation after biological indicators show recovery, together with the establishment of co-management frameworks with local communities and capacity building for record-keeping, legal compliance, and sustainable harvest practices. Community livelihoods should be supported through alternative pathways by encouraging sustainable utilisation of the resources whilst promoting conservation aligned economic activities while stocks rebuild.

CHAPTER 6: GENERAL DISCUSSION AND RECOMMENDATIONS

1. GENERAL DISCUSSION

This chapter integrates the ecological, biological, and fisheries-use evidence collected at FBD and GAD into a single interpretive narrative. Unlike previous assessments, the current results show pronounced and unprecedented declines in water levels, species richness, fish abundance and catch-per-unit-effort. These declines signify not only environmental stress but also structural weaknesses in resource governance, inconsistent utilisation patterns and a lack of fisheries-directed management. These factors challenge the sustainability of both fisheries and the ecological functioning of the impoundments. In what follows, the discussion synthesises several themes:

- the ecological consequences of severe water recession;
- the collapse of biological signals needed to estimate life-history parameters;
- the intensifying pressure of unregulated utilisation;
- the governance vacuum shaping fisheries trajectories; and
- the pathway toward sustainable inland fisheries development in Limpopo Province.

A conceptual overview of these interacting chapters of the project is provided in Figure 6.1, which visually illustrates the possible drivers of the fish stock decline and the requirements for recovery in both FBD and GAD.

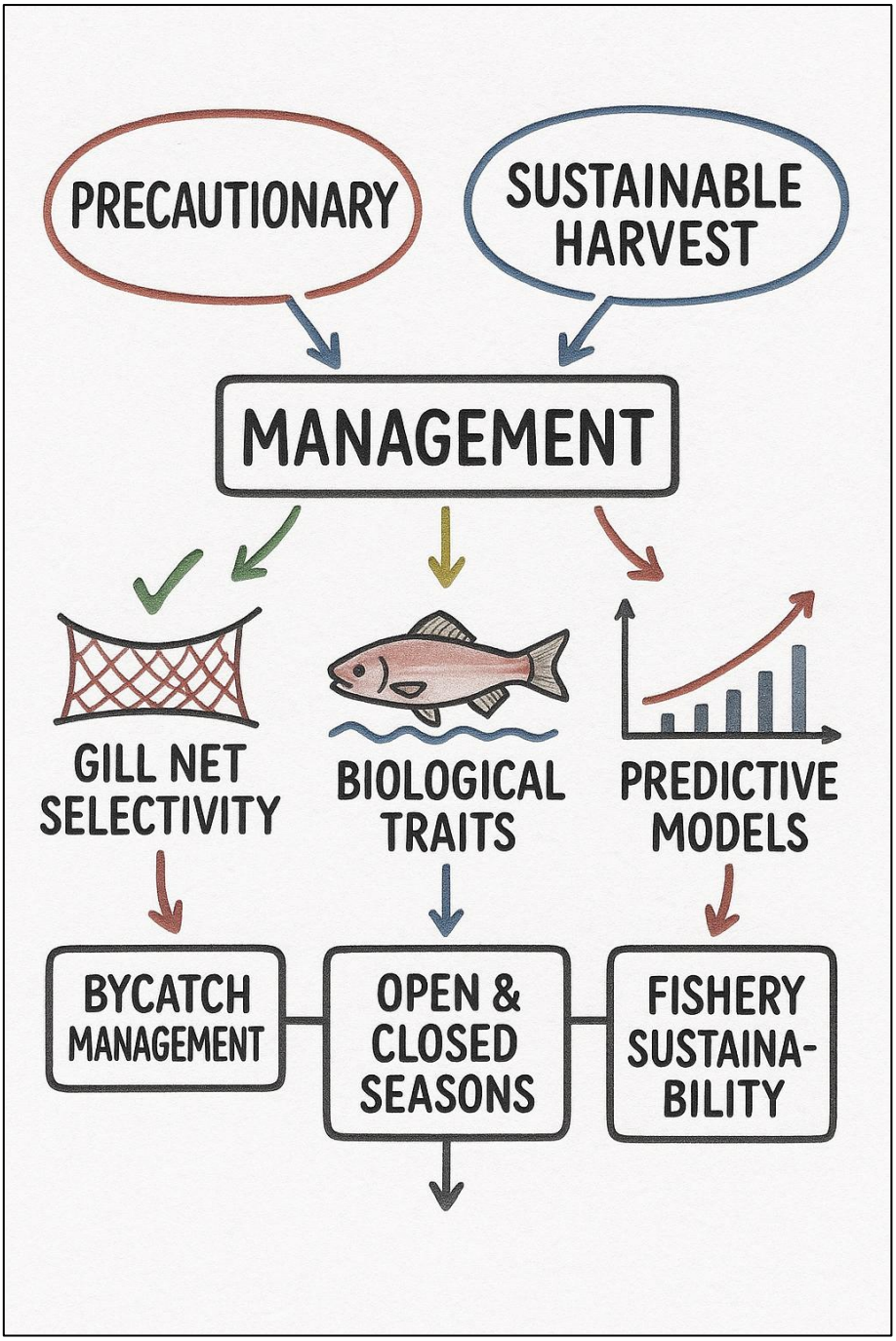


Figure 6.1: A visual synthesis of the causal interactions among water-level decline, habitat loss, biological collapse, fishing pressure, governance gaps, and the necessary recovery actions.

The drastic decline of GAD from 52% storage capacity in May 2024 to 2% in November 2024 represents an ecological shock with immediate consequences. The rapid transformation of submerged habitats into desiccated terrestrial zones resulted in the exposure of former littoral vegetation, the expansion of thin, unstable substrates, and the steep reduction of shaded and structured habitats essential for many fish species.

Species richness declined sharply from twelve species in May to only five in November, demonstrating that habitat contraction rapidly translated into biological depopulation. Fish were forced into the diminishing basin adjacent to the dam wall, producing dense aggregations, heightened competition, increased predation, and susceptibility to hypoxic conditions. Such crowding likely contributed to large-scale mortalities.

