INLAND FISHERIES CONTRIBUTIONS TO RURAL LIVELIHOODS: AN ASSESSMENT OF FISHERIES POTENTIAL, MARKET VALUE CHAINS AND GOVERNANCE ARRANGEMENTS

Report to the
WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

South Africa's post 1994 democratic government is under increasing pressure to address the persisting challenges of rural poverty, inequality and unemployment. Therefore, the need to realise the socio-economic potential of South Africa's inland fisheries has become urgent. While it is important to ensure that rural communities derive optimum value from freshwater fisheries, this positive transition needs to be undertaken without jeopardising the sustainability of resource. Sustainable fishery utilisation is limited by inadequate information on the productive potential of public dams, the economic value of the resource, the potential value chain benefits for rural communities and how to manage the resources sustainably so that they continue to benefit future generations.

This is the final report of the project titled "Towards Enhancing Contributions of Inland Fisheries to Rural Livelihoods: An Empirical Assessment of Freshwater Fish Stocks, Fisheries Potential, Market Value Chains, Governance and Co-Management Arrangements" funded by the Water Research Commission (project No. K5/2497/4). It is a follow-on project of the project titled "Baseline and scoping study on the development and sustainable use of storage dams for inland fisheries and contributions to rural livelihoods" that had also been funded by the WRC (project No. WRCK5/1959/4 reported in Britz et al., 2015). The project set out to test the recommendations made by the preceding baseline and scoping study with regard to the formalisation of an inland fisheries sector in South Africa. The baseline and scoping study recommended that the establishment of fisheries should be based on a developmental approach (a move away from the conservation oriented historical approach); on an inclusive approach to deal with historical marginalisation of (small-scale) fishing communities; and on a defensible scientific approach that could ensure biological and socio-economic sustainability of the sector. In order to contribute towards the development and formalisation of such a sector, the present study approach used three case studies to provide knowledge and information, necessary for implementing sustainable fishery governance and management arrangements in terms of the governments inland fisheries policy, visibly i) an assessment of fish stocks and their potential; ii) description of the market value chains associated with inland fisheries and their economic value; iii) institutional arrangements for the governance of inland fisheries; and iv) strategies for optimising the inland fisheries-based rural livelihoods and rural economies.

Without the sufficient knowledge on the size of fish stocks and the productivity of the dams, it is not possible to institute evidence-based sustainable levels of harvesting and utilization of inland fisheries. Therefore, one of the key objectives of this study was to assess the fish stocks and fisheries potential using a selection of small and large dams in the provinces with the most productive dams, in order to recommend the appropriate harvesting levels and techniques and the process for formulating these. Chapter two of this report is a synthesis of the work done on this aspect under this project.

Past studies indicate that more than 1.5 million people participate in or are involved in freshwater angling activities and value chains in South Africa annually, and that this sector is worth about R9 billion annually. For historical reasons the majority of participants in this sector are white. Thus, the sector provides potential for broadening participation by the rural poor women and men that have been historically marginalised. The second objective of the project was, therefore, to deepen our understanding of the economic value of inland fisheries, and the nature of existing formal and informal Market value Chains (MVCs) associated with inland fisheries, and how these could be made more pro-poor. Chapter 3 is a synthesis of the work on economic value of the sector and the market value chains that characterise the sector.

Without appropriate management and governance of the transformation and transition towards greater participation of, and benefits for rural communities, this could result in the destruction of resources, erosion of the benefits and the general devaluation of the ecosystems services provided by public dams. Therefore, the third key objective of the study was to consider the institutional arrangements for governance and co-management of inland fisheries for sustainable utilization. Chapter 4 describes and evaluates the institutional and governance arrangements for a sustainable inland fisheries sector.

Chapter 5 of the report discusses and makes suggestions and recommendations on how South Africa can move towards the development of an inclusive sustainable small-scale inland fisheries sector, using the findings of this project, other studies, and the experiences of developing and managing small-scale fisheries in other African countries and beyond.

The study was undertaken by a multidisciplinary team of researchers from the Institute for Poverty, Land and Agrarian Studies (PLAAS) at the University of the Western Cape (UWC), the University of Limpopo, the South Africa Institute of Aquatic Biodiversity (SAIAB) and the Department of Ichthyology and Fisheries Science at Rhodes University. The empirical part of the research used a case study approach using three dams, namely Pongola in KwaZulu-Natal, Flag Boshielo in Limpopo and Voëlvlei in the Western Cape. For stock assessment Loskop dam was also included for reasons explained in Chapter 2 on stock assessment. The methodologies used for each component, namely 'Stock Assessment', 'Market Value Chains' and 'Institutional Arrangements' are outlined in detail in the synthesis chapters of each of the these components. The rest of this executive summary provides the key findings under each chapter.

Chapter 1: Introduction: Global and South African Perspectives on Small-Scale Fisheries

The introductory chapter provide a global and African perspective on small-scale fisheries in terms of size in comparison to industrial fisheries, the benefits that the sector provides and the management and governance challenges that characterise small-scale fisheries. This provides the backdrop to small-scale inland fisheries in South Africa in terms of what role it could play towards poverty reduction and food security.

The chapter highlights that small-scale fisheries are responsible for about 60% of the global fish catch and employ over 95% of all men and women engaged directly or indirectly in fisheries worldwide, thereby providing livelihoods for millions of people. Small-scale fisheries contribute about two-thirds of catches destined for direct human consumption, thereby playing a significant role in poverty alleviation, food security and the provision of livelihoods. It is estimated that more than 200 million Africans rely on fish as an affordable source of protein and important micronutrients, and that fish is estimated to contribute an average of over 33% of animal protein in Africa. While inland (freshwater) small-scale fisheries contribute only about 12% to the total production by the sector globally, such simple comparisons of gross production can be misleading since inland fisheries generate a wide variety of benefits for millions of people in many developing countries. Such benefits include food security, poverty reduction, income, social and cultural values, the well-being of communities.

The chapter also considers the special socio-economic role that small-scale fisheries play, and the challenges of managing them using Africa as reference point. Many African countries face challenges in relation to the conservation and sustainable management of fish resources. The constraints and challenges in achieving sustainable development of small-scale fishing communities on the continent include their often-remote location, limited access to social and other services as well as markets, low levels of education and inadequate organisational structures which make it difficult for them to make their voices heard. As a result, most small-scale fisheries are effectively unregulated, unreported and poorly monitored. Customary practices for allocation and sharing of resource benefits that generally used to be in place in small-scale fisheries have often been eroded because of centralised fisheries management systems, technology development and demographic changes. The chapter argues that in order for African countries to optimize the development of small-scale fisheries, it is necessary to improve the policy and legislative frameworks in support of strengthening the inclusive governance and co-management of the fisheries.

The governance of South Africa's small-scale fisheries is then discussed, including the need to align the development of the sector to the constitution, national relevant legislative frameworks (e.g. NEMA, NEMBA, NWA, etc.), and food and nutrition security and developmental policies.

The chapter concludes with an introduction of the project's aims and objectives, the methodology employed and the outputs.

Chapter 2: Case Studies of Fisheries Potential of South African Inland Fisheries

Because of the paucity of information on the fish stocks and fisheries potential of South Africa's inland waters, the existing predictions require validation. Fishery feasibility assessments were conducted using fishery surveys, resource surveys and stock assessments in order to recommend harvesting levels, strategies and techniques for sustainable utilization. Monthly fish surveys were undertaken at Flag Boshielo Dam, while rapid fishery appraisals were conducted at Loskop and Pongolapoort Dams. These surveys included an assessment of the fish diversity and composition in each waterbody to determine whether species with proven commercial potential were present at each site, and establishing biological baselines for 1) length-weight relationships; 2) catch-per-unit effort; 3) age-at-maturity; 4) gear selectivity estimates; 5) natural, fishing, and total mortality that are necessary to 6) apply the yield-per-recruit and spawner-biomass-per-recruit models to determine initial exploitation rules for potentially exploitable species. Catch data from all fishing gear were used to determine species composition and biological parameters, viz., growth estimators, age at maturity, and the mortality of candidate species, with gillnet data used specifically to establish the catch-per-unit effort (CPUE) and gillnet selectivity.

The rapid assessment survey of Pongolapoort resulted in very low catch rates with only 40 specimens, 4 species from 3 families, being captured using gill-, fyke, and seine nets during the week-long survey. Consequently, an appraisal of the fishing potential could not be performed. The result indicates a low abundance of fish in this impoundment, which is likely a result of poor recruitment linked to the extended decline in the water level of the reservoir, or due to a shortcoming of the rapid appraisal method.

In comparison, the rapid assessment survey of Loskop Dam recorded 1392 specimens, 15 species from six families. Mozambique tilapia (*Oreochromis mossambicus)* (58%) and rednose labeo (*Labeo rosae)* (15%) dominated the biomass captured by gillnets. Rednose labeo demonstrated a bimodal length frequency and was dominated by specimens 230-270 mm TL and 300-400 mm TL. Mozambique tilapia had a truncated population structure with a skewed distribution dominated large individuals 300-500 mm TL. Mean CPUE for rednose labeo and Mozambique tilapia at Loskop Dam were 10.1 and 28.4 kg/100 m net/hr, respectively. A large number of juvenile Mozambique tilapia (mean TL of 114 mm) captured in seine nets was evidence of recent recruitment and a potentially self-sustaining population. The missing size classes for both species could have been as a result of the preceding drought, pollution events, or can be attributed to site selection and sampling duration.

By contrast, a year-long monthly assessment survey of Flag Boshielo Dam recorded only 1376 specimens, 11 species from six families in gillnets. It should be noted that these surveys were conducted during a drought where the impoundment was at less than 50% of full capacity, including long periods at less than 30% of capacity. Rednose labeo (59%) and Mozambique tilapia (21%) dominated the biomass captured by gillnets. Mean CPUE for rednose labeo and Mozambique tilapia at Flag Boshielo Dam were 5.5 and 1.7 kg/100 m net/hr, respectively. Length frequency data for rednose labeo was unimodal and dominated by adult fish, indicative of limited or no recent recruitment. Mozambique tilapia had a bi-modal distribution with peaks at 150- and 200-mm total length (TL), reflective of a self-sustaining population driven by internal recruitment processes.

Biological data for Flag Boshielo and Loskop dams were aggregated to apply yield-per-recruit (YPR) and spawner biomass-per-recruit (SBR) models to recommend generic harvest strategies that would maximise yield at low risks of stock collapse for rednose labeo and Mozambique tilapia. Analyses demonstrate that, for both species, YPR is maximised at fishing mortalities exceeding 0.3 yr^{-1} and at ages of selection exceeding 3 years, whereas for SBR, species recruitment is reduced rapidly when fish are selected at young ages. At fishing mortality approximating those necessary to maximise YPR, the SBR would be maintained at above 25% of unfished levels, if fish are selected at sizes corresponding to ages of 4 years or older.

Model results indicate that for a gillnet fishery to be initiated for these two species in Flag Boshielo Dam, an initial mesh size restriction of 100 mm would be necessary to minimise the risk of stock collapse. However, the use of a 100 mm mesh net could result in low catch rates at Flag Boshielo Dam since the overall catch rate for a hypothetical fishery for both species is shown to decrease with an increase in mesh size. The absence of larger specimens of both species in Flag Boshielo Dam indicates that the fishery is likely to be already fully exploited by the current small-scale informal gillnet fishery. As a result, the current harvest rates of these informal fisheries need to be considered when planning for future fisheries development. Given that models indicate limited room for growth in the Flag Boshielo fishery, managers should focus on working with existing fishers to increase yield by, for example, adjusting fishing effort and gillnet mesh sizes to improve yields.

Several studies have revealed that fish from the Olifants River System have been contaminated by heavy metals and prolonged consumption of these fish poses a long-term risk to human health. This, in itself, has serious implications for individuals trading and consuming fish from water bodies in this system. Should fisheries be established at either impoundment, the risks associated with consuming fish from these impoundments need to be determined periodically and clear advisories developed.

Chapter 3: Using Market Value Chains to Enhance the Contribution of Inland Fisheries to Rural Livelihoods in South Africa

Markets are a useful instrument for transferring products to people who are willing to pay more for them. In the context of natural resources, this may provide options to enhance rural livelihoods using less primary resource and generate funds for protecting threatened ecosystems. Rural communities are often uninformed about their comparative advantage in harnessing indigenous knowledge to produce high-valued commodities for extended market value chains. Accordingly, this chapter investigated the market value chains of inland fisheries at selected dams, namely

Pongola in KwaZulu-Natal Province, Flag Boshielo in Limpopo Province and Voëlvlei Western Cape Province. The methodology used was derived and adapted from the renowned Greater Access to Trade Expansion (GATE) project. The chapter also looks at the economic value that dams provide.

The study found that market value chains involving small scale fishers were generally short. The value chains were estimated to generate a monthly profit of R28,500 for gill-net fishers and R6,600 for fish vendors at Phongola Dam; R1,500 for line fishers and R11,500 for gill-net fishers at Flag Boshielo Dam, and R500 for line fishers at Voëlvlei Dam. Small-scale fishers and fish vendors can upgrade their positions in the MVCs by: (i) adding greater value by processing fish products (salted, dried and smoked) and marketing to urban communities; (ii) using weight-based pricing to generate more revenue from produce; and (iii) getting organized to create monopoly power and sell to niche markets, e.g. lodges, fish shops. In any case, the main value of the inland fisheries is not just the commodity value of the tonnage landed by small-scale fishers, but lies in the food security and sustainable livelihood benefits to rural communities and the socio-economic benefits of the tourism and equipment supply associated with recreational fishing. There are opportunities for benefit sharing schemes with local communities in respect of output or expenditures associated with recreational fishing. The Inland Fisheries policy needs to facilitate the recognition of all values associated with inland fisheries and craft mechanisms for sustainable inclusion of small-scale fisheries and rural communities living in the vicinity of dams. Inland fisheries could contribute to improved rural livelihoods if small-scale fishers and their communities were pro-actively integrated into all the Value Chains on public dams and other natural freshwater resources. Such integration could also prove beneficial in times of crisis such as downturn of the economy due to Covid-19.