Notably, the recession was not caused by drought or climatic anomalies; it arose from managerial decisions related to water abstraction. This distinction is critical: it means the decline was avoidable. It also signals that the fish kill was not a natural event but a function of governance failure, causing artificial habitat loss in a system historically capable of sustaining diverse fish communities. The FBD, although less affected, also showed worrying declines in fish abundance and species composition. A reduction in CPUE biomass relative to previous studies underscores broader regional pressures affecting impoundment fisheries in Limpopo.

An important requirement for sustainable fisheries development is the ability to generate biological parameters such as growth rates, age structure, mortality, recruitment patterns, and length-at-maturity data. However, the current state of both dams, particularly GAD, made such assessments impossible. Historically abundant species, including *O. mossambicus* and *L. rosae*, were either recorded in low numbers or absent entirely. Only twelve specimens of *O. mossambicus* were captured in the entire current sampling programme, and *L. rosae* was absent. This collapse means that population-size structures and representative samples needed for parameter estimation were unattainable. The scarcity of these species, once dominant in previous assessments (Brits, 2006; Sara *et al*., 2017; Hlungwani *et al*., 2023), indicates a profound ecological shift and demonstrates that the current fish community no longer reflects the historical steady state.

As a result, any attempt to fit growth curves, assess mortality, or estimate exploitation reference points would be biologically meaningless. Thus, the present dataset cannot compute biological parameters required for fisheries management. The stocks are depleted, unrepresentative and unstable. This failure is not a methodological limitation but a reflection of the precarious state of the systems. It underscores the urgent need

for stock recovery, restocking programmes, and long-term ecological monitoring before management models can be meaningfully applied.

Both formal and informal fishing activities are widespread in FBD and GAD; however, the current utilisation patterns show characteristics associated with overexploitation, especially for FBD. Monofilament gill nets are widely deployed despite the lack of research on their sustainable use and the risks they pose to non-target species such as crocodiles. Interviews with resource users, field rangers and local stakeholders indicated that a commercially oriented “syndicate” provides monofilament gill nets to fishers and purchases the captured fish for resale. This unregulated supply chain places sustained pressure on declining stocks, particularly *O. mossambicus*, a species already reduced to negligible representation in the current study.

As the CPUE and species richness are already low, any additional pressure will accelerate the complete collapse of the fishery. The current level of exploitation is fundamentally incompatible with resource renewal. Thus, under present conditions, recommending a formal fishery would be ecologically and economically reckless. However, this does not imply that a fishery is impossible in principle. Rather, it frames the precondition that stock recovery and governance reform must precede any movement toward formalisation.

South Africa’s inland fisheries sector suffers from a well-documented policy vacuum (Weyl *et al.,* 2007; Weyl *et al*., 2020). Although the NFWCFP was gazetted in 2022, its implementation has slowed due to capacity limitations and the fragmented governance arrangements between dam managers, provincial departments and rural communities. In practice, this means that fishing continues without effective monitoring, regulation or enforcement. The absence of coordinated governance has four major implications;

- No mechanisms exist to prevent overexploitation, especially by monofilament gill nets;
- Hydrological decisions such as water abstraction are made without reference to ecological thresholds;
- Biological information is not collected systematically, leaving managers blind to stock dynamics;

- Communities lack co-management platforms, creating tension and reducing compliance.

In such a governance environment, any move toward fishery formalisation would replicate failure unless preceded by institutional strengthening.

2. RECOMMENDATIONS

Given the collapse of biological indicators, immediate investment in stock recovery is essential. Restocking programmes must be cautiously designed, ensuring genetic integrity, habitat suitability, and long-term monitoring. Recovery of *O. mossambicus* and *L. rosae* is critical as they are ecological keystone species and central to potential small-scale fisheries in FBD. A sustainable fishery requires more than biological recovery, it requires governance that is participatory, enforceable and coherent. Limpopo Province should develop dam-specific co-management committees comprising dam managers, enforcement authorities, local communities, traditional leaders and conservation authorities. Co-management has proven successful in comparable African inland fisheries, particularly where enforcement capacity is low, but community stakes are high. Water abstraction must be regulated to maintain minimum ecological water levels, especially for GAD. Without hydrological stability, habitat will continue to collapse regardless of fishery efforts. A formal policy requirement should link water release and abstraction decisions directly to ecological risk thresholds.

A formal fishery could become viable in the long term in FBD and GAD, but only after:

- stocks recover to biologically meaningful levels;
- life-history parameters can be reliably generated;
- governance structures are functional;
- illegal gill netting is controlled; and
- hydrological risks are stabilised.

Until these conditions are met, formalisation would threaten both ecological integrity and rural livelihoods. The combined pressures of extreme water recession, habitat loss, declining species richness, overexploitation and governance failures have driven

both GAD and FBD into a state inconsistent with sustainable fisheries utilisation. Biological signals required for stock assessment have collapsed, making it impossible to estimate growth, mortality or productivity. Without these parameters, no science-based harvest strategies can be developed. The implications are profound: the current results cannot serve as a foundation for fisheries management. Instead, they highlight the urgent need for stock recovery, restocking initiatives, hydrological safeguards and institutional reform. Only once the ecological and governance conditions stabilise should the formalisation of a fishery be reconsidered

The synthesis of ecological, managerial and governance shortcomings across the GAD and FBD clearly demonstrates that the sustainability of inland fisheries in Limpopo is currently compromised by a convergence of biological decline, institutional fragmentation, and destructive utilisation patterns. The results of this study, particularly the extremely low catches of *O. mossambicus* and *L. rosae*, recurrent dominance shifts and the demonstrated sensitivity of fish stocks to water-level manipulation indicate that meaningful fisheries development will not be possible without strategic and sustained intervention. The following recommendations provide a structured pathway aimed at ecological rehabilitation, monitoring, institutional strengthening and the gradual emergence of a regulated and socially beneficial fishery.

The precipitous decline in key species, especially *O. mossambicus* and *L. rosae*, requires deliberate rehabilitation interventions. Given that the limited catches of these species prevented the computation of basic biological parameters, managers should prioritise restocking programmes grounded in genetic and ecological integrity. The recovery of these species is essential for both ecological stability and any future aspirations of a productive fishery. In parallel, the removal of illegal monofilament gill nets must be intensified, as their disproportionate targeting of *O. mossambicus* is directly linked to the collapse of the species in both dams. Protection of nursery habitats, particularly shallow vegetated margins, will also be essential to facilitate natural recruitment following restocking.

The absence of coordinated governance, combined with severe capacity gaps within local authorities, has contributed significantly to the degradation observed. Effective fisheries management in Limpopo requires the urgent establishment of operational co-management structures, comprising dam managers, conservation agencies, local

fishers, researchers, and community representatives. These bodies should be empowered to oversee gear regulation, issue fishing permits, conduct compliance patrols and manage the interface between water abstraction and biodiversity conservation. Training programmes for enforcement and monitoring staff will be essential, given the historical deficit in technical expertise and operational resources.

Given the dynamic nature of the two systems and the large uncertainties surrounding stock structure, water-level response and exploitation pressure, a long-term monitoring programme must be institutionalised. Standardised sampling, both fishery-dependent and independent should be conducted biannually, with an emphasis on tracking species richness, abundance, size structure, CPUE and habitat conditions. Such data will enable managers to identify trends, validate restocking success, anticipate ecological risks and gradually develop species-specific harvest guidelines. Without this foundational dataset, policy implementation under the NFWCFP will remain poorly informed.

The ecological collapse at GAD following the abrupt drop from 52% to 2% capacity demonstrates that unmanaged water abstraction can trigger catastrophic fish kills. Water managers must therefore adopt environmental flow frameworks that explicitly incorporate fish habitat requirements, seasonal hydrology, and the prevention of hypoxic collapse. Joint planning meetings between fisheries authorities, water resource managers, and conservation agencies should be mandatory during periods of expected drawdown. The protection of minimum ecological water levels should become a non-negotiable requirement, especially in impoundments that support emerging fisheries or sensitive species.

Although there is a temptation to formalise fisheries rapidly due to socio-economic demand, the evidence presented in this study strongly suggests that such an approach would be premature and potentially harmful. The current exploitation levels, particularly illegal gill-netting syndicates, have already pushed stocks below thresholds needed for sustainable yield. A phased approach is recommended, where fishing effort is gradually formalised only after measurable biological recovery has been demonstrated. Interim regulatory steps could include the banning of monofilament nets, mandatory registration of fishers, issuance of limited-access permits and strict penalties for unauthorised gear. Over time, as monitoring data

become available and stock health improves, provincial authorities may cautiously define harvest limits for selected species.

The persistence of illegal fishing syndicates and the commercialisation of unregulated catches underscore the need for community-based interventions. Awareness campaigns focused on the ecological and long-term socio-economic consequences of fish stock depletion should accompany robust enforcement. Formal recognition of community stewards, trained to monitor fishing activity, report infractions and support habitat protection would assist to reduce reliance on external enforcement agencies. Encouraging alternative livelihoods, where feasible, could further mitigate pressure on fish stocks while empowerment initiatives may foster local buy-in for conservation objectives.

Significant gaps remain in the biological, ecological, and socio-economic understanding of the two systems. Future research should prioritise life-history studies of key species, trophic modelling, hydrological-ecological interactions, and assessments of fisher livelihoods. Studies on genetic integrity of restocked species will be critical to avoid outbreeding depression or hybridisation impacts. Integrated ecosystem assessments including nutrient loading, pollution sources, and climate-induced stressors should complement fisheries-focused research to provide a holistic baseline for long-term management.

3. CONCLUSION

This study demonstrates that the fishery resources of GAD and FBD are at a critical juncture. Severe declines in species richness, unsustainable exploitation patterns, hydrological mismanagement and institutional fragmentation have collectively pushed these systems toward ecological instability. The low catches of *O. mossambicus* and *L. rosae,* combined with the inability to determine even the most basic biological parameters underscore how compromised these fisheries have become. As such, the establishment of a formal inland fishery at this stage would be ecologically irresponsible and economically short-lived. However, with coordinated intervention, recovery is possible. Restocking, monitoring, governance reform and habitat protection can gradually rebuild the ecological foundations required for sustainable utilisation. Such a trajectory aligns with the objectives of the NFWCFP, which seeks

to transform inland fisheries while safeguarding biodiversity. Ultimately, the future of these systems depends on whether management agencies can shift from reactive crisis responses to proactive, evidence-based stewardship. If implemented with commitment, the pathway outlined in this chapter offers a viable route toward ecological recovery, socio-economic benefits and the eventual development of a sustainable and regulated inland fishery in FBD and GAD.

REFERENCES

ABELL R, THEIME ML, REVENGA C, BRYER M, KOTTELAT M, BOGUTSKAYA N, COAD B, MANDRAK N, CONTRERAS-BALDERAS S, BUSSING W, STIASSNY MLJ, SKELTON P, ALLEN GR, UNMACK P, NASEKA A, NG R, SINDORF N, ROBERTSON J, ARMIJO E, HIGGINS JV, HEIBEL TJ, WIKRAMANAYAKE E, OLSON D, LOPEZ HL, REIS RE, LUNDBERG JG, SABAJ PEREZ MH, PETRY P (2008) Freshwater Ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. *BioScience* 58:403–414.

ADDO-BEDIAKO A, MARR SM, JOOSTE A, LUUS-POWELL WJ (2014a) Are metals in the muscle tissue of Mozambique tilapia a threat to human health? A case study of two impoundments in the Olifants River, Limpopo, South Africa. *International Journal of Limnology* 50:201–210.

ADDO-BEDIAKO A, MARR SM, JOOSTE A, LUUS-POWELL WJ (2014b) Human health risk assessment for silver catfish *Schilbe intermedius* Rüppell, 1832, from two impoundments in the Olifants River, Limpopo, South Africa. *Water SA* 40:607–613.

ALLANSON BR and JACKSON PBN (1983) Limnology and Fisheries Potential of Lake le Roux. South African National Scientific Programmes Report No. 77. 182 pp.

ASHTON PJ (2010) The demise of the Nile crocodile (*Crocodylus niloticus*) as a keystone species for aquatic ecosystem conservation in South Africa: The case of the Olifants River. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20: 489–493.

ASHTON PJ and DABROWSKI JM (2011) An overview of water quality and the causes of poor water quality in the Olifants River Catchment. WRC Project No. K8/887. Water Research Commission, Pretoria.

ASHTON PJ, LOVE D, MAHACHI H and DIRKS PHGM (2001) An overview of the Impact of Mining and Mineral Processing Operations on Water Resources and Water Quality in the Zambezi, Limpopo and Olifants Catchments in Southern Africa. In*,* CSIR Report No. ENV-P-C 2001-042, Centre for Scientific and Industrial Research, Pretoria, Pretoria.