The study found that there are currently no national estimates for the economic value of inland fisheries for South Africa and that deriving such assessments would require valuations across the three subsectors, namely small scale fishing (for the subsistence fishing component of this sector, the value of the fish should ideally be measured in terms of food security metrics including income, nutritional status, and welfare savings by the state), recreational fishing and commercial fishing. Based on a number of past studies, the Marketed Use Value (MUV) of South African inland fisheries was estimated at about US$30 million per year, which compares well to the South African fisheries GDP of US$322.5 million. Economic assessments indicate that recreational fisheries contribute significantly to provincial and national economies with a survey by Leibold & Van Zyl (2008) indicating that recreational angling and sport fishing generated an Non Marketed Use Value (NMUV) of approximately R9 billion (US$600 million) per annum for South Africa. As can be observed, the recreational value of inland fishing dwarfs the value of the inland small-scale fisheries' catch. Using the MUV and NMUV figures derived above, the Total Use Value (TUV) for South African inland fisheries can be estimated at about US$630 million per year. Thus, there is a need to find ways to allow the small scale fishers to tap some of the value from inland fisheries including recreational fishing. Such opportunities can be investigated by looking at the inland fisheries value chains and identifying opportunities for upgrading small scale fishers.

Chapter 4: Management and Governance Arrangements for South African Inland Fisheries

Central government departments hold the mandates and responsibilities for ensuring the sustainable utilization of natural resources and maintenance of biodiversity in public dams and their dam catchment areas on behalf of society. These mandates are provided for through appropriate legislation and policies such as the NWA, NEMA, NEMBA, SAMSA, future Inland Fisheries Policy, Tourism Act, Food and Nutrition policies, etc. In most instances, the central government mandates are implemented by their provincial departments and local governments, which usually involves decentralisation of authority. Historically, the management of biodiversity on public dams had been done through provincial legislation and through provincial departments of the environment or parastatals (for example Ezemvelo KZN Wildlife in KwaZulu-Natal and Cape Nature in the Western Cape). The proposed Inland fisheries policy is based on centralising legislative mandate for inland fisheries into the hands of the Department of Environmental Affairs and Fisheries: branch Fisheries. This would ensure one overarching policy and legislation from which provinces can derive decentralised authority and responsibility, and for the co-management bodies at bottom (which is actually the coal face management) devolutionary authority and responsibility.

There are many stakeholders that benefit from the ecosystem services that are provided by dams. Key among these are domestic and industrial water provisioning, small scale fishers, recreational anglers, irrigation farmers, tourism operators such lodge owners, etc. In addition, these economic activities provide employment to people that act as part of the value chain actors, supporters, suppliers and influencers. Thus these activities extend benefits along the value chains (vertical) and value networks (horizontal). Consumers of the various ecological products at the top tier of the value chains create demand for the products and services.

Civil society and Academia working with fishers and doing research form a key category of stakeholders. The former have the role of helping communities derive maximum benefits from public dams through advocacy and policy implementation activities, while the latter conduct independent natural and social science research in support of evidence-based findings in support of advisory services, monitoring and policy and legislation review.

For inclusive and legitimate co-governance, most of these keys stakeholders will need to be involved. This can vary based on scale and/or level and also on who the stakeholders on a specific dams are. In most instances, the primary stakeholders (those that have a direct involvement and therefore stake in a dam) will need to be included in the ground level co-management arrangements that directly impact on their activities and benefits. Some level of vested involvement is essential for legitimacy and effectiveness of co-management arrangements since ultimately, primary users control whether a management system will work or not. Hence, if direct users cannot live with a regulatory system and its framework, it hardly matters what other interests think or find appropriate. Without such active involvement by primary stakeholders and vested interests, the legitimacy and strength of co-management arrangements is diluted.

Chapter 5: Towards development of an inclusive sustainable small-scale inland fisheries sector

This project set out to test the recommendations made by the preceding baseline and scoping study with regard to the development and formalisation of an inland fisheries sector in South Africa. This chapter discusses and makes suggestions and recommendations on how South Africa can move towards the development of an inclusive sustainable small-scale inland fisheries sector, using the findings of this project, other studies, and the experiences of developing and managing small-scale fisheries in other African countries and beyond. The chapter suggests that in order to develop and formalise an inland fisheries sector in South Africa, we will need to establish a Fisheries Management Regime (FMR) for the sector comprised of Fisheries Management Systems (FMSs), Monitoring Control and Surveillance systems and a Fisheries Judicial Systems. The chapter proposes and discuss that some of the key questions that this FMR we will need to deal with visibly: 1) How should inland fisheries be organised in terms of FMSs in practice and reality, and what criteria should be used for the establishment of these management systems?; 2) What types of input and technical regulations are necessary for each FMS (or each impoundment?) for sustainable utilization?; 3) Will output regulations be used in the sector, and if so, what procedures would be used for determining the annual upper limits?; 4) What management procedures and processes would be required for the sustainable utilization of inland fisheries in each FMS?; 5) What type of rights would be appropriate for equitable sustainable utilization of inland fisheries, and how would these be distributed?; 6) What institutional and organisational arrangements would be appropriate for inclusive and equitable management of inland fisheries?; 7) How should management of inland fisheries be funded?; and 8) What legislative changes would be necessary for recognition of the sector; and how could communities organise themselves better for improved access to inland fisheries value chains?

In order to develop and formalise a biologically, socially and economically sustainable inland fisheries sector, these and other issues and questions would have to be dealt with systematically. Such a process will need to include and involve all the key stakeholders.

Chapter 6: Recommendations for action and suggestions for future research

This final chapter makes some conclusions, recommendations and suggest some areas for further action and research. The recommendations and suggested areas for further research are those that could progress the development and formalisation of a sustainable inland fisheries sector. These aspects are around geographic management areas, programmes of routine data and information collection for decision-making, the types of fishing rights, how fishers and vendors could organise themselves for enhanced benefits, upgrading of positions on the MVCs for fishers and vendors, benefits in the form of social economic values and the creation of niche markets by fishers and vendors for increased benefits.

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ACRONYMS AND ABBREVIATIONS

AU	Africa Union
AU-IBAR	African Union Inter-African Bureau for Animal Resources
CBFM	Community Based Fisheries Management
CBNRM	Community Based Natural Resource Management
CCRF	Code of conduct for Responsible Fisheries
CMAs	Catchment Management Agencies
COFI	Committee on Fisheries
COGTA	Department of Cooperative Governance and Traditional Affairs
CPUE	Catch per unit effort
CT	Customary Tenure
DAFF	Department of Agriculture, Forestry and Fisheries (South Africa)
DDT	dichlorodiphenyl-trichloroethane
DEFF	Department of Environment, Forestry and Fisheries (South Africa)
DoT	Department of Transport (South Africa)
DWA	Department of Water Affairs (South Africa)
DWAF	Department of Water Affairs and Forestry (South Africa)
DWS	Department of Water and Sanitation (South Africa)
EKZN	Ezemvelo KwaZulu-Natal Wildlife (South Africa)
FAO	Food and Agriculture Organisation of the United Nations
FJS	Fisheries Judicial System
FMR	Fisheries Management Regime
FMS	Fisheries Management System
GATE	Greater Access to Trade Expansion Project
GDP	Gross Domestic Product
GIS	Geographic Information System
IKS	Indigenous Knowledge Systems
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported and Unregulated fishing
IWRM	Integrated Water Resources Management
LEDET	Limpopo Department of Economic Development, Environment and Tourism (South Africa)
LIFDCs	Low-Income, Food-Deficit Countries

MCS	Monitoring Control and Surveillance
MSY	Maximum Sustainable Yield
MVCs	Market Value Chains
NEDLAC	National Economic Development and Labour Council (South Africa)
NEMA	National Environmental Management Act (South Africa)
NEMBA	National Environmental Management Biodiversity Act (South Africa)
NEPAD	New Partnership for Africa Development
NPC	National Planning Commission (South Africa)
NPCA	NEPAD Planning and Coordinating Agency
NMUV	Non-Marketed Use Value
NUV	Non-Use Value
NWA	National Water Act (South Africa)
PAF	Partnership for African Fisheries
PFRS	Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa
PLAAS	Institute for Poverty, Land and Agrarian Studies (UWC, South Africa)
RMPs	Resource Management Plans (South Africa)
SADC	Southern Africa Development Community
SADSAA	South Africa Deep Sea Angling Association
SAIAB	South Africa Institute of Aquatic Biodiversity
SAMSA	South Africa Maritime Safety Authority
SAPS	South African Police Service
SASACC	Sport Anglers and Casting Confederation (South Africa)
SASCOC	South African Sports Confederation and Olympic Committee
SBR	Spawner Biomass-per-Recruit
SDGs	Sustainable Development Goals
SMME	Small, Micro to Medium Enterprise
SSF	Small-Scale Fisheries
SSF Guidelines	Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication
SUP	Sustainable Use Plan (South Africa)
TEV	Total Economic Value
TURF	Territorial Use Rights in Fisheries
UNDP	United Nations Development Programme

UNFSA	United Nations Fish Stocks Agreement
UV	Use Value
UWC	University of the Western Cape (South Africa)
WRC	Water Research Commission (South Africa)
WUA	Water User Association (South Africa)
WWF	World Wildlife Fund
YPR	Yield-per-recruit

CHAPTER 1. INTRODUCTION: GLOBAL AND SOUTH AFRICAN PERSPECTIVES ON SMALL-SCALE FISHERIES

Mafaniso Hara

1.1 A global and African perspective on small scale (Inland – freshwater) fisheries: size, benefits and management and governance challenges

Small-scale fisheries are recognised as the dominant fishery sector globally in terms of socio-economic benefits. It is estimated that the sector employs over 95% of all men and women engaged directly or indirectly in fisheries worldwide, thereby providing livelihoods for over 200 million people (FAO, 2016; Ratner and Allison, 2012). Of these, more than 90% are to be found in developing countries (FAO, 2009). Small-scale fisheries contribute nearly 60% to the global fish catch and landed about 22 million tonnes in 2010 alone (Pauly and Zeller, 2016). Therefore, the sector plays a significant role in poverty alleviation, food security and the provision of livelihoods (Jentoft and Chuenpagdee, 2015). Small-scale fisheries contribute about two thirds of catches destined for direct human consumption (FAO, 2013).

In 2015, inland fisheries produced an estimated 11.47 million tonnes, representing 12.2 percent of total global capture fishery production (FAO, 2018). While the inland fisheries contribution on a global scale is relatively small, Neiland et al. (2005) caution that simple comparisons of gross production can be misleading since inland fisheries generate a wide variety of benefits for millions of people in many developing countries. Such benefits include food security, poverty reduction, income, social and cultural values, the well-being of communities and to both rural and national economies (Kapetsky & Petr, 1984; Sarch & Allison, 2000; Allison et al., 2002; FAO, 2003; Allison, 2005; Heck et al., 2007; Béné et al., 2007; Béné et al., 2010).

Fisheries are important for provision of protein, livelihoods and economic growth, especially among the rural and poor populations of Africa. In 2010, the total fish production for the whole continent was estimated at 9.4 million tonnes, 60 percent of which was landed by small-scale fishers (FAO and NPCA, 2014). In particular, inland fisheries play a prominent role in Sub-Saharan Africa where the great lakes (e.g. Victoria, Malawi/Nyasa, Tanganyika, Kariba, Banguelu), river systems and impoundments provide the main source of fish and fisheries livelihoods (Kolding et al., 2019; Hara and Njaya, 2016; Jul Larsen et al., 2003). Almost all the catches from the small-scale fishing sector are destined for human consumption (Kolding et al., 2019; FAO and NPCA, 2014.). The sector provides significant employment and income for poor rural communities. In Africa, an estimated 12.3 million people were employed in capture fisheries and aquaculture sectors in 2010 as fishers (50%), traders and processors (42%) and fish farmers (8%) and a further 90 million people depended on fishing as part of a diversified livelihood strategy (FAO and NPCA, 2014; AUC-NEPAD, 2014). Females make up more than one-fourth of the workforce in the African fisheries and aquaculture sector. The great majority of women are employed in post-harvest (91.5 percent), 7.2 percent work as fishers (mostly in inland fisheries) and 1.3 percent in aquaculture (AU-IBAR, unpublished). For many of those involved in small-scale fisheries, the sector represents a way of life. More than 200 million Africans rely on fish as an affordable source of protein and important micro-nutrients, and fish is estimated to contribute an average of over 33% of animal protein in Africa (WorldFish Center, 2009). In terms of volume and value, fish and fish products contributed 19% and 5% of total agricultural exports respectively in 2013 (AUC-NEPAD, 2014).

The small-scale fisheries contributed 76% (43% from marine and 33% from inland) of the fisheries contribution to the continent's US$ 24 billion Gross Domestic Product (GDP) in 2011.

Fish is a rich source of easily digestible high-quality proteins containing all essential amino acids. In addition, it provides essential fats (for example long-chain omega-3 fatty acids) not found in most other protein sources, vitamins (D, A and B) and minerals (including calcium, iodine, zinc, iron and selenium), particularly when eaten whole, which is the case in most developing countries (HLPE, 2014). Fish is usually high in unsaturated fats and thus provides health benefits, especially protection against cardiovascular diseases (FAO, 2016). Fish also aids foetal and infant development of the brain and nervous system. Even when taken in small quantities, which is the case in many low-income, food-deficit countries (LIFDCs) and least-developed countries, fish can have significant positive nutritional impact on plant-based diets. With all these valuable nutritional properties, fish can play an important role in correcting unbalanced diets and in countering obesity (HLPE, 2014; FAO, 2016), which is one of the growing problems in some SADC countries, such as South Africa (Shisana et al., 2013).