AZEEZ OI, MYBURGH JG, MEINTJES RA., OOSTHUIZEN MC and CHAMUNORWA JP (2017) Histomorphology, ultrastructure and fatty acid composition of the adipose tissue in pansteatitis, the potentials in understanding the underlying mechanism and diagnosis of pansteatitis in the Nile crocodile. *Lipids in Health and Disease* 16(1): 47.

BARKHUIZEN LM (2015) An assessment of fish and fisheries in impoundments in the Upper Orange-Senqu and lower Vaal River Basin. PhD thesis, University of the Free State, Bloemfontein.

BARKHUIZEN LM, WEYL OLF and VAN AS JG (2016) A qualitative and quantitative analysis of historic commercial fisheries in the Free State Province in South Africa. *Water SA* 42 (4): 601–605.

BARKHUIZEN LM, WEYL OLF and VAN AS JG (2017) An assessment of recreational bank angling in the Free State Province in South Africa using license sale and tournament data. *Water SA* 43 (3): 442–449.

BÉNÉ C, HERSOUG B and ALLISON EH (2010) Analyzing the pro-poor functions of small-scale fisheries in developing countries. *Development Policy Review* 28(3): 325–358.

BOOTH AJ and KHUMALO N (2009) Age, growth, mortality and reproduction of *Marcusenius pongolensis*, *Oreochromis mossambicus* and *Schilbe intermedius* in an oligotrophic impoundment in Swaziland. *African Journal of Ecology* 48: 481–489.

BORGSTRÖM R (1989). Direct estimation of gill-net selectivity for roach (*Rutilus rutilus* (L.)) in a small lake. *Fisheries Research* 7: 289–298.

BOTHA H, Van HOVEN W and GUILETTE LJ (2011) The decline of the Nile crocodile population in Loskop Dam, Olifants River, South Africa. *Water SA* 37: 103–108.

BRITS DL (2006) Distribution and status of the silver carp *Hypophthalmichthys molitrix* (Valenciennes, 1844) in the Flag Boshielo Dam (Arabie Dam) and its influence on the ecology of the Dam. Unpublished PhD thesis, University of Limpopo, Sovenga, South Africa. 253 pp.

BRITZ PJ, HARA MM, WEYL OLF, TAPELA BN and ROUHANI QA (2015) Scoping study on the development and sustainable utilisation of inland fisheries in South Africa. Volume 1: Research Report, WRC Report No. TT 615/1/14.

BUCKLAND ST (1984). Monte-Carlo confidence intervals. *Biometrics* 40: 811–817.

CLARK JR (1960) Report on selectivity of fishing gear. 2: 27–36.

COOKE SJ, ALLISON EH, BEARD TD, ARLINGHAUS R, ARTHINGTON AH, BARTLEY DM, COWX, FUENTEVILLA C, LEONARD NJ, LORENZEN K, LYNCH AJ, NGUYEN VM, YOUN SJ, TAYLOR WW and WELCOMME, RL (2016) On the sustainability of inland fisheries: finding a future for the forgotten. *Ambio* 45: 753–764.

COPE JM and PUNT AE (2007) Admitting ageing error when fitting growth curves: an example using the von Bertalanffy growth function with random effects. *Canadian Journal of Fisheries and Aquatic Sciences* 64(2): 205–218.

COWX IG (1998) Aquatic resource planning for resolution of fisheries management issues. pp 97–105. In Hickley P and Tompkins H (Eds) Recreational Fisheries: Social, Economic and Management Aspects. Blackwell Science, Oxford.

DABROWSKI J, OBERHOLSTER PJ and DABROWSKI JM (2014) Water quality of Flag Boshielo Dam, Olifants River, South Africa: historical trends and the impact of drought. *Water SA* 40**:** 345–357.

DABROWSKI J, OBERHOLSTER PJ, DABROWSKI JM, BRASSEUR J and GIESKES J (2013) Chemical characteristics and limnology of Loskop Dam on the Olifants River (South Africa), in light of recent fish and crocodile mortalities. *Water SA* 39**:** 675–686.

DE VILLIERS P (2003) Freshwater fisheries conservation and management in South Africa with specific reference to the Free State province. In: Proc. 3rd International Conference of the Pan-African Fish and Fisheries Association, 10–14 November 2003, Cotonou, Benin. 230–231.

DE VILLIERS S and MKWELO ST (2009) Has monitoring failed the Olifants River, Mpumalanga? *Water SA* 35: 271–276.

DE VILLIERS S and THIART C (2007) The nutrient status of South African rivers: Concentrations, trends and fluxes from the 1970s to 2005. *South African Journal of Science* 103: 343–349.

DEFF. Department of Environment, Forestry and Fisheries (2020) Draft National Freshwater (Inland) Wild Capture Fisheries Policy of South Africa.

DOLL JC, THOMAS ND and LAUER TE (2014) Gill net selectivity of yellow perch. *Journal of Freshwater Ecology.*

EFRON B (1982) The jackknife, the bootstrap and other resampling plans. Society for Industrial and Applied Mathematics, Philadelphia. 92 pp.

ELLENDER BR (2008) The impact of angling on smallmouth and largemouth yellowfish, *Labeobarbus aeneus* and *Labeobarbus kimberleyensis*, in Lake Gariep, South Africa. M.Sc. Thesis, Rhodes University, South Africa. 111 pp.

ELLENDER BR and WEYL OLF (2014) A review of current knowledge, risk and ecological impacts associated with non-native freshwater fish introductions in South Africa. *Aquatic Invasions* 9(2): 117–132.

ELLENDER BR, WEYL OLF and WINKER H (2009) Who uses the fishery resources in South Africa's largest impoundment? Characterising subsistence and recreational sectors on Lake Gariep. *Water SA* 35: 677–684.

ELLENDER BR, WEYL OLF, WINKER H and BOOTH AJ (2010a) Quantifying the annual fish harvest from South Africa's largest freshwater reservoir. *Water SA* 36(1): 45–52.

ELLENDER BR, WOODFORD DJ, WEYL OLF and COWX IG (2014) Managing conflicts arising from fisheries enhancements based on non-native fishes in southern Africa. *Journal of Fish Biology* 85: 1890–1906.