Therefore, small-scale fisheries is important for the continent due to its social and economic value to the extent that the African Union has lifted it up as a priority area of the Policy Framework and the Reform Strategy adopted in June 2014 (AU and NEPAD, 2014). Other commitments and initiatives adopted at the pan-African and at global level (United Nations including FAO, for example the FAO voluntary guidelines for securing small-scale fisheries – FAO, 2013) confirm this priority and importance to small-scale fisheries in the role it plays to meet nutritional needs, and improving the living conditions of small-scale fisheries communities.

However, the contribution of the sector is threatened by poor governance, insufficient organisational structures, limited access to finance resources, markets and social services, low level of participation of the small-scale fishers in decision-making, lack of accurate data, overfishing due to open access, bad fishing practices, high post-harvest losses and lack of mechanisms for value addition (FAO, 2018; FAO, 2005). Thus, despite the benefits and contributions of small-scale fisheries, management of sector wherever it is dominant remains a major challenge. Studies around the world show that most small-scale fisheries are over exploited mainly because of fishing over capacity and the rife social and economic problems and conflicts that arise as a result of competition over a common pool resource (Béné et al., 2010; Andrew et al., 2007; Salayo et al., 2008; Salas et al., 2007; Stobutzki et al., 2006). The true extent of the impacts of small-scale fisheries is not known since most exist in developing countries in Africa, Latin America and Asia, which lack the resources for proper and adequate monitoring and documentation of fishing effort (Dunn et al., 2010). Thus, there is a need to quantify fishing effort in small-scale fisheries and understand how effort is deployed in order to understand its impacts and to prevent over fishing (Hara and Njaya, 2016; Dunn et al., 2010; Stewart et al., 2010). In this context, the sector represents a significant policy and governance challenge for many African governments (AU and NEPAD, 2014).

1.2 Definition of the small-scale fisheries

The need to define small-scale fisheries is a recurring issue in policy, management and research (COFI, 2014; Garcia et al., 2008; European Parliament Committee on Fisheries, 2012; Guyader et al., 2013; Symes, 2013). The interchangeability of terms normally associated with small-scale fisheries – artisanal, local, coastal, traditional, subsistence, non-industrial, low-tech – is in itself revealing of the many values, characteristics, diversity in terms of user communities, catch levels and composition, seasons and fishing techniques employed and outcomes underlying the definition of the sector. The sector is characterised by high labour intensive operations, which reflect comparatively lower capital investments and varying degrees in the utilisation of technology. It is common to see what is considered as a small-scale fishery in one country being classified as a large-scale fishery in another (FAO, 2018; FAO, 2002). Another important characteristic of the small-scale fisheries is the numerous formal and informal organisational or institutional arrangements, which often differ across countries and even within the same country (Chuenpagdee and Jentoft, 2015; Weeratunge, 2014). Consequentially, small-scale fisheries need to be considered within their specific socio-economic, cultural and ecological context for the purpose of management (Béné, 2006; Sowman, 2006). The lack of a common definition for small-scale fisheries contributes to the difficulty of managing the sector and implementing targeted policies in Africa (AU and NEPAD, 2014).

A universally applicable definition of small-scale fisheries is therefore problematic. As a result, an over-arching characterization of small-scale fisheries is viewed as being more useful. Thus small-scale fisheries can broadly be defined as "*a fishing sector that includes those who harvest predominantly for their own household consumption, those who sell to the market but retain a portion of their catch for local consumption, and those who harvest almost exclusively for the market but on a small-scale compared to large-scale industrial fisheries*" (FAO, 2013). In Africa, the small-scale fisheries usually refer to 'all fishing activities that are not industrial or high seas. using relatively small amount of capital and energy, relatively small fishing vessels (if any), from on feet gleaning, a one-man canoe to more than 20-metre trawlers, seiners, or long-liners and making short fishing trips, close to shore, for local consumption or export'' (FAO, 2016). In the South African Marine Small-Scale Fishing Policy (DAFF, 2012: 4) small scale fishing means (or has been defined as) "the use of a ... living resource on a full-time, part-time or seasonal basis in order to ensure food security and livelihood security. For the purposes of the South African policy, fishing also means the engagement (by men and women) in ancillary activities such as, pre- and post-harvesting (including preparation of gear for harvesting purposes), net making, boat building, beneficiation, distribution and marketing of produce which provide additional fishery-related employment and income opportunities to these communities".

"Small-scale fisheries can be broadly characterized as a dynamic and evolving sector employing labour intensive harvesting, processing and distribution technologies to exploit marine and inland water fishery resources. The activities of this subsector, conducted fulltime or part-time, or just seasonally, are often targeted on supplying fish and fishery products to local and domestic markets, and for subsistence consumption. Export-oriented production, however, has increased in many small-scale fisheries during the last one to two decades because of greater market integration and globalization. "... Small-scale fisheries operate at widely differing organizational levels ranging from self-employed single operators through informal microenterprises to formal sector businesses. ...." (Excerpt from the description by the FAO Working Group on Small-scale Fisheries).

Small-scale fishing in Africa, which is carried out in precarious conditions, can be characterized in particular by the following elements (AU-IBAR, unpublished Africa Fisheries Report):

- Lack of harbour infrastructure and fishing shelters, reducing fishing activities at sea and the lifespan of boats, engines and other production tools, given the lack of protective seawalls to facilitate entry and exit operations at sea;
- Lack of, or erratic supply of fuel, fishing gear and spare parts and other supplies;

- Lack of marketing and ice making facilities that results in huge post-harvest losses and poor quality fish resulting in inability to maximize prices;
- Absence of fish markets where it is possible to control the quality, quantity and price of products and issue administrative, sanitary or regulatory certificates….
- Absence of premises, maintenance and repair workshops on the landing sites and remoteness of fishermen's homes from their workplaces has a major impact on their professional activities; and
- Lack of training and education of fishers and lack of village infrastructure and basic social facilities such as drinking water, electricity and sanitation, which have an adverse impact on the social life of fishing communities and encourage marine nomadism and rural exodus.

1.3 Status of Governance

Due to the informal nature of most small-scale fisheries, the socio-economic contribution of production is often not captured in national statistics such as the gross domestic product (GDP) (Njaya et al., 2018; Dunn et al., 2010). As a result, the sector has historically been overlooked by fishery policy makers, who usually focus on promoting commercial fisheries, which generate rent that can be used by the state (Njaya et al., 2018; Béné et al., 2010). In developing countries where millions depend on small-scale fisheries for livelihoods, concerns have arisen in recent years around this marginalisation of small-scale fishers in favour of industrial fisheries (Béné et al., 2010) leading to international efforts to reform fishery governance to recognise the rights of small-scale fishers and protect their livelihoods (FAO, 2015). Thus, the role of inland fisheries in poverty reduction, food security and livelihoods provision and regional economic development has received increasing recognition, for example in Africa (Jentoft and Chuenpagdee, 2015; AU and NEPAD, 2014; FAO, 2003; Marshall and Maes, 1994). As a result, the fishery sector has been identified by the African Union as a priority investment area for poverty alleviation and regional economic development, and given substance through the NEPAD 'Partnership for African Fisheries" programme. (http://www.nepad.org/foodsecurity/fisheries/about).

African countries face many challenges that undermine efforts related to the conservation and sustainable management of fish resources. The FAO's 'Guidelines for Securing Sustainable Small-Scale Fisheries' note that 'the constraints to and challenges in achieving sustainable development in small-scale fishing communities include their often remote location, limited access to social and other services as well as markets, low levels of education and inadequate organisational structures which make it difficult for them to make their voices heard. As a result, most small-scale fisheries are effectively unregulated, unreported and poorly monitored. Customary practices for allocation and sharing of resource benefits that generally used to be in place in small-scale fisheries have often been eroded because of centralised fisheries management systems, technology development and demographic changes' (Raakjaer Nielsen et al., 2004; Hara and Raakjaer Nielsen, 2003). Various studies and field observations indicate that fish "stocks" are steadily decreasing due to the continent's lack of capacity to manage the resources in a sustainable manner and to stop their over-exploitation, in particular to prevent illegal fishing whether of industrial or artisanal origin as practiced by local people and/or foreign fishers (AU and NEPAD, 2014). The resulting decline in catches is usually accompanied by intensification of unsustainable fishing practices to maintain gains, thereby cumulatively resulting in further deterioration of the resource (Hara and Njaya, 2016; Béné et al., 2010; Dunn et al., 2010; Stewart et al., 2010).

In order for African countries to be able to optimize the development of their aquatic resources and improve the contribution of the fisheries and the aquaculture sector to the fight against poverty and food and nutritional security, it is necessary to improve the policy and legislative frameworks to support the development of sustainable fisheries. Given its potential contribution to poverty alleviation and food and nutrition security, special attention needs to be paid to small-scale fisheries and the organization of this sector. This implies a significant strengthening of the governance of the fisheries sector in African countries and the establishment of sustainable fisheries management frameworks (AU and NEPAD, 2014).

1.4. Recognition of small-scale fisheries in international instruments

A number of international conventions are related to, recognise or are linked to small-scale fisheries. Some of these are as follows:

The **1995 FAO Code of Conduct for Responsible Fisheries (CCRF).** This asks states to protect the rights of fishers and fish workers, particularly those engaged in subsistence, small-scale and artisanal fisheries, to a secure and just livelihood, as well as preferential access, where appropriate, to traditional fishing grounds and resources in the waters under their national jurisdiction (Article 6.18).

The **2015 Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (the SSF Guidelines)** is the first internationally agreed instrument dedicated entirely to the small-scale fisheries sector. They were developed to provide harmonizing guidance in support of the overall principles and provisions of the Code of conduct for Responsible Fisheries (CCRF) and are intended to support the visibility, recognition and enhancement of the already important role of small-scale fisheries and to contribute to global and national efforts towards the eradication of hunger and poverty.

The **Agenda 21**: Section 17.74b emphasizes that states must take into account traditional knowledge and interests of local communities, small-scale artisanal fisheries and indigenous people in development and management programmes.

The 1995 **Fish Stocks Agreement (UNFSA)** asks states to take into account the special requirements of developing states and, in particular, the need to avoid adverse impacts on, and ensure access to fisheries by subsistence, small-scale and artisanal fishers and women fish workers, as well as indigenous people in developing states, especially Small Island Developing States (SIDS), while establishing management measures for straddling and highly migratory fish stocks (Article 24.2 (b))

Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa (PFRS). In order to improve governance and management of the small-scale fisheries sector for increased benefits for African populations and countries, the African Union (AU) in collaboration with the New Partnership for Africa's Development (NEPAD) Agency developed a the 'Policy Framework and Reform Strategy for Fisheries and Aquaculture (PFRS)**'**, which was adopted by the 23rd Summit of African Heads of States and Governments in Malabo, Equatorial Guinea in June 2014. One of the main objectives of this pan African Policy document is to improve and strengthen the contribution of small-scale fisheries to poverty alleviation, food and nutrition security and socio-economic growth especially for the fishing communities in Africa.

Consistent with the call for action in response to the Africa Agriculture Transformation Agenda by 2025 and also in line with the implementation of key policy pillars of the Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa, AU-IBAR, in collaboration with the NEPAD, embarked on a process of formulating Pan African Plans of Actions on enhancing the contribution of fisheries and aquaculture towards the attainment of the objectives of food and nutrition security and poverty reduction goals of African Union.

A comprehensive and consolidated **Plan of Action for the sustainable development of small-scale fisheries in African context** was formulated in 2016 with the support from AU-IBAR. The overall policy objective of this 10-year Action Plan is to improve and strengthen the contribution of small-scale fisheries to poverty alleviation, food and nutrition security and socio-economic benefits of fishing communities. The implementation of the three priority areas, listed below, that had been identified by the stakeholders through continent wide consultation process aim to improve the governance of small-scale fisheries and achieve the overall objective of the action plan within the African countries and at the regional level.

- **Priority Area 1:** Role and importance (contribution) of fisheries for improved livelihoods, food and income of small scale fishing communities and related operators are evident, recognized and secured in Member States.
- **Priority Area 2:** Bilateral and regional cooperation for effective management of shared fishery resources and ecosystems is strengthened.
- **Priority Area 3:** Fishers are organized to foster good fisheries governance, sustainable development and responsible use of natural resources.

AU-IBAR, Regional institutions (Regional Economic Commissions – RECs and Regional Fisheries Bodies – RFBs) and Member States are responsible for the Monitoring and Evaluation (M&E) of the implementation of the Action Plan (2017-2027). In addition, AU-IBAR has initiated collaboration with FAO for the implementation of the action plan in the framework of the implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication.

As a first step, the NEPAD Agency implemented the Partnership for African Fisheries (PAF), which aimed to support an emerging policy framework by defining processes for building capacity of Africa to consider, to identify and implement sensitive reforms in fisheries governance in Africa. To be effective, the PAF emphasized the emergence of strong and effective African political leadership to drive reforms in African fisheries governance. The four pillars on which the PAF worked were: i) reform of fisheries governance; ii) the fight against IUU fishing; iii) trade and iv) aquaculture development. These same pillars had been taken up in the framework of two important continental programs, FishGov (FishGov 2 started in 2020) and Fish Trade, which are, in a way, the frameworks for the implementation of the PFRS.

1.4.1 SADC Protocol on Fisheries

In recognition of the important role that fisheries plays in the livelihoods, food security, alleviating poverty and general social and the economic well-being of the people of the region, the SADC promulgated the 'SADC Protocol on Fisheries'. The Protocol (SADC, 2001), signed in 2001by members states, came into force in 2003. The Protocol stipulates and emphasizes the responsibilities of Member States in the sustainable and effective management of national and shared fish stocks and aquatic resources. By signing the Protocol, Member States agreed to harmonise their domestic fisheries legislation and the management of shared aquatic resources, to take adequate measures to optimize fisheries law enforcement and thus protect the aquatic environment and the resources therein in order to safeguard the livelihoods of fishing communities. The SADC Statement of Commitment to combat Illegal, Unreported and Unregulated (IUU) fishing, which is an Annex to the Protocol on Fisheries, aims to (a) improve regional and inter-regional cooperation for eradicating IUU fishing, (b) strengthen fisheries governance and legal frameworks for eliminating IUU fishing, (c) developing a regional plan of action on IUU fishing, and (d) strengthen regional fisheries monitoring control and surveillance capacity.

The Protocol is implemented through an implementation strategy approved in 2010 in Victoria Falls, Zimbabwe by the Ministers responsible for Environment and Natural Resources. The implementation strategy consists of five areas of focus, namely a) aquaculture**,** b) management of shared fisheries resources**,** c) combating illegal, unreported and unregulated (IUU) fishing**,** d) small-scale/artisanal fisheries**,** and e) fish trade. Derived from the implementation strategy of the Protocol on Fisheries is the SADC Fisheries Programme, which guides SADC member states, the SADC Secretariat and partner organizations on the priority projects and interventions identified towards the implementation of the Protocol, regional strategies and plans.

1.5 Inland Fisheries in South Africa.

In South Africa, the marginalisation of small-scale fisheries mirrors the international experience. Historic legislation has promoted the marine commercial fisheries sector and the inland fisheries the recreational sector. Small-scale fisheries, both marine and inland, are conducted largely on an informal basis by disadvantaged communities with only the marine small scale fishery achieving policy recognition in recent years (DAFF, 2012a; Britz et al., 2015). The major ongoing challenge is providing the institutional support required to realise their potential contribution to poverty reduction and economic development. There continues to be contestation for fishing rights with the industrial sector, which were awarded as long-term rights between 2006 and 2020. Inland fisheries are still not recognised in national policy (though a national inland fisheries policy is being developed), despite thousands of inland storage dams and impoundments which support growing small-scale and recreational fishing sub-sectors. Thus, inland water resources remain largely underutilised as a source of fish protein despite their potential as a source of income and employment for the rural poor living in the vicinity of these impoundments (Britz et al., 2015).

The management of biodiversity in dams and the catchments surrounding dams, and the control and development of mechanisms for access rights to dams and their fish resources on public dams has historically been fragmented between government departments and has not been directed by a coherent policy (Britz et al., 2014; Hara and Backeberg, 2014; Weyl et al., 2007). This lack of a national policy has, thus, been major bottleneck in the development of inland fisheries

In this context, fishing in inland waters has historically been regarded as a recreational activity, with management authority delegated to the provincial environmental and nature conservation authorities (Britz et al., 2014). Recreational fishing is also recognized in the Department of Water Affairs policy, which promotes the development of recreational activities on state dams as a secondary beneficial use (DWAF, 2006). Because the provincial environmental agencies do not have a development mandate, they have very limited capacity to promote livelihoods based on fisheries, although a number of projects have been promoted in various provinces over the years including the Free State, Limpopo and KwaZulu-Natal. The low value of freshwater fish (Ellender et al., 2010), and Apartheid era exclusion of people from accessing fish resources, have also contributed to South African inland fisheries being utilised primarily by recreational anglers (Weyl et al., 2007). In recent years however, there is evidence of increasing utilization of inland fisheries by small-scale fishers (van der Waal et al., 2000; Ellender et al., 2009; Hara and Backeberg, 2014). While small-scale fishers from local communities are generally regarded as having a legitimate claim to fish, in the absence of a supporting rights-based governance framework, their activities are usually illegal, unmanaged and often unsustainable, which has led to growing conflicts among water resources users (especially between small-scale and recreational fishers) on a number of public dams (Britz et al., 2014). The institution of equitable and sustainable use of South Africa's inland fish resources, through the development and enactment of the inland fisheries policy, will thus require fundamental reform of the very rudimentary inland fishery governance arrangements (Hara and Backeberg, 2014).

1.5.1. Aligning South African Inland fisheries to National legislation, Food and Nutrition security and Developmental Policies

South African citizens' environmental rights and the legislative provisions for these are rooted in the Constitution of the Republic of South Africa (Republic of South Africa, 1996), specifically Section 24 (Environmental rights), which states that every citizen has the right:

1) to an environment that is not harmful to their health or well-being
2) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that:

a) prevent pollution and ecological degradation
b) promote conservation
c) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development

Subsection (2c) provides the foundation and justification for the establishment and development of an inland fisheries sector based on restoring the environmental rights and dealing with past injustices for the rural poor with regard to denial of such rights, while (2b) provides that this should be undertaken on the basis of promoting conservation and biodiversity for the benefit of current and future generations. The implication of this principle is that any development or activities shall not compromise the ecological integrity of the resource and environment (Blackmore, 2014). The constitutional 'environmental Right' is primarily operationalised through South Africa's environmental legislation and, in particular, the National Environmental Management Act (NEMA) 107 of 1998 and other subsidiary legislation aligned to NEMA. The constitutional and NEMA provisions have guided the formulation of policy and legislation governing the use of the country's natural resources in the democratic era particularly for addressing apartheid-era inequalities.

The National Environmental Management Act (NEMA) is the overarching legislation for environmental management. The purpose of the National Environmental Management Act (NEMA) (Act No. 107 of 1998) is stated as being:

> "An Act to provide for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and to provide for matters connected therewith".

The principles set out by NEMA apply to the whole republic and to the actions of all organs of the state that may significantly affect the environment (2(1)). Among others, these principles shall: Apply alongside all other appropriate and relevant considerations....including fulfilment of the social and economic rights outlined in chapter 2 of the constitution (2,1-a); Promote environmental management that must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, cultural and social interests equitably (2-2); Promote development that must be socially, environmentally and economically equitable (2-3); Promote sustainable development that would require consideration of all relevant factors (2,4-a); Promote the participation of all interested and affected parties in environmental governance and that all people must have the opportunity to develop the understanding, skills and capacity necessary for achieving equitable and effective participation (2,4-f); Promote decisions that take into account the interests, needs and values of all interested and affected parties, including recognizing all forms of knowledge, including traditional and ordinary knowledge (2,4-g); Promote community well-being and empowerment through environmental education, raising of environmental awareness, sharing of knowledge and experience and other appropriate means (2,4-h); Consider and assess the socio, economic and environmental impacts of activities (both benefits and disadvantages) and take decisions on the basis of such considerations (2,4i); Promote openness and transparency in decision-making including ensuring access to information in accordance with the law (2,4-k); Promote intergovernmental co-ordination and harmonisation of policies, legislation and actions relating to the environment (2,4-l); Take into account global and international responsibilities relating to the environment, but discharged in the national interest (2,4-n); and Promote and recognize the full participation of women and youth in environmental management and development (2,4-q).

Chapter 2 of the NEMA outlines the organisations for management, their composition, their functions and procedures for formation of these bodies. Chapter 3 outlines procedures for co-operative governance, including the purposes, objectives and statutory requirements of environmental management and implementation plans. It also outlines procedures for formulation of these plans. Chapter 4 is about fair decision-making and conflict management while chapter 5 outlines the objectives and implementation of integrated Environmental management. Chapter 6 outlines how to deal with international obligations and agreements.

Thus, the NEMA is the primary legislation that gives legal effect to the environmental rights defined in the Constitution. The environment is defined in terms of human wellbeing, with the main objectives of the NEMA being: ‘to promote sustainable development through the utilisation and protection of South Africa’s natural and cultural resources; to foster equitable access to the benefits that can be derived from South Africa’s natural and cultural resources; to empower the South African public, community organisations through participation, environmental education, capacity building, and research and information services’. Additionally, NEMA establishes principles to guide the decisions and actions of all organs of state in environmental management; provides for establishment of institutions that can co-ordinate and harmonise environmental functions of the state and the promotion of participation of stakeholders in environmental governance; establishes procedures for cooperative governance; establishes procedures for conflict management; promotes integrated environmental management by establishing minimum procedures for environmental impact assessments, and also enables national or provincial authority agencies to prescribe environmental impact assessment regulations; establishes procedures for ratification of, and giving effect to international environmental instruments; and promotes compliance and enforcement of provisions of the Act.

Also crucial is that NEMA promotes co-management (co-governance) by enabling the establishment of environmental management cooperation agreements that can promote the principles of integrated environmental management. The NEMA is thus a very progressive and powerful instrument for guiding the reform of inland fisheries rights and governance of the sector in accordance with the Constitution and in alignment with other relevant legislation and policies.

The National Environmental Management Biodiversity Act (NEMBA) (amendment Act 10 of 2004), which is based on the principles of the NEMA, is concerned with the management and conservation of South Africa's biodiversity. The act is binding for all organs of state, and all spheres and levels of government – that is national, provincial and local. The act applies to both terrestrial and marine environments. It also applies to human activities affecting South Africa's biological diversity and its components.

As the over-arching legislation for environmental management, the principles and instruments within NEMA and NEMBA jointly provide for a legalised developmental approach to natural resource management including inland fisheries. Correctly applied, these should enable redress the past inequities in terms of access to and benefits from inland fisheries (Britz et al., 2014).

1.5.2 Governance of Inland fisheries

Although the Marine Living Resources Act (Act 13 of 1998) guided marine fisheries reform post 1994, the primary environmental acts governing inland aquatic resources (the National Environmental Management Act (NEMA), Act 107 of 1998; and the National Water Act (NWA), Act 36 of 1998) do not specifically provide for inland fisheries. The lack of policy to guide South African inland fishery governance has been highlighted (for example Weyl et al., 2007; McCafferty et al., 2012; Hara and Backeberg, 2014), with suggestions to guide the establishment of appropriate institutional and management arrangements in the future.

In particular, Weyl et al. (2007) provided recommendations, based on a case study of the inland fishery potential of the dams in the North-West Province, for fishery development based on the productivity of each dam, biodiversity considerations, user group characteristics, and socio-economic objectives – particularly the promotion of rural livelihoods (Britz et al., 2014). The authors suggested that the provincial Departments of Agriculture, with their smallholder/ rural livelihoods development mission, should logically be mandated to promote inland fishery development. This subsequently came into effect through the creation of the Department of Agriculture, Forestry and Fisheries (DAFF) in 2009, which has been reconstituted as the Department of the Environment, Forestry and Fisheries (DEFF) after the 2019 elections. Weyl et al. (2007) did however caution that the provincial agriculture departments did not possess the capacity to promote inland fishery development, and thus considerable institutional capacity building would be required. Based on the recommendations of the baseline scoping study that preceded this project (reported in Britz et al., 2014), DAFF (now DEFF) assumed responsibility for inland fisheries and is in the process of promulgating a policy for inland fisheries in South Africa (DAFF, 2016). Britz et al. (2014) argue that the inclusion of inland fisheries into the DAFF Fisheries Branch mandate has created an appropriate institutional arrangement to develop an inland fisheries policy which is aligned with national developmental goals such the National Development Plan (National Planning Commission, 2012) and the

DAFF Integrated Growth and Development Plan (DAFF, 2012b). The WRC funded "baseline and scoping study on the development and sustainable utilisation of storage dams for inland fisheries and their contribution to rural livelihoods" provided a knowledge base to inform the development of policy and institutional arrangements for inland fishery governance (Britz et al., 2014).

The Inland fisheries policy being developed (DAFF, 2016) is based on a development-orientated co-management approach. According to Britz et al. (2014), this will replace the outdated and incomplete South African inland fishery policy framework and bring South African policy in line with normative international fishery governance guidelines and conventions including the FAO's "Framework for the Development and Management of Inland Fisheries" (Wellcome, 1997), the "FAO Code of Conduct for Responsible Fisheries" (FAO, 2010) and "Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication" (FAO, 2015). The FAO guidelines (FAO, 2013) adopt a rights-based approach to fisheries governance with clearly defined social and economic objectives, to address the legacies of disadvantage and marginalisation borne by poor fishing communities, which would be in line with South Africa's rights-based constitution.

As inland fisheries have historically been a provincial competency, cooperative institutional arrangements and the harmonisation of provincial ordinances governing inland fishing would be required. In any case, provincial governments will need to play a key role given that their mandate also includes poverty reduction and economic development for rural communities. The proposed organisational arrangements for inland fisheries in the policy being developed recognises and includes the involvement provincial governments. Weyl et al. (2012) also noted that the development of inland fisheries governance arrangements was constrained by a paucity of information and identified 'an urgent need for research covering the biological, social, economic and governance aspects, if inland fisheries are to be developed in a rational and sustainable manner that promotes South Africa's national policy goals'. This project was a contribution to this information gathering. Even then, there is likely to be need for programmes of routine biological, environmental, social, economic, etc. data and information collection and processing that should underlay informed decisions for the sustainable management and governance of formalised inland fisheries in South Africa.

1.6. Background, Aims and Objectives of the Project

This WRC funded project (K5/2497/4), titled "Towards Enhancing Contributions of Inland Fisheries to Rural Livelihoods: An Empirical Assessment of Freshwater Fish Stocks, Fisheries Potential, Market Value Chains, Governance and Co-Management Arrangements" is a follow-on project of the project titled "Baseline and scoping study on the development and sustainable use of storage dams for inland fisheries and contributions to rural livelihoods" that had also been funded by the WRC (project No. WRC K5/1959/4). South Africa's post 1994 democratic government has been under increasing pressure to address the persisting challenge of rural poverty, inequality and unemployment. Thus the need to realise the socio-economic potential of South Africa inland fisheries has become urgent. The Water Research Commission funded baseline and scoping study undertaken by researchers from the Institute for Poverty, Land and Agrarian Studies (PLAAS) at the University of the Western Cape (UWC), the South Africa Institute of Aquatic Biodiversity (SAIAB), and the Department of Ichthyology and Fisheries Science at Rhodes University (reported in Britz et al., 2014) found that inland fisheries contribute to livelihoods, food security and employment of many men and women (Tapela et al., 2014; Jaganyi et al., 2008). Despite its importance, this informal sub-sector has largely remained invisible, unrecognised and undervalued (Turpie et al., 2014; Weyl et al., 2007; Rouhani & Britz, 2004; van del Wall, 2000; Andrew et al., 2000; Heeg and Breen, 1982).