FAO. FOOD AND AGRICULTURE ORGANISATION (2003) Fisheries Management 2. The ecosystem approach to fisheries. F*AO Technical Guideline for Responsible Fisheries*. Rome; FAO: 112 pp.

FAO. FOOD AND AGRICULTURE ORGANISATION (2024). The State of World Fisheries and Aquaculture 2020. *Sustainability in Action*. Rome.

FLUET-CHOUINARD E, FUNGE-SMITH S, MCINTYRE PB (2018) Global hidden harvest of freshwater fish revealed by household surveys. *Proceedings of the National Academy of the Sciences of the United States of America* 115: 7623–7628.

FOUCHÉ PSO (2009) Aspects of the ecology and biology of the Lowveld largescale yellowfish (*Labeobarbus marequensis*) (Smith 1843), in the Luvuvhu River, Limpopo River System, South Africa. Unpublished PhD thesis, University of Limpopo, Sovenga, South Africa.

FOUCHÉ PSO, VLOK W, ROOS JC, LUUS-POWELL W and JOOSTE A (2013) Establishing the fishery potential of Lake Nandoni in the Luvuhu River, Limpopo Province. Water Research Commission Report WRC No. 1925/1/12. Pp 154.

FUNGE-SMITH SJ (2018) Review of the state of world fishery resources: inland fisheries. FAO Fisheries and Aquaculture Circular No. C942 Rev.3, Rome. 397 pp.

GULLAND JA and HARDING D (1961) The selection of Clarias gariepinus (Peters) by nylon gillnets. *Journal of marine science* 26: 215–222.

HAMLEY JM and REGIER HA (1973) Direct estimates of gillnet selectivity to walleye *(Stizostedion vitreum vitreum)*. *Journal of the Fisheries Research* 30(6): 817–30.

HAMMAN KCD (1981) Aspekte van die bevolkingsdinamika van die Hendrik Verwoerddam met verwysing na die ontwikkeling van ‘n visserybestuurplan. Ph.D. Thesis, Rand Afrikaans University, South Africa. 208 pp.

HARA MM and BACKEBERG GR (2014) An institutional approach for developing South African inland freshwater fisheries for improved food security and rural livelihoods. *Water SA* 40(2): 277–286.

health assessment index protocol. *African Journal of Aquatic Science* 37(1): 27–37.

HEATH R, COLEMAN T and ENGELBRECHT J (2010). Water quality overview and literature review of the ecology of the Olifants River. WRC Report No. TT452/10. Water Research Commission, Pretoria. 119 pp.

HECHT T (1980) A comparison between otolith and scale methods of ageing, and the growth of *Sarotherodon mossambicus* (Pisces: Cichlidae) in a Venda impoundment (Southern Africa). *South African Journal of Zoology* 15: 222–228.

HLUNGWANI HA (2021) Assessing the potential of establishing a freshwater inland fishery in Flag Boshielo Dam, Limpopo Province, South Africa. *Research Thesis*. Biodiversity Department, University of Limpopo. 187

HLUNGWANI HA, MARR SM, WEYL OLF & SARA JR (2023). *Biological and life-history parameters for Labeo rosae and Oreochromis mossambicus from Flag Boshielo Dam, Limpopo Province, South Africa.* African Journal of Aquatic Science.

HLUNGWANI HA, MARR SM, WEYL OLF, HOFFMAN AC, BOTHA H & SARA JR (2024). *Using a rapid assessment to estimate biological and life history parameters of potential fishery species at Loskop Dam, Limpopo River System, South Africa.* African Journal of Aquatic Science.

HOBBS P, SUZAN P, OELOFSE H and RASCHER J (2008) Management of Environmental Impacts from Coal Mining in the Upper Olifants River Catchment as a Function of Age and Scale. *Water Resources Development* 24: 417–431.

HODGSON FDI and KRANTZ R (1998) Investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam with specialised investigation in the Witbank Dam sub-catchment. in, Report No. 291/1/98. Water Research Commission, Pretoria.

HUCHZERMEYER KDA, GOVENDER D, PIENAAR DJ and DEACON AR (2011) Steatitis in wild sharptooth catfish, *Clarias gariepinus* (Burchell), in the Olifants and Lower Letaba rivers in the Kruger National Park, South Africa. *Journal of Fish Diseases* 34(7): 489–498.

IRVINE K, ETIEGNI CA and WEYL OLF (2019) Prognosis for long-term sustainable fisheries in the African Great Lakes. *Fisheries Management and Ecology* 26: 413–425.

JACKSON PBN (1973) Internal report on the potential of South African inland waters for commercial fisheries. Unpublished report to the Water Research Commission, Pretoria. 27 pp.

JACKSON PBN (1974) Freshwater fish for farm profit: Water, dams and management under the spotlight. Farmer's Weekly (October 1974). 42–47.

JACKSON PBN (1976) Water Resources and Freshwater Fisheries in southern Africa. In: Baker G (ed.) Resources of Southern Africa: Today and Tomorrow. The Associated Scientific and Technical Societies of South Africa, Johannesburg. 196–207.

JACKSON PBN (1980) Fresh and brackish water fish production as an employment source in the Transkei. In: Transkei and Ciskei Research Society, Proc. 6th biennial meeting, Umtata, 7-9 March, 1980. 155–159.

JACKSON PBN (1981) Orange River dams fish population project. Rhodes University Institute for Freshwater Studies, Progress Report (August). Rhodes University, Grahamstown. 1–11.

JOOSTE A, MARR SM, ADDO-BEDIAKO A and LUUS-POWELL WJ (2014) Metal bioaccumulation in the fish of the Olifants River, Limpopo province, South Africa, and the associated human health risk: A case study of rednose labeo *Labeo rosae* from two impoundments. *African Journal of Aquatic Science* 39: 271–277.

KANTOUSSAN J, ECOUTIN JM, GUY FONTENELLE G, DE MORAIS LT and LAE R (2014) Catch Per Unit Effort and Yields As Indicators Of Exploited Fish Communities: Application To Two West African Reservoirs. *Lake and Reservoir Management*19: 86–97.

LEBEPE J, MARR SM and LUUS-POWELL WJ (2016) Metal contamination and human health risk associated with the consumption of *Labeo rosae* from the Olifants River system, South Africa. *African Journal of Aquatic Science* 41(2): 161–170.

LEIBOLD M & VAN ZYL C (2008) The economic impact of sport and recreational angling in the Republic of South Africa: Extensive report. Report of project to scientifically determine the overall economic impact and strategic value of sport and recreational angling in South Africa. Development Strategies International (Pty.) Ltd

LYNCH AJ, ELLIOTT V, PHANG SC, CLAUSSEN JE, HARRISON I, MURCHIE KJ, STEEL EA and STOKES GL (2020) Inland fish and fisheries integral to achieving the Sustainable Development Goals. *Nature Sustainability*.

MADANIRE-MOYO GN, LUUS-POWELL WJ and OLIVIER PAS (2012) Diversity of metazoan parasites of the Mozambique tilapia, *Oreochromis mossambicus* (Peters, 1852), as indicators of pollution in the Limpopo and Olifants River Systems. *Onderstepoort Journal of Veterinary Research* 79 (1): 9.

MARR SM, HLUNGWANI HA, WEYL OLF & SARA JR (2024). *Per-recruit analysis and proposed sustainable harvest strategy for rednose labeo (Labeo rosae) and Mozambique tilapia (Oreochromis mossambicus) at Flag Boshielo Dam.* African Journal of Aquatic Science.

MARR SM, JOOSTE A, ADDO-BEDIAKO A and LUUS-POWELL WJ (2015) Should people be eating fish from the Olifants River, Limpopo province? Ed. P ARDERNE, In: Proceedings of the 18th Yellowfish Working Group Conference. Black Mountain Hotel, Thaba ´Nchu' Free State Province, South Africa: 25–35.

MARR SM, LEBEPE J, STEYL JCA, SMIT WJ and LUUS-POWELL WJ (2017). Bioaccumulation of selected metals in the gill, liver and muscle tissue of rednose labeo *Labeo rosae* from two impoundments on the Olifants River, Limpopo river system, South Africa. *African Journal of Aquatic Science* 42(2): 123–130.

MCCAFFERTY JR, WEYL OLF, ELLENDER BR and BRITZ P (2012) The use of water resources for inland fisheries in South Africa. *Water SA* 38: 327–343.

MILLAR RB. R Code for fitting SELECT models to gillnet data, 2009. [cited 2014 25 January]; Available from: https://www.stat.auckland.ac.nz/~millar/selectware/R/gillnets/gillnetfunctions.R.

OBERHOLSTER PJ, BOTHA AM, HILL L and STRYDOM WF (2017) River catchment responses to anthropogenic acidification in relationship with sewage effluent: an ecotoxicology screening application. *Chemosphere* 189: 407–417.

OBERHOLSTER PJ, MYBURGH JG, ASHTON PJ and BOTHA AM (2010) Responses of phytoplankton upon exposure to a mixture of acid mine drainage and high levels of nutrient pollution in Lake Loskop, South Africa. *Ecotoxicology and Environmental Safety* 73: 326–335.

POLLOCK KH, JONES CM and BROWN TL (1994) Angler survey methods and their applications in fisheries management. *American Fisheries Society*, Bethesda, Md. (USA).

POTTS W, BOOTH AJ, HECHT T and ANDREW TG (2006) The life history and fishery potential of *Labeo umbratus* (Teleostei: Cyprinidae) in five small South African reservoirs. *African Journal of Aquatic Science* 31(2): 285–295.

POTTS WM (2003) Towards the development of species-specific fish production models for small reservoirs in southern Africa. Ph.D. Thesis, Rhodes University, South Africa. 148 pp.

POTTS WM, WEYL OLF and ANDREW TG (2004) Final report on an initial assessment of the fisheries potential of Gariep Dam Prepared by: Enviro-Fish Africa (Pty) Ltd for: Department of Economic Affairs, Environment and Tourism, Northern Region, Province of the Eastern Cape. 38 pp.

PUERTAS PE and BODMER RE (2004) “Hunting effort as a tool for community-based wildlife management in Amazonia". In Kirsten M. Silvius, Richard E. Bodmer & José M. V. Fragoso (ed.). People in Nature: Wildlife Conservation in South and Central America. *Columbia University Press*. 123–136.

RICHARDSON TJ, BOOTH AJ and WEYL OLF (2009) Rapid assessment of the fishery potential of Xonxa Dam near Queenstown, South Africa. *African Journal of Aquatic Science* 34(1): 87–96.

ROUHANI Q (2001) A report on an assessment of the potential for small-scale fisheries development on Disaneng and Setumo dams in the North-West Province. Rural Fisheries Programme, Department of Ichthyology and Fisheries Science, Rhodes University. 17 pp.

RYDER RA (1982) The Morphoedaphic Index--Use, Abuse, and Fundamental Concepts. *Transactions of the American Fisheries Society* 111: 154–164.

SARA JR, LUUS-POWELL WJ, FOGELSON SB, BOTHA H, GUILLETTE TC, SMIT WJ, HOFFMAN A, KUNUTU KD, KOELMEL JP and BOWDEN JA (2020) A histological evaluation of pansteatitis-affected Mozambique tilapia, *Oreochromis*

mossambicus (Peters 1852), from different geographical locations in South Africa. *Journal of Fish Diseases* 43: 1185–1199.

SARA JR, MARR SM, CHABALALA NM, SMIT WJ, ERASMUS L and LUUS-POWELL WJ (2018) Human health risks of metalloids and metals in muscle tissue of silver carp *Hypophthalmichthys molitrix* (Valenciennes, 1844) from Lake Flag Boshielo, South Africa. *African Journal of Aquatic Science* 43: 405–411.

SARA JR, WEYL OLF, MARR SM, SMIT WJ, FOUCHE PSO and LUUS-POWELL WJ (2017) Gill net catch composition and catch per unit effort in Flag Boshielo Dam, in Limpopo Province, South Africa. *Water SA* 43: 463–469.

SCHRAMM M (1993) A comparison of Cyprinid fish populations in three large Transkei reservoirs with respect to abundance and reproduction. *South African Journal of Aquatic Science* 19: 74–88.

SKELTON P (2001) A complete guide to the Freshwater fishes of Southern Africa. *Struik Publishers*. 395 pp.