Although users of fish resources on public dams include both small-scale fishers and recreational anglers, the latter is by far the most developed, largely as a result of historical privilege (Hara and Swarts, 2014; Tapela et al., 2013; Weyl et al., 2007). South Africa's inland small-scale fishing remains poorly developed despite attempts at developing the sector dating back to the 1970s (Koch and Schoonbee, 1980; Allanson & Jackson, 1983; Jackson, 1980; Andrew, 2001), thereby raising questions about its actual potential for contributing to the informal rural livelihoods and economies. The development and management of inland fisheries for sustainable rural livelihoods therefore needs to be a priority for national and provincial governments.

There is a paucity of information on the actual potential of the fish stocks on most public dams (Britz et al., 2014). Without the knowledge on fish stocks and productivity of the dams, it is not possible to institute evidence-based sustainable levels of harvesting and utilization of inland fisheries. Despite definitive information and data deficiencies, Fouche et al. (2012) estimated that the sustainable harvest levels from large dams could range from 10 to 200 kg per ha per year, depending of factors such as water quality, depth and shape of the dam, fish species and other limnological factors. McCafferty (2012) used a more conservative estimate of 40 kg per ha per average production, indicating that South African water bodies could potentially yield between 1000 and 2000 tonnes per year. While is it important to ensure that rural people derive great value in ecosystem services from freshwater fisheries than they have historical enjoyed under the repressive colonial and apartheid regimes, there is the danger that the drive to promote this positive transition could lead to overexploitation of inland fisheries resources like has happened in a lot of other African countries (Hara and Njaya, 2016). Therefore, one of the key objectives of this study was to assess the fish stocks and fisheries potential in selected small and large dams in the provinces with the most productive dams, namely Limpopo, Mpumalanga, KwaZulu-Natal, Eastern Cape and Western Cape in order to recommend the appropriate harvesting levels and techniques and the process of formulating these.

According to Leibold and van Zyl (2008), more than 1.5 million people are involved in freshwater angling in South Africa and that this sector is worth about R9 billion annually. The majority of participants in this sector are white people. Therefore, the sector provides potential for broadening participation by the rural poor women and men that have been historically marginalised in terms of transformation of the sector. A second key objective of the project was thus deepening our understanding the economic value of inland fisheries, and the nature of existing formal and informal Market Value Chains (MVCs) associated with inland fisheries and the key actors in these value chains, the factors affecting entry into these chains by rural women and men and the requisite institutional interventions for ensuring that MVCs associated with inland fisheries are sufficiently pro-poor. Without sound management and governance of transformative transition towards greater benefits for rural communities, this could result in the erosion of the resource and destruction of the ecosystems. Indigenous/ customary Knowledge Systems (IKS) related to inland fisheries remain unrecognised in law and thus these declining institutions cannot guarantee sustainable utilization given the factors such as population mobility, societal shifts, commercialisation of fishing and insecure rights. The history of denial and alienation of resources from the poor and fracturing of communities through forced removals and cramming them into limited geographic areas (bantustanisation) may have eroded much of the IKSs and social capital associated with community-based sustainable inland fisheries (Tapela, 2014). Therefore, the third key objective of the study was to consider the institutional arrangements for governance and co-management of inland fisheries for sustainable utilization in South Africa (Hara and Backeberg, 2014; Hara and Britz, 2014).

1.6.1 Project Aims

The project aims were:

1. To assess fish stocks and fisheries potential in selected small and large dams in some of the provinces with the most productive dams, including Limpopo, KwaZulu-Natal, Mpumalanga and/or Western Cape
2. To characterize and map existing formal and informal Market Value Chains associated with inland fisheries as well as the multiple user groups that access water and fisheries resources in dams
3. To determine the economic value of inland fisheries in selected South Africa dams
4. To identify requisite institutional mechanism to ensure that Market Value Chains associated with inland fisheries are sufficiently pro-poor
5. To identify factors affecting entry by rural women and men into lucrative inland fisheries Market Value Chains and access to related social and economic benefits associated with various types of subsistence, recreational and commercial fisheries in specific dams
6. To develop and test effectiveness of co-management and governance arrangements for selected cases studies in inland fisheries.

1.6.2. Methodological Approach – Case Study Approach

The research used a case study approach. Three dams, namely Pongola in KwaZulu-Natal, Flag Boshielo in Limpopo and Voëlvlei in the Western Cape were used. For the stock assessment fish data from Loskop dam in conjunction with data from Flag Boshielo, for reasons that are explained in the chapter 2, were used. The methodologies used for each component, namely 'Stock Assessment', 'Market Value Chains' and 'Institutional Arrangements' are outlined in detail in the synthesis chapters of each component.

Members of the team meeting some representatives of fishing communities on Flag Boshielo Dam (source – Mafaniso Hara)

1.6.3. Outputs

Eleven deliverables/outputs have resulted from this project, as follows:

Deliverable No.	Title of deliverable
1	Review report on fish stocks and fisheries potential
2	Review report to characterize Market Value Chains
3	Review report on governance and co-management arrangements as well as progress report
4	Research report to characterize Market value chains
5	Interim Research report to assess fish stocks and the fisheries potential as well as progress report
6	Research report on institutional mechanisms for pro-poor Market Value Chains
7	Final Research report on fish stocks and fisheries potential as well as progress report
8	Report on co-management and governance
9	Report on economic value of inland fisheries as well as progress report
10	Report on stakeholder consultation and policy dialogue seminar
11	Final synthesis report

1.7. Structure of the report

This report is structured into six chapters. Chapters 1 is the introductory chapter on while 2, 3 and 4 are synthesis chapters on the three components of the project namely, Stock Assessment and fisheries potential of small-scale fisheries; Market Value Chains and Economic Value of small-scale fisheries; and Governance and Institutional Arrangements for small scale fisheries. Chapters 5 and 6 are the Report Synthesis chapter and the Recommendations chapter respectively. The Following are the title of the individual chapters:

- Chapter 1: Introduction: Global and South African Perspectives on Small-Scale Fisheries
- Chapter 2: Case Studies of Fisheries Potential of South African Inland Fisheries
- Chapter 3: Using Market Value Chains to Enhance the Contribution of Inland Fisheries to Rural Livelihoods in South Africa
- Chapter 4: Management and Governance Arrangements for South African Inland Fisheries
- Chapter 5: Towards development of an inclusive sustainable small-scale inland fisheries sector
- Chapter 6: Recommendations for action and suggestions for future research

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CHAPTER 2: Case Studies of Fisheries Potential of South African Inland Fisheries

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2.1. Introduction

South Africa's National Development Plan, Vision 2030, which is closely aligned with the United Nations Development Programme's 17 Sustainable Development Goals (SDGs) for 2030 (UNDP, 2015), aims to eliminate poverty and reduce inequality in South Africa by 2030 (National Planning Commission, 2013). The proportion of the population living in poverty was estimated to be 56% (30,4 million people) in 2015 (Statistics South Africa, 2017a). One of the consequences of poverty is inadequate or severely inadequate access to food – food insecurity. Globally, it was estimated that 9.3±0.4 % experienced severe food insecurity in 2016, with almost half of the 688.5±27.6 million people living in Africa (FAO et al., 2017). South Africa being food secure at the national level, almost 21% of South African households experience food insecurity (Statistics South Africa, 2017b). While this is below the estimated 27.4±0.7% of people for Africa (FAO et al., 2017), it is an unacceptable figure for one of the most affluent countries in Africa. In South Africa, food insecurity varies between provinces with Limpopo and Gauteng provinces having the highest levels of food security, with 94% and 84% of households in these provinces, respectively, having food security (Statistics South Africa, 2017b). In contrast, North West and Northern Cape provinces had the lowest levels of food security with only 64% and 67% of the households, respectively, considered to be food secure. In addition, the population group of the household head and the household size are correlated to the probability of whether a household will experience food insecurity; larger households are more likely to experience food insecurity (Statistics South Africa, 2017b). In addition to poverty, environmental stressors and conflict are strong drivers of food insecurity in southern Africa (Misselhorn, 2005). In particular, global climate change represents a major challenge to the future livelihood and food security of social groups currently vulnerable to inadequate access to food (Bohle et al., 1994).

South Africa is a semi-arid country with an average annual rainfall of less than 450 mm, approximately half the global average (Nomquphu et al., 2007). South Africa is regarded as the 30th most water-stressed country globally with an annual freshwater availability of fewer than 1700 m^3 per capita (Aphane and Vermeulen, 2015). Besides, the geographical distribution of rainfall is highly variable with the northern and eastern regions receiving more rain than the southern and western regions (Cessford and Burke, 2005). South African rivers have distinct seasonal flows with considerable year-to-year variability in runoff (Davies et al., 1993). To compensate for the seasonality in water availability, the South African government has constructed numerous water storage impoundments and inter-basin transfer schemes to store water during the dry periods and to move water to areas where the water demand exceeds the natural supply from run-off. Hara and Backeberg (2014) estimated that South Africa has over 4 700 storage dams constructed primarily for domestic, irrigation, and industrial water supply, of which about 700 are owned and controlled by government agencies. Given widespread rural unemployment, poverty, and undernourishment, Hara and Backeberg (2014) suggested that the development of inland fisheries on public dams and natural water bodies has the potential for improving rural livelihoods and food security, including the potential for the inclusion of communities in other value chains linked to economic activities around public dams. Lynch et al. (2020b) showed that synergies within the relationships between freshwater fish production, sustainable inland fisheries, and functioning freshwater systems and the SDGs, could contribute towards progressing a number of the SDGs, particularly No Poverty (SDG 1), Zero Hunger (SDG 2), Clean Water and Sanitation (SDG 6), Responsible Consumption and Production (SDG 12) and Life on Land (SDG 15). These authors found that SDGs normally touted as synergistic with inland fisheries, such as Gender Equality (SDG 5) and Decent Work and Economic Growth (SDG 8), both had balanced positive and negative outcomes.

Using empirical models, Britz et al. (2015) estimated the total potential inland fisheries yield from South Africa's impoundments to be *ca.* 15 000 tonnes/yr. Due to the climatic conditions included in the empirical models, most of the impoundments in South Africa were predicted to have relatively low productivity and fish yield. While the 15 000 tonnes/yr. estimate precludes the development of large-scale commercial fisheries in South Africa's inland waters, it was suggested that there is considerable scope for the development of small-scale fisheries to enhance food security, directly and through employment opportunities. However, South Africa lacks an inland fisheries policy, both at the provincial and national level, and this was identified as a major bottleneck for the sustainable development of inland fisheries resources (Weyl et al., 2007). Britz (2015) concurred stating that the governance of South Africa's inland fishery resources needed a guiding policy, supporting legislation and government capacity based on the social, economic, and environmental objectives.

As South Africa currently lacks an inland fisheries sector, Britz et al. (2015) recommended prioritising fisheries development initiatives in areas where success was most likely; i.e. the warmer regions of South Africa: such as Limpopo and northern KwaZulu-Natal provinces. However, due to the paucity of information available on the fish stocks and fisheries potential of South Africa's inland waters, Britz et al. (2015) cautioned that the empirical model predictions could only be considered as preliminary estimates and required validation through fishery feasibility assessments of water bodies in the regions highlighted as containing suitable fish stocks for harvest before decisions on the type of fishery, and how this fishery should be developed and managed, could be finalised. Britz et al. (2015) recommended that the fishery feasibility assessments should include: 1) a fishery survey to determine species composition and current use of the dam; 2) a resource survey based on experimental catch rates to estimate initial catch rates and the population structure of harvestable fish in the dam; 3) a stock assessment to determine a sustainable harvest strategy; 4) economic feasibility to determine if a fishery is likely to succeed and assess economic risks of failure; 5) market access research to determine where and how harvested fish could be marketed; and 6) monitoring and surveillance plan to ensure that the rights of commercial fishers are protected once a formal fishery is put into place.

The objective of the current chapter was to apply the recommendations of Britz et al. (2015) to three large reservoirs located within areas of high productivity (Figure 2.1). The reservoirs selected were the 1,288 ha Flag Boshielo Dam in Limpopo, the 2,428 ha Loskop Dam in Mpumalanga, and the 13,273 ha Pongolapoort Dam in northern KwaZulu-Natal (Figure 2.1). Fish surveys were undertaken monthly at Flag Boshielo Dam, while rapid appraisals were conducted at Loskop and Pongolapoort impoundments. These surveys included an assessment of the fish composition in each waterbody to determine whether species with proven commercial potential were present at each site following Weyl et al. (2007) in addition to establishing 1) length-weight relationships; 2) catch-per-unit effort; 3) age-at-maturity; 4) gear selectivity estimates; 5) natural, fishing and total mortality and 6) apply the yield-per-recruit and spawner-biomass-per-recruit models for potentially exploitable, species.

2.2. Literature Review

The current project is a continuation of the work completed in a previous Water Research Commission Project K5/1954/4 described in two volumes by Britz et al. (2015) and Tapela et al. (2015). To avoid information published in these two volumes, the literature presented in this chapter review focuses on literature published after the completion of WRC Project K5/1954/4.