SMITH BG, BRADLEY J, BLACKWELL MR, WUELLNER BDS, and GRAEB DWW (2017) Contact selectivity for four fish species sampled with North American standard gill nets. *North American Journal of Fisheries Management* 37(1): 149–161.

SWANEPOEL PJ, Barkhuizen LM, ELLENDER BR; VAN As LL & WEYL OLF (2025) Temporal trends in fisher catch and effort, and the impact of Covid-19 on inland fisheries: A case study from Gariep Dam, South Africa. *Water SA*, 51

TAPELA BN, BRITZ BJ and ROUHANI QA (2015) Scoping study on the development and sustainable utilisation of inland fisheries in South Africa. Vol 2: Case studies of small-scale inland fisheries. WRC Report No. TT615/2/14. Water Research Commission, Pretoria. 156 pp.

THORPE A and VAN ANROOY R (2010) Strategies for the rehabilitation of the inland fisheries sector in Central Asia. *Fisheries Management and Ecology* 17(2): 134–140.

TÓMASSON T (1983) The biology and management consideration of abundant large cyprinids in Lake le Roux, Orange River, South Africa. PhD Thesis, Rhodes University, South Africa. 218 pp.

TÓMASSON T, CAMBRAY JA, ECCLES DH, JACKSON PBN and WHITE PN (1983) Fisheries of Lake le Roux. In: Allanson BR, Jackson PBN (eds.). *Limnology and Fisheries Potential of Lake le Roux*. South African National Scientific Programmes Report No. 77. 153–160 pp.

TÓMASSON T, BRUTON MN and HAMMAN KC (1985) The demography and management of large Cyprinids in a reservoir on the Orange River, South Africa. *Fish. Res.* 3: 279–308.

TWEDDLE D, COWX IG, PEEL R and WEYL OLF (2015) Challenges in fisheries management in the Zambezi, one of the great rivers of Africa. *Fisheries Management and Ecology* 22: 99–111.

VAN RENSBURG BJ, WEYL OLF, DAVIES SJ, WILGEN LJ, PEACOCK DS, SPEAR D and CHIMIMBA CT (2011) Chapter 15: Invasive Vertebrates of South Africa. in *Biological Invasions: Economic and Environmental Costs of Alien Plant, Animal, and Microbe Species.* 2nd Edition. PIMENTEL, D. (Ed.), Boca Raton, Florida: CRC Press. 326–378.

WEYL OLF (2018) Enhancing contributions of inland fisheries to rural livelihoods: An empirical assessment of freshwater fish stocks, fisheries potential, market value chains, co-management and governance arrangements. Presentation during Water Research Commission Reference Group Meeting. PLAAS, University of Western Cape. February 2018.

WEYL OLF and BOOTH AJ (1999) On the life history of a cyprinid fish, *Labeo cylindricus*. *Environmental Biology of Fishes* 55: 215–225.

WEYL OLF and COWLEY PD (2015) Fisheries in subtropical and temperate regions of Africa. Pp 241–255. In: JF CRAIG (Editor). *The Ecology of Freshwater Fisheries.* John Wiley and Sons Ltd. United Kingdom.

WEYL OLF and HECHT T (1998) The biology of *Tilapia rendalii* and *Oreochromis mossambicus* (Pisces: Cichlidae) in a subtropical lake in Mozambique. *South African Journal of Zoology* 33: 178–188.

WEYL OLF and HECHT T (1999). A successful population of largemouth bass, *Micropterus salmoides*, in a subtropical lake in Mozambique. *Environmental Biology of Fishes* 54(1): 53–66.

WEYL OLF, BARKHUIZEN LM, CHRISTISON K; DALU T, HLUNGWANI HA; IMPSON D; SANKAR K; MANDRAK NE; MARR S; SARA JR; SMIT NJ; TWEDDLE D; VINE NG; WEPENER V; ZVAVAHERA M and COWX IG (2020) Ten research questions to support South Africa's Inland Fisheries Policy. *African Journal of Aquatic Science*. 1–10.

WEYL OLF, BOOTH AJ, WINKER H, TRAAS GRL, McCAFFERTY JR, PEEL RA and WARTENBERG R (2010a) Assessment of the fishery potential for alien species on Darlington Dam. Report No. 5. SAN-Parks: Sundays River Freshwater Fish Research Project, Project ID: PO64438. 1–59.

WEYL OLF, POTTS WM, ROUHANI Q and BRITZ PJ (2007) The need for an inland fisheries policy in South Africa: A case study on the Northwest Province. *Water SA* 33: 497–504.

WEYL OLF, RIBBINK AJ and TWEDDLE D (2010b) Lake Malawi: fishes, fisheries, biodiversity, health and habitat'. *Aquatic Ecosystem Health and Management* 13(3): 241–254.

WINKER H, ELLENDER B, WEYL OLF and BOOTH AJ (2010) Validation of growth zone deposition in otoliths of two large endemic cyprinids in Lake Gariep, South Africa. *African Zoology* 45(1): 133–138.

WINKER H, WEYL OLF, BOOTH AJ and ELLENDER BR (2012) Life history strategy and population characteristics of an unexploited riverine cyprinid, *Labeo capensis*, in the largest impoundment in the Orange River Basin. *African Zoology.* 47: 85–99.

WOODBORNE S, HUCHZERMEYER K, GOVENDER D, PIENAAR D, HALL G, MYBURGH J, DEACON A, VENTER J and LÜBCKER N (2012) Ecosystem change and the Olifants River crocodile mass mortality events. *Ecosphere* 3: 1–17.

YOKOTA K, FUJIMORI Y, SHIODE D and TOKAI T (2001) Effect of thin twine on gill net size selectivity analysed with the direct estimation method. *Fisheries Science* 67: 851–856.

ZARR JH (1996) Biostatistical analysis. 3rd Edition. Prentice-Hall, Inc. New Jersey: 662 pp.