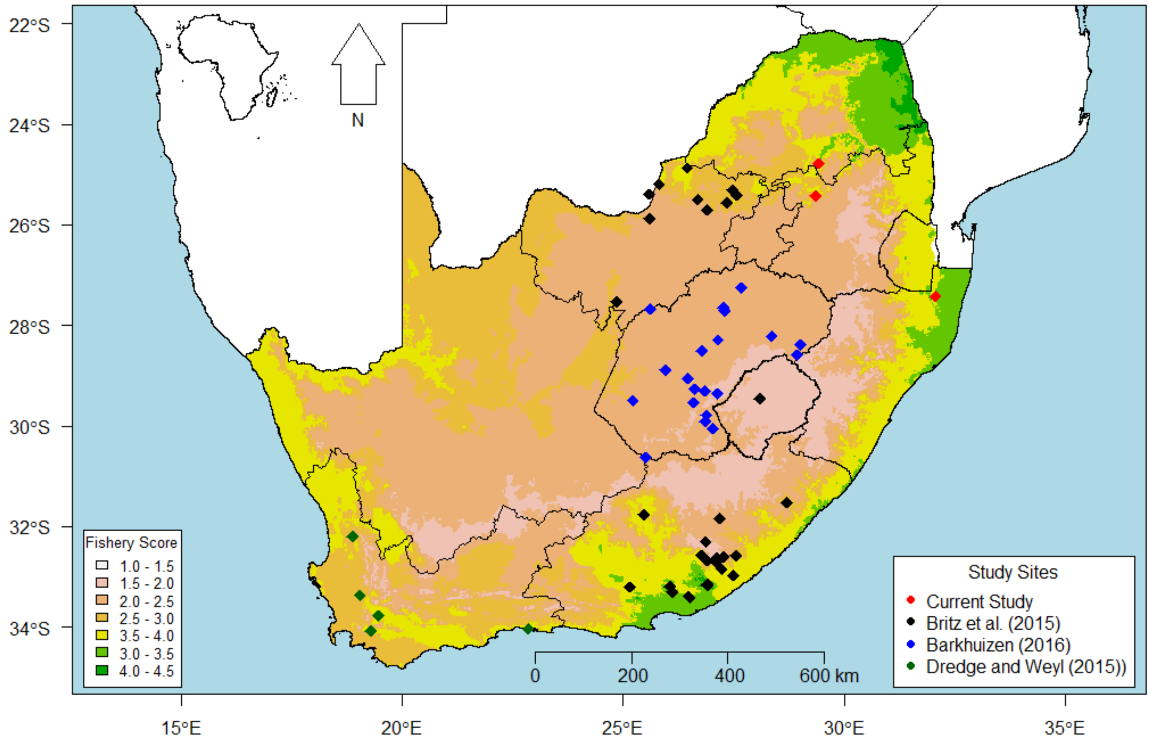

Figure 2.1: Survey data for inland water bodies in South Africa overlain on the fishery potential score determined by Britz et al. (2015). Black markers represent data collated during the WRC K5/1954/4Project Britz et al. (2015), blue markers represent dams surveyed during the recent Ph.D. research by Barkhuizen (2015); and green markers represent the five Western Cape localities surveyed by SAIAB/CapeNature Dredge and Weyl (2015). The red markers show the three sites surveyed in the current project.

2.2.1. The Rome Declaration

The challenges faced by inland fisheries are universal among nations and include competition for water, degraded landscapes and water quality, migration barriers, and unsustainable development – most of which have been done in isolation from the impact that these alterations would have on inland fisheries habitats and fisheries production (Taylor and Bartley, 2016). It can be questioned whether decision-makers consider the trade-offs of development projects in terms of the potential loss of value for inland fisheries productivity and aquatic ecosystem services (Taylor and Bartley, 2016). In January 2015, nearly 250 experts on freshwater fisheries, including scientists, resource managers, policymakers, and community representatives, from more than 40 countries conferenced at the United Nations Food and

Agriculture Organization (FAO) in Rome for the Global Conference on Inland Fisheries, *Freshwater, Fish and the Future,* organized by the FAO and Michigan State University. The outcome from this conference was called "The Rome Declaration: Ten steps to responsible inland fisheries" (FAO (Food and Agriculture Organization of the United Nations) and MSU (Michigan State University), 2016). The 10 recommendations that emerged from the conference are: 1) improve the assessment of biological production to enable science-based management, 2) correctly value inland aquatic ecosystems, 3) promote the nutritional value of inland fisheries, 4) develop and improve science-based approaches to fishery management, 5) improve communication among freshwater users, 6) improve governance, especially for shared water bodies, 7) develop collaborative approaches to cross-sectoral integration in development agendas, 8) respect equity and rights of stakeholders, 9) make aquaculture an important ally, and 10) develop an action plan for global inland fisheries. The proceedings from the *Freshwater, Fish and the Future* conference in Rome were subsequently published through the American Fisheries Society as Taylor et al. (2016).

Four years after the *Freshwater, Fish and the Future* conference and Rome declaration, Lynch et al. (2020a) sought to evaluate what successful implementation of the Rome declaration would look like, assess current examples of implementation, suggest potential signals of progress, and provide some specific, indicative examples of progress for each step. While promising signs of progress were noted, Lynch et al. (2020a) conclude that a strong need to galvanize momentum for sustained action to ensure that inland fish and fisheries are accounted for and incorporated into broader water resource management discussions and frameworks is required.

2.2.2. Inland fisheries policy

Recognising the need for an Inland Fisheries Policy, South Africa's Department of Agriculture, Forestry, and Fisheries drafted a policy document (Department of Agriculture Forestry and Fisheries, 2018) and circulated it for public comment in June-July 2018. Subsequently, a second draft policy document has been compiled (Department of Agriculture Forestry and Fisheries, 2019) and circulated for public comment in June-July 2019. However, before the establishment of inland fisheries in South Africa's water supply impoundments, the feasibility of these fisheries needed to be established.

The purpose of the Inland Fishery Policy is to guide the sustainable development of inland fisheries; including legislative reform and harmonization, the definition of access rights, criteria for ensuring sustainable harvest levels, government organisational structure and capacity, cooperative governance and co-management arrangements, and the empowerment of rural communities to participate equitably in sustainable resource use (Department of Agriculture Forestry and Fisheries, 2019). The policy is grounded in the principles of inclusivity, inland fisheries being an economic sub-sector, equitable access to freshwater aquatic resources, transformation, sustainable development, follows an ecosystem approach to fisheries, embraces the precautionary principle approach, encourages the value chain approach and a developmental approach, and supports good governance. Focus areas for the implementation of the Inland Fisheries Policy include a legal and regulatory framework; access rights and authorisations; resource sustainability; maximising economic and social benefits; corporate governance and co-management; research development and monitoring, inland fisheries development support; transformation and broadening of participation; capacity building; monitoring, evaluation and enforcement; and food safety monitoring. Until national legislation is promulgated, inland fisheries will continue to be governed in terms of the cooperative governance provisions of the NEMA and the provincial environmental acts and ordinances (Department of Agriculture Forestry and Fisheries, 2019).

2.2.3. Research questions for inland fisheries

In June 2018, the South African Society for Aquatic Scientists convened a dedicated "Inland Fisheries" workshop to update and further develop a list of priority knowledge requirements for inland fisheries in the country. The main themes that emerged during the workshop were developed and contextualized as ten research questions (Weyl et al., in press): 1) What is the exploitation potential of inland fisheries?; 2) What are the health risks of consuming freshwater fishes?; 3) Who currently uses inland fisheries and what are their harvests?; 4) What can we learn from historical constraints to freshwater/inland fisheries development?; 5) How will the governance of fisheries have to change in an evolving multi-sectoral environment?; 6) What are the options for fisheries enhancement?; 7) What are the most appropriate fisheries technologies?; 8) What value chains and employment opportunities are associated with inland fisheries?; 9) What is the impact of water level fluctuations on fish production?; and 10) What are the impacts of pathogenic diseases on fish populations?

2.2.4. Recent research on inland fisheries

Two provincial-level projects were completed as a result of the increased interest in inland fisheries. The most significant was Barkhuizen (2015), a Ph.D. thesis entitled "AN ASSESSMENT OF FISH AND FISHERIES IN IMPOUNDMENTS IN THE UPPER ORANGE-SENQU RIVER BASIN AND LOWER VAAL RIVER BASIN". The research presented in the thesis focused on developing management recommendations for inland fisheries in the dams of that province. This was achieved by conducting a rapid appraisal of the fisheries potential of impoundments using empirical approaches; collating a 40-year time series of catch returns from recreational angling tournaments and commercial fisheries; conducting surveys to determine fish species composition in 21 impoundments and testing a new fishing gear. Barkhuizen (2015) collated the first complete database of commercial fisheries yields in South Africa between 1979 and 2014. Despite the issuing of licenses to operators on several water bodies, only 9 036 tonnes of fish were harvested by commercial fishery enterprises operating sporadically in seven impoundments. Commercial fisheries yields were dominated by Bloemhof Dam (73%) and Kalkfontein Dam (23%) with sporadic attempts to develop commercial fisheries at the five other impoundments contributing only 4% to the total yield over the 35-years of operation. Interestingly, only two commercial ventures operated at one impoundment (Bloemhof Dam) continuously for more than 32 years. The success of these operations was attributed to: prior knowledge, skills, experience, and, most importantly, a pre-existing and self-initiated market.

The second project by Dredge and Weyl (2015) titled "FISHERIES SUITABILITY ANALYSIS FOR GROENVLEI, VOëLVLEI, THEEWATERSKLOOF, GREATER BRANDVLEI AND CLANWILLIAM DAMS", was conducted jointly by SAIAB and Cape Nature. CapeNature's chose to explore opportunities for managing fisheries in its dams to align with national policy objectives including food security, economic empowerment, tourism development, the optimal economic benefit from water, poverty eradication, sustainability, and conservation. At CapeNature's request, SAIAB undertook baseline surveys of a natural lake (Groenvlei) and four dams (Theewaterskloof, Voëlvlei, Quaggaskloof/Brandvlei, and Clanwilliam dams) to conduct a fisheries suitability analysis for the five waterbodies. The survey methodology was the same as the one used for this project and included: 1) an empirical assessment of potential yield; 2) an assessment of the fish diversity in each water body to determine the presence of species with proven commercial potential; 3) a preliminary assessment of the relative fish abundance; and 4) qualitative assessment of suitability based on access and stakeholder perceptions. In general, the development of gillnet fisheries was not a viable option on most dams due to potential conflicts between existing users (recreational and subsistence anglers), low catch rates in experimental gear, and large numbers of fish listed as Endangered or Vulnerable in the IUCN Red-list. It was therefore recommended that the dams be used by recreational and subsistence anglers. The exception was Theewaterskloof Dam, where estimated potential yields ranged between 58 and 260 t/year, and the potential for a limited commercial fishery operating alongside existing recreational and subsistence fisheries was suggested. Only alien fish species, African sharptooth catfish, common carp, largemouth bass, smallmouth bass, and banded tilapia, were recorded at this locality. A license was issued to one experimental commercial fishery to target carp and sharptooth catfish. Due to its large size, this dam is considered capable of yields that might sustain a commercial fishery. It was recommended that such a fishery, should, however, be developed in consideration of the current users of the dam and its considerable tourist value.

Together, these assessments add another 26 inland water bodies to the database of those surveyed in the country and add considerably to the spatial coverage of fish survey data for South Africa (Figure 2.1). What is evident, however, is the lack of survey data available for the areas evaluated as areas of high potential fish production during the K5/1954/4 Project; i.e. in Mpumalanga, Limpopo, and Natal. The three dams chosen for the current study therefore allow for a reanalysis of productivity using a dataset with good geographic representation.

2.2.5. Fisheries assessment methods

The proper assessment and management of a fishery require an understanding of the biology, life history, and distribution of the target species (King, 2013). Given that most dams in South Africa have limited existing informal fisheries; the use of assessment methods that allow for analysis that incorporates the response of the stock to changes in management strategy is essential; e.g. a change in gill net mesh size or effort. A research protocol for the formulation of a holistic management strategy recognises that: 1) management advice is often an immediate rather than a future concern in resource management and; 2) that the assessment protocol must be flexible enough to allow management advice to be obtained from each stage in the protocol and prioritises research activity according to the management information that can be obtained from each level of the protocol Weyl (1998).

The first priority in fisheries assessments should be to determine the target species and the selectivity of each harvesting gear. Subsequently, catch and effort trends as well as the biological parameters pertinent for the application of analytic models should be investigated for each of the target species. By comparing the size-at-selectivity of each species harvested in each fishery to the age-at-maturity, the sustainability of each gear can be assessed. The subsequent determination of age and growth allows for an increase in the resolution of management advice. The determination of fish length-at-age allows for the determination of mortality rates, which together with growth parameters can then be used to apply fisheries models which are used to identify biological management targets to the fishery. Once such biological management targets have been identified, social and economic assessments will be necessary to assess the impact of their implementation on the users of the fishery. This is of particular importance on dams where different users may have varying views on management (e.g. commercial gillnetters and recreational fishers) and calculate trade-offs in resource utilisation will need to be incorporated into the management strategy. To do this will require:

1. An assessment of the composition of fish stocks in the dam
2. A preliminary assessment of the population dynamics of the most important target species in the fishery. These will be species that are considered important enough to be actively managed sustainably through the application and utilisation of the correct mesh size and/or closed season. These will differ according to impoundment and will need to be selected after the initial surveys have been conducted.
3. Management recommendations on resource use for the optimal utilisation of the fish resources to maximise yields (socio-economic gains) from the fishery without compromising sustainability or conservation goals for the water body will be developed.
4. Limits of acceptable change based on species distribution and abundance.
5. Development of a monitoring system involving the collection of recreational, subsistence and commercial fisheries catch data.

2.3. Methods

2.3.1. Criteria used to select study sites

The main consideration in selecting study sites was whether the waterbody was located in regions identified as being suitable for fisheries development by the GIS model (Figure 2.1). A secondary consideration was whether the impoundments were included in the extensive sociological assessment by Tapela et al. (2015) and were considered ideal for the testing of inland fisheries developmental concepts because of multiple stakeholders that include recreational, subsistence, and small-scale commercial fishers using gill nets, e.g. Flag Boshielo Dam and Pongolapoort Dam. Loskop Dam was added because the impoundment being located within a conservation area where public access to the lake is restricted to non-consumptive recreational angling.

Despite a paucity of information on South African reservoirs and their fisheries (McCafferty et al., 2012), there is relatively good information on the fish species present on a basin-scale; see Skelton (2001); van Rensburg et al. (2011); Weyl and Cowley (2015). In comparison with other areas of South Africa, the east-flowing Limpopo, Phongolo, and Incomati River systems, contain a relatively large fish fauna due to their historical connections to the more tropical river systems of the Zambezian Lowveld Ecoregion (Thieme et al., 2005; Abell et al., 2008). These include potential fisheries species which generally, tend to be larger species of high market value, e.g. large cichlids in the southern African context (Tweddle et al., 2015).