APPENDIX A (QUESTIONNAIRE)

Small-scale fishery impacts

Start of Block: Consent

Q1 Dam location

_____

Q2 Interviewer

_____

Q3 Hello, my name is <YOURNAME>, I'm a researcher from <YOURORGANIZATION>, we are here at <DAMLOCATION> to speak with fishers about their dam usage. This forms part of a research project funded by the WRC, to explore the uses of dam and the potential impacts of the development of a small-scale fishery. This research will be used to inform the Implementation Plan of The National Freshwater (Inland) Wild Capture Fisheries Policy. I have come to you to ask for your participation in a short survey that will look at your participation in fishing at this location and your preferences and perceptions around the fishery. Your participation is completely anonymous and voluntary and nothing you say will be used against you in any way. You may refuse to answer any questions that you feel are sensitive. You may refuse to participate at any time. You must be 18+ years of age to participate. If you have any questions about the researcher you may ask them at any time. This research is being led by Dr. <ProjectLead>. Their email is <ProjectLEADEMAIL>

Do you agree or disagree to participate in this research by completing a short questionnaire?

○ Agree (1)	○ Disagree (2)

End of Block: Consent

Start of Block: Fishing behaviour

Q4 **How many days do you fish at this dam per year?**

_____

Q5 What are the TOP 5 species you TARGET at this dam and which gears do you use for that species? (can be less than 5)

Which species?	Which gear type is used for each species?
Top 1	
Top 2	
Top 3	
Top 4	
Top 5	

Q6 What are the TOP 5 species you CATCH at this dam? (can be less than 5)

Which species?
Top 1
Top 2
Top 3
Top 4
Top 5

Carry Forward Selected Choices from "What are the TOP 5 species you CATCH at this dam? (can be less than 5)"

Q7 What do you do with the TOP FISH you catch? (read out each species)

	Sell	Eat	Give away	Use for bait	Release	Other
Top 1 ____						
Top 2____						
Top 3 ____						
Top 4 ____						
Top 5 ____						

Q8 Why do you sell fish? (if any fish are marked as "sell")

_____

Q9 What is your main motivation for participating in fishing? (choose the most important one)

○ For the relaxation (recreational)	○ For sport (recreational)	○ To get out and enjoy nature (recreational)

○ To feed myself/family (small-scale)	○ To sell fish to support myself/family (small-scale)	○

End of Block: Fishing behaviour

Start of Block: Recreational Fishing

Q10 Was fishing at this dam a primary motivation for visiting this area?

○ Yes (1)	○ No (2)

Q11 How far did you travel from your home to fish here?

Q12 Did you spend any money locally (within 75km of this dam) on any of the following items pertaining to your fishing trip?

☐ Food	☐ Drinks	☐ Petrol	☐ Car hire	☐ Accommodation
☐ Bait	☐ Fishing Tackle	☐ Camping equipment	☐ Other	

Carry Forward Selected Choices from "Did you spend any money locally (within 75km of this dam) on any of the following items pertaining to your fishing trip?"

Q13 How much did you spend on the following items for this specific trip?

Food _____	Drinks _____	Petrol _____	Car hire _____	Accommodation _____
Bait ____	Fishing Tackle _____	Camping equipment _____	Other _____	

Q14 What is the main reason for choosing this fishing location?

○ Plenty of fish	○ Unique fish species	○ Scenery	○ Close to home	○ Well managed	○ Tradition	○ Other

Q15 If the following rules or policies were implemented, please state how much more or less you would participate in fishing at this dam.

	The same amount	25% less	50% less	75% less	I wouldn't fish here anymore
Obtaining a special fishing permit					
Bag limits on retained fish					
Gillnets are no longer allowed					
Sharing the dam with a small-scale fishery that uses rod and reel					
Sharing the dam with a small-scale fishery that uses gillnets					
Sharing the dam with a small-scale fishery that uses encircling nets					
Specific zones for recreational fishing only and small-scale fishing only					

End of Block: Recreational Fishing

Start of Block: **Small Scale Fishing**

Display This Question:

If What do you do with the TOP FISH fish you catch? (read out each species) = Sell

Q16 How much do you sell for on average a fish that you caught?

R25 or less	R26 to R50	R51 to R100	R100 to R200	R200 or more

Carry Forward Selected Choices - Entered Text from "What are the TOP 5 species you CATCH at this dam? (can be less than 5)"

Q17 How many of the top species that you catch (mentioned above) do you catch per day and how many of them do you sell?

	How many of each of the following fish do you catch per day?	How many each of the fish species that you catch do you sell?
Species	# caught	# sold
Top 1 _____		
Top 2 _____		
Top 3 _____		
Top 4 _____		
Top 5 _____		

Q18 Which ways do you process the fish before selling it?

Cleaning (gutting/de-scaling)	Freezing	Drying	Smoking	Cooking	Other _____

Q19 Who do you sell fish your fish to?

Local restaurant	Tourists	Store/shop	Family/friends
Local accommodation	Recreational fishers	Other	

Q20 In your opinion, are fish getting harder or easier to catch at this dam?

Much harder	Slightly harder	No change	Slightly easier	Much easier

Q21 Which species are getting harder to catch? (list up to 5)

Species 1 _____	Species 2 _____	Species 3 _____
Species 4 _____	Species 5 _____	

Q22 Why do you think it is getting harder?

_____

Q23 If the dam ran out of fish, what else could you do for food or income?

_____

End of Block: Small Scale Fishing

Start of Block: Personal

Q24 How important is fishing in this dam for you personally?

Not at all important	Slightly important	Moderately important	Very important	Extremely important

Q25 How much do you agree or disagree that there should be harvest limits for main target species in this dam?

Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

Q26 Why? _____

Q27 How often when fishing at this dam, have you seen officials monitoring activities (ie. monitoring catch, enforcing rules) ?

Every time	Frequently	Sometimes	Rarely	Never

Q28 Have you ever had a conflict with other resource users at this dam?

○ No	○ Yes

Q29 If yes, which users?

Small scale fishers	Recreational fishers	Researchers
Law enforcement	Other	

End of Block: Personal

Start of Block: Demographics

Q30 How far from the dam do you currently stay (kms)? _____

Q31 What is your age? _____

Q32 Which race group do you belong to?

African	Indian/Asian	White
Coloured	Prefer not to answer	Other _

Q33 How many individuals are in your household?_____

Q34 How many in your household fish? _____

Q35 What is your current citizenship status?

South African (SA)	Dual (including SA)	Foreign	Prefer not to answer

Q36 What is your employment status

Unemployed	Student	Formally employed (part time)	Formally employed (full time)
Self employed	Pensioner	Prefer not to answer	

End of Block: Demographics

……..