2.3.2. Flag Boshielo Dam

Flag Boshielo Dam (24° 46’ 50” S; 029° 25’ 32” E), previously Arabie Dam, was constructed in 1987 to secure water for agricultural, municipal, and mining activities in neighbouring municipal districts, particularly for Polokwane (van Koppen, 2008). Flag Boshielo Dam is situated downstream of the confluence of the Olifants and Elands rivers, approximately 30 km from the town of Marble Hall in Limpopo province (Figure 2.2). The dam was raised by 5 m during 2007 and 2008 to meet increasing water demands, increasing the storage capacity from 100 to 188 million m^3 and the annual supply from 56 to 72 million m^3(DWAF, 2005).

Flag Boshielo Dam is surrounded by typical central sandy bushveld savanna vegetation with many partly and fully submerged dead trees providing habitat for piscivorous birds like darters, herons, cormorants, and fish eagles (Jooste et al., 2015a). The reservoir also hosts a considerable, albeit declining, population of Nile crocodiles (Botha, 2010; Botha et al., 2011). The Schuinsdraai Nature Reserve covers a large portion of the impoundment's western shores, restricting public access to recreational anglers and wildlife enthusiasts. In contrast, besides the state-run Thompi Seleka Agricultural College and the privately-owned Aloe Park Holiday and Fishing Resort, public access to the eastern shore of the impoundment is unrestricted.

In addition to being ecologically and socio-economically important, Flag Boshielo Dam supports a subsistence fishery that is important to rural communities surrounding the impoundment (Dabrowski et al., 2014b; Tapela et al., 2015). Subsistence anglers can regularly be seen fishing along the eastern bank. However, the illegal use of monofilament nets has recently increased along both shores of the dam lake (Sara et al., 2017b). Flag Boshielo Dam has also become an important recreational fishing venue, hosting regular angling competitions for the indigenous Mozambique tilapia; *Oreochromis mossambicus* (Peters, 1852) and alien sport-fishes; mostly largemouth bass *Micropterus salmoides* (Lacepède, 1802), common carp; *Cyprinus carpio* Linnaeus, 1758, and silver carp; *Hypophthalmichthys molitrix* (Valenciennes, 1844). The latter species is a major draw-card for coarse and species-specific recreational anglers after it was 'accidentally' introduced into the impoundment from an aquaculture research facility in the early 1990s (Brits, 2006).

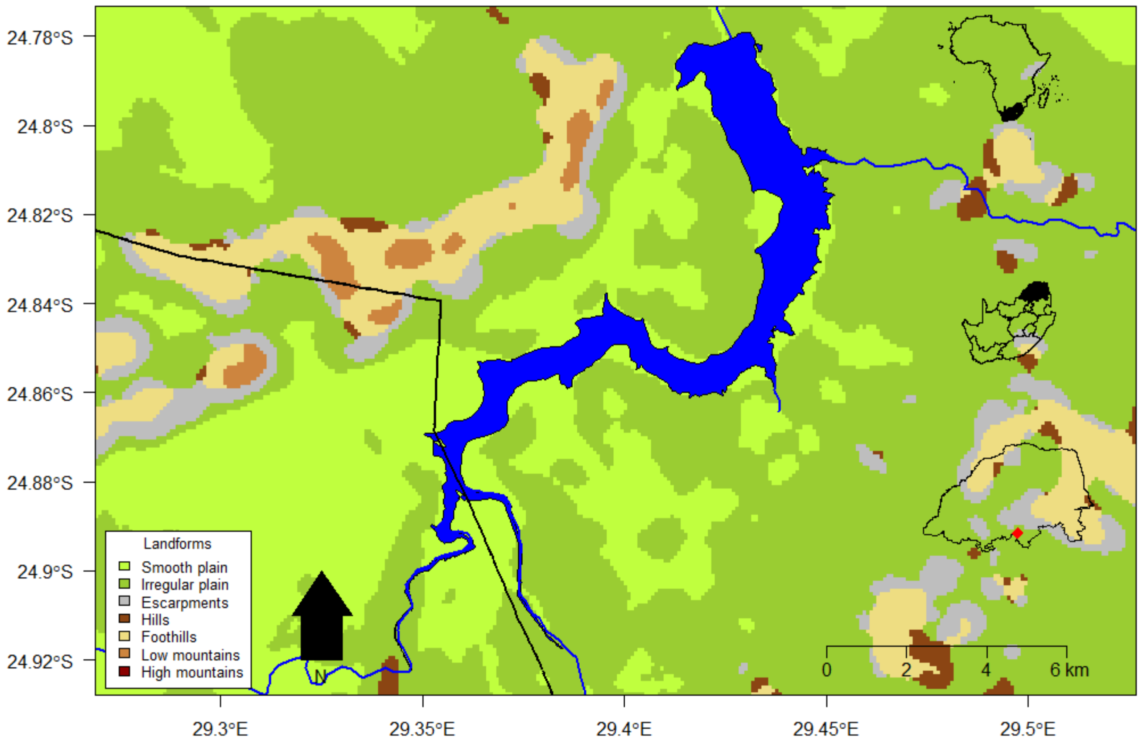

Figure 2.2: Map of Flag Boshielo Dam showing the surrounding landforms.

The composition and abundance of the ichthyofauna in Flag Boshielo Dam have been evaluated by Brits (2006) and Sara et al. (2017b). Both studies indicated that rednose labeo and Mozambique tilapia had the greatest fishery potential (Table 2.1). In addition to the species listed in Table 2.1, Brits (2006) reports the presence of *Engraulicypris brevianalis* (Boulenger, 1908)‡, *Enteromius paludinosus* (Peters, 1852), *Enteromius unitaeniatus* Günther, 1866), *Labeobarbus polylepis* (Boulenger, 1907), *Micralestes acutidens* (Peters, 1852), *Pseudocrenilabrus philander* (Weber, 1897), and alien species *Ctenopharyngodon idella* (Valenciennes, 1844) and *Micropterus salmoides* (Lacepède, 1802), all collected using seine nets.

Table 2.1: The relative abundance (abundance and % biomass by weight) of fish species captured in gill nets at Flag Boshielo Dam from October 1998 to December 2001 (Brits (2006) and January 2013 to December 2013 (Sara et al., 2017b).

Species	Common name	Britz (2006)		Sara et al. (2017)	
		N (%)	Biomass (%)	N (%)	Biomass (%)
Enteromius rappax (Guimarães, 1884)*	Papermouth	4.17	1.93	0.75	0.52
Enteromius trimaculatus (Peters, 1852)*	Threespot Barb	1.85	0.03	19.53	1.59
Labeo cylindricus Peters, 1852	Redeye Labeo	0.47	0.27	0.53	0.23
Labeo molybdinus Du Plessis, 1963	Leaden Labeo	2.16	0.63		
Labeo rosae Steindachner, 1894	Rednose Labeo	11.08	4.99	14.30	36.87
Labeobarbus marequensis (A. Smith, 1841)	Largescale Yellowfish	4.64	2.25	10.99	9.80
Marcusenius pongolensis (Folwer, 1934)†	Bulldog	1.74	0.35	3.20	2.38
Micralestes acutidens (Peters, 1852)	Silver robber			8.11	0.42
Clarias gariepinus (Burchell, 1822)	Sharptooth Catfish	2.32	10.71	0.64	7.61
Schilbe intermedius Rüppell, 1832	Butter Catfish	3.48	0.82	15.05	10.09
Synodontis zambezensis Peters, 1852	Brown Squeaker	1.00	0.17	12.91	5.91
Coptodon rendalli (Boulenger, 1896)**	Redbreast Tilapia	2.37	0.95	0.11	0.12
Oreochromis mossambicus (Peters, 1852)	Mozambique Tilapia	63.40	68.65	10.46	15.66
Pseudocrenilabrus philander (Weber, 1897)	Southern Mouthbrooder			0.11	<0.01
Tilapia sparrmanii Smith, 1840	Banded Tilapia	0.16	<0.01	0.11	0.01
Cyprinus carpio Linnaeus, 1758***	Common Carp	0.42	1.09	1.39	4.24
Hypophthalmichthys molitrix (Valenciennes, 1844)***	Silver Carp	0.74	7.16	0.21	0.80
Micropterus salmoides (Lacepède, 1802)***	Largemouth Bass			1.60	3.75

* indicates the genus previously known as *Barbus sensu* Skelton (2016); ** the genus previously known as *Tilapia sensu* Dunz and Schliewen (2013), and † the species previously known as *Marcusenius macrolepidotus* (Peters, 1852) *sensu* Maake et al. (2014), *** indicates alien species.

Pollution associated with land use, acid mine drainage, and effluent from anthropogenic sources within the upper Olifants River sub-catchment has resulted in this system becoming one of the most threatened and polluted in southern Africa (Heath et al., 2010; Ashton and Dabrowski, 2011; Huchzermeyer et al., 2011; Jooste et al., 2015a; Azeez et al., 2017; Oberholster et al., 2017). Recent research undertaken at Flag Boshielo Dam has primarily focused on the limnology (Dabrowski et al., 2014b), fish parasites (Madanire-Moyo et al., 2012a; Madanire-Moyo et al., 2012b), water quality (Heath et al., 2010; Jooste et al., 2015a) and the metal content in the muscle tissue of selected fish species and the health risks associated with humans consuming these species, e.g. Mozambique tilapia (Addo-Bediako et al., 2014a); butter catfish *Schilbe intermedius* Rüppell, 1832 (Addo-Bediako et al., 2014b; Marr et al., 2015); rednose labeo *rosae* Steindachner, 1894 (Jooste et al., 2014; Lebepe et al., 2016; Marr et al., 2017); African sharptooth catfish *Clarias gariepinus* (Burchell, 1882) (Jooste et al., 2015b; Marr et al., 2015) and brown squeaker *Synodontis zambezensis* Peters, 1852 (Sara et al., 2017a) and *Hypophthalmichthys molitrix* (Sara et al., 2018).

2.3.3. Loskop Dam

Loskop Dam (Figure 2.3) is located within the 23 612 ha Loskop Nature Reserve, approximately 32 km from the town of Groblersdal in Mpumalanga Province. This dam was closed in 1938 by the Department of Water Affairs and in 1979 the wall was raised to its current height of 54 metres (Botha et al., 2011). The man-made lake has a surface area of 2,428 ha and a storage capacity of 362 million m^3. Loskop Dam supplies water to a vast irrigation scheme covering approximately 25,600 ha of agricultural land and to the municipalities of Loskop, Groblersdal, and Marble Hall. The catchment area above Loskop Dam is intensively mined for coal and other minerals, e.g. iron, vanadium, and manganese. Industrial effluents, acid mine drainage from abandoned coal mines, agrochemicals, and poorly operated waste treatment works in the catchment impact the water quality of the impoundment (Huchzermeyer et al., 2017). The lake water is classified between meso- and eutrophic but the high influx of nutrients drives the primary production of phytoplankton resulting in substantial blooms of the cyanobacterium *Microcyctis aeruginosa* (Kützing) Kützing 1846 and the dinoflagellate *Ceratium hirudinella* (O.F. Müller) Dujardin 1841 during spring and summer (Dabrowski et al., 2013).

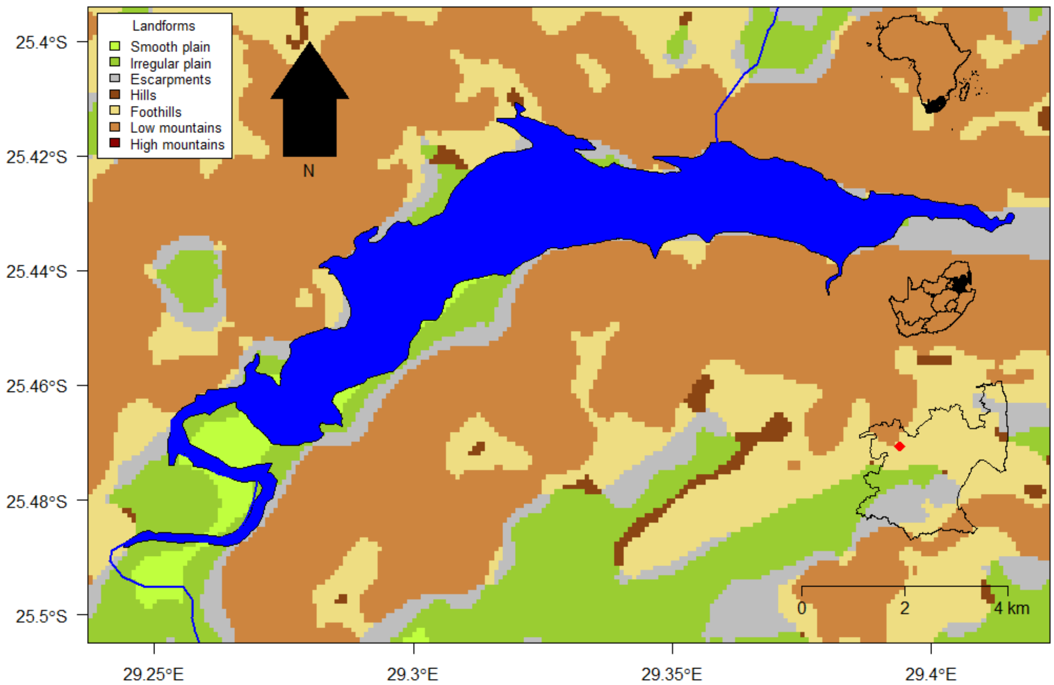

Figure 2.3: Map of Loskop Dam showing the surrounding landforms.

The Loskop Dam Nature Reserve is managed by Mpumalanga Tourism and Park Agency and public access to the reservoir's fish stocks is limited to anglers frequenting and utilising the Forever Resort facilities. The impoundment holds large populations of largescale yellowfish, common carp, African sharptooth catfish; red-breasted tilapia, and Mozambique tilapia. The impoundment is regarded as one of the prime coarse angling sites in South Africa (http://www.mpumalanga.com/our-provincial-parks/loskop-dam-nature-reserve), especially for its large-sized specimens of Mozambique tilapia. The reservoir is also a popular bass angling venue with regular tournaments being hosted. Tourist value is considered high due to the water sports activities and the recreational fishing value provided by the dam.

Due to several recorded instances of fish kills (Ashton, 2010) and the gradual decline in the resident crocodile population since 2005 (Botha et al., 2011; Huchzermeyer et al., 2017) attention has on the impact of pollution on the lake's ecosystem has increased (Oberholster, 2009; Ashton, 2010). Recent studies have investigated the limnology and sediment quality (Dabrowski et al., 2013), endosulfan pollution (van Dyk and Greeff, 1977; van Dyk et al., 1982), the clinical manifestation of pansteatitis in crocodiles (Botha et al., 2011) and fish (Bowden et al., 2016a; Bowden et al., 2016b; Bangma et al., 2017; Huchzermeyer et al., 2017) of Loskop Dam. Pansteatitis is a disease that results in the hardening of the adipose tissue in both crocodiles and fish (Huchzermeyer et al., 2011; Bowden et al., 2016a; Bowden et al., 2016b). Lebepe et al. (2016) and Lebepe et al. (2020a) investigated the bioaccumulation of metals in *Labeo rosae* and *Oreochromis mossambicus* and assessed the associated health risks to humans while Marr et al. (2017) investigated the metal concentrations in gill, liver and muscle tissue of *L. rosae* and Lebepe et al. (2020b) investigated the histopathology of the gills and liver of *L. rosae* in this impoundment.

2.3.4. Pongolapoort Dam

The 124 000 ha Pongolapoort Dam was closed in 1973 to provide water for agriculture in northern KwaZulu-Natal (Figure 2.4). However, the planned agricultural investments never materialised and the impoundment only irrigates about 3000 ha, mainly sugarcane (van Vuuren, 2009). Closure of the dam altered the flow regime of the Pongola River and negatively impacted the downstream floodplain fisheries. As a result, most research associated with this system has focused on the impact of the managed flow regime of the Pongola River on environmental flows (Schreiner, 2007; Pacini et al., 2008; Dube et al., 2015), fish physiology and pesticide pollution (McHugh et al., 2011) and the traditional fisheries in floodplains downstream (McCafferty et al., 2012; Coetzee et al., 2015; Dube et al., 2015). Fish is an important component of the diet of the communities in the Pongola floodplain, third after chicken and red-meat (Coetzee et al., 2015). Communities in the floodplain consume fish, on average, twice a week.

The main uses of the impoundment are ecotourism, such as tigerfish *Hydrocynus vittatus* Castelnau, 1861 fishing, boating, birding, game viewing from boats, and game drives on both lands under private concessions and protected areas managed by Ezemvelo KZN Wildlife (Tapela et al., 2015). The northern region of the impoundment is surrounded by the Pongola Game and Nature Reserve under the management of Ezemvelo KZN Wildlife. There are many fishing lodges and hunting camps that cater to tourists (Tapela et al., 2015). However, little information is available on the ichthyofauna of the Pongolapoort Dam. Most fishing activities occur predominantly in the river and floodplain downstream of the dam with red-breasted tilapia and Mozambique tilapia being the species most targeted and, to a lesser extent, the African sharptooth catfish and the brown squeaker.

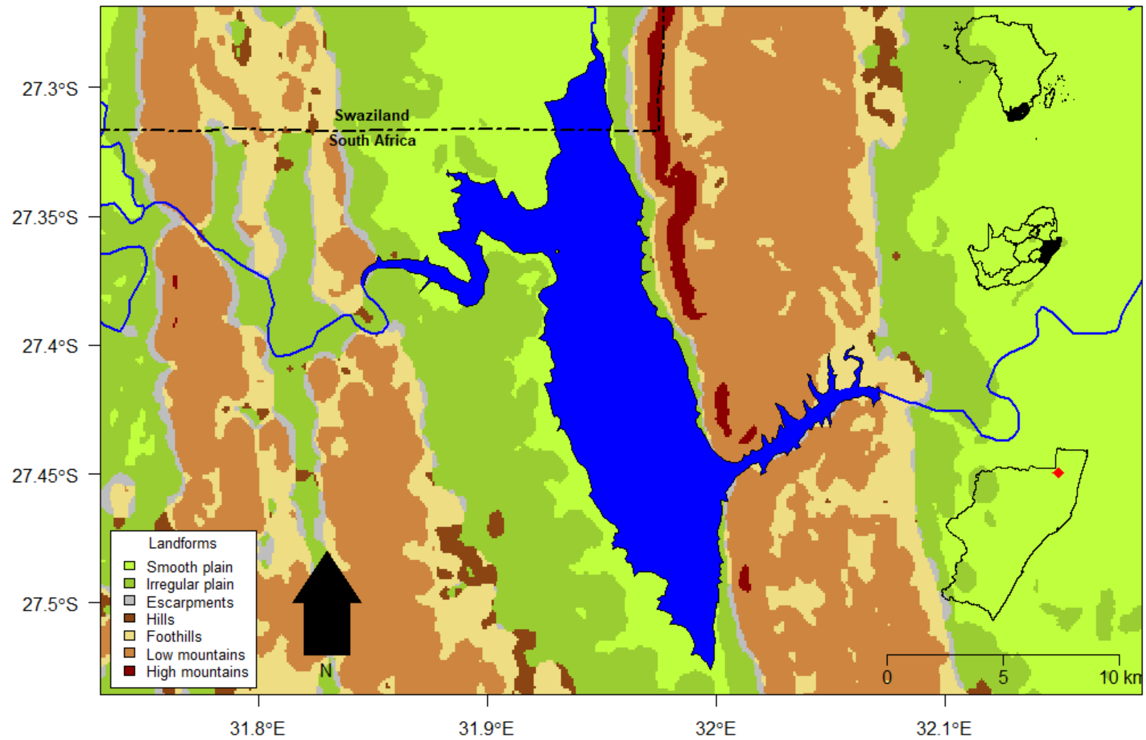

Figure 2.4: Map of Pongolapoort Dam showing the surrounding landforms.

Formally documented information on the fisheries of the Pongolapoort Dam is currently limited to the interview-based assessment with local fishers. Subsistence anglers use the Pongolapoort Dam in areas where they have access. Besides, a group of licensed gillnet fishers, the Sizabantu group, operate from the Department of Water Affairs (DWA) slipway on a 'formalised' basis. Fishing without permits (or poaching) is reportedly carried out on the eastern shore bordering protected areas managed by Ezemvelo KZN Wildlife. The Sizabantu artisanal fishers sell their catch to an organized group of local women (Abathengi boFish), who re-sell the fish in the town of Jozini and further afield. The species primary target by the artisanal gillnet fishery are red-breast tilapia and Mozambique tilapia (Tapela et al., 2015).

A list of fishes expected for the Pongola River system was compiled (Table 2.2). The Pongola River is the southernmost limit of the tigerfish distribution. Tigerfish from Pongolapoort Dam attain relatively old ages (9 years for females) but grow considerably slower, and mature at a smaller size, than fish from warmer regions further north (Soekoe, 2012). Compared to Flag Boshielo and Loskop dams, little is known about the bioaccumulation of metals in fish from the Pongolapoort Dam. However, a review by Ansara-Ross et al. (2012) highlights pesticides detected in fish from this reservoir that include synthetic organochlorine pesticides such as dichlorodiphenyl-trichloroethane (DDT), which is used for malaria control in the region, in investigations conducted by Bouwman et al. (1990) and McHugh et al. (2011).

2.3.5. Fish surveys

Potential target species for fisheries exploitation were determined based on fish composition and potential catch rates for different fishing gear. Target species were identified as those species making up more than 15% of the catch biomass in any of the mesh sizes. Fish populations were sampled using a fleet of four composite gill nets comprising 5 m panels having stretch mesh sizes of 44, 60, 70, 100, and 144 mm, fyke nets, and a 25 m seine net with a mesh size of 10 mm size for use to sample shallow habitats. Sampling sites were selected to be representative of the riverine, transition, and main basin zones of each impoundment. Gill and fyke nets were set in all available habitat types to ensure representative sampling. For each survey, gill nets were, for the most part, set approximately two hours before sunset and left to soak for four to six hours. Fyke nets were set to soak overnight. Seine nets were used in areas where the habitat was conducive for sampling; e.g. areas with gently sloping sandy banks void of submerged trees, rocks, crocodiles, and hippopotami. For gill and fyke nets, the soaking time was recorded. After the nets were retrieved, they were cleared of fish. Specimens were identified using Skelton (2001), counted, weighed (g) and the standard, fork, and total length (mm) determined using a balance and measuring board, respectively.

Team members setting nets for catching samples on Flag Boshielo (source – Joseph Sara)

Table 2.2: Checklist of native freshwater fishes from the Phongolo River (Maputo River system). Their likely presence in dams (0 = unlikely; 1 = occasional; 2 = common) and fisheries suitability (0 = no; 1 = occasional bycatch; 2 = target) is indicated; after Scott et al. (2006).

Species	Presence in Dam	Fisheries suitability
Anguilla mossambica (Peters, 1852)	1	1
Enteromius paludinosus (Peters, 1852)*	1	1
Enteromius radiatus (Peters, 1853)*	1	1
Enteromius trimaculatus (Peters, 1852)*	1	1
Brycinus imberi (Peters, 1852)**	1	1
Clarias gariepinus (Burchell, 1822)	2	2
Clarias ngamensis Castelnau, 1861	1	1
Coptodon rendalli (Boulenger, 1896)**	2	2
Hydrocynus vittatus Castelnau, 1861	2	2
Labeo rosae Steindachner, 1894	2	1
Labeo congoro Peters, 1852	2	1
Labeo cylindricus Peters, 1852	2	1
Labeo molybdinus Du Plessis, 1963	2	1
Labeobarbus marequensis (A. Smith, 1841)	2	2
Labeobarbus polylepis (Boulenger, 1907)	1	1
Marcusenius pongolensis (Fowler, 1934)	1	1
Engraulicypris brevianalis (Boulenger, 1908)***	1	0

Species	Presence in Dam	Fisheries suitability
Micralestes acutidens (Peters, 1852)	1	0
Oreochromis mossambicus (Peters, 1852)	2	2
Schilbe intermedius Rüppell, 1832	2	2
Synodontis zambezensis Peters, 1852	2	1
Tilapia sparrmanii Smith, 1840	2	1

* Likely to be caught in gillnets having stretch mesh sizes ≤ 44 mm
** Likely to be caught in gillnets having stretch mesh sizes ≤ 50 mm
*** Caught using a seine net with a mesh size of ≤ 10 mm.

Specimens of the most abundant species were retained for biological assessments whereby fish were sacrificed by severing the spinal cord behind the head in order to determine the age, growth, and stage of maturity.

At each sampling site, the water temperature one to two metres below the surface was recorded in situ between 6:00-10:00 am using a multi-parameter meter (Model: YSI 554 Datalogger and multiprobe). Surveys were conducted during April, May, June, August, September, October, November 2016, and February and April 2017 at Flag Boshielo Dam. For logistical reasons, rapid assessments were conducted over two weeks during September/October 2017 at Loskop Dam and two weeks during October/November 2017 at Pongolapoort Dam.

Members of the team setting a gillnet for sampling on the Flag Boshielo Dam
(source – Joseph Sara)

The project was executed with the appropriate permits from the respective provincial conservation authorities and with animal ethics clearance from the primary research institution, the University of Limpopo. Permits for the project were obtained from the Limpopo Department of Economic Development, Environment and Tourism (LEDET) to sample fish at Flag Boshielo Dam (ZA/LP/HO/3370), from Mpumalanga Parks and Tourism to sample at Loskop Dam (MPB. 5586), and from Ezemvelo KZN Wildlife to sample at Pongolapoort Dam (Permit No. OP2563/2017). Animal Ethics Approval for the project was obtained from the University of Limpopo Animal Research Ethics Committee (AREC/09/2017:PG) for the project.

2.3.6. Data Analysis

From the data collected during the field surveys, several biological and fisheries-related analyses were performed.

Maturity

On capture, a sample of a wide size range of selected specimens of the most abundant species were sacrificed, dissected, and the gonads visibly inspected and categorised according to the five developmental stages described in Table 2.3. The sample size was determined by availability. Mean length at sexual maturity was determined from fish collected during the peak reproductive season between October and April. The proportion of sexually mature individuals (ψ) by length (L) was fitted to the logistic curve:

$$\psi = \frac{1}{1+e^{-(L-Lm_{50})/\delta}} \qquad [1]$$

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

Growth estimation of target species

To determine age, the sagittal otoliths were removed and stored dry for subsequent sectioning. The otoliths were set in clear casting resin and sectioned transversely at a thickness of 0.3 mm through the nucleus with a double-bladed diamond-edged saw and mounted on microscope slides using DPX mountant. Fish age was determined by counting alternating light and dark growth bands in otoliths (Figure 2.5) as done by Weyl and Hecht (1998, 1999), Richardson et al. (2009), Winker et al. (2010), and Taylor and Weyl (2012, 2013). Age data were modelled against total length by fitting the von Bertalanffy growth function of the form:

$$L_a = L_\infty (1-\exp(-K(a-t_o))) \qquad [2]$$

where t_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).

Table 2.3: Macroscopic criteria used to categorise gonadal development; after Weyl and Hecht (1998).

Stage	Development	Macroscopic appearance
I	Juvenile	Not possible to visibly distinguish sex. Gonad appears as a translucent gelatinous strip.
II	Resting	Ovaries white or slightly yellowish. Oocytes are macroscopically distinguishable. Testes are discernible as thin white bands.
III	Developing	Ovaries enlarged, oocytes readily visible, and yellow. Testes broadened, distended, and cream in colour.
IV	Ripe	Oocytes of maximum size. Oocytes yellow to green and hydrated in *O. mossambicus* and *C. rendalli*. Testes swollen to maximum size.
V	Spent	Ovaries flaccid and sac-like with few vittellogenic oocytes visible. Testes reduced in size and dirty grey.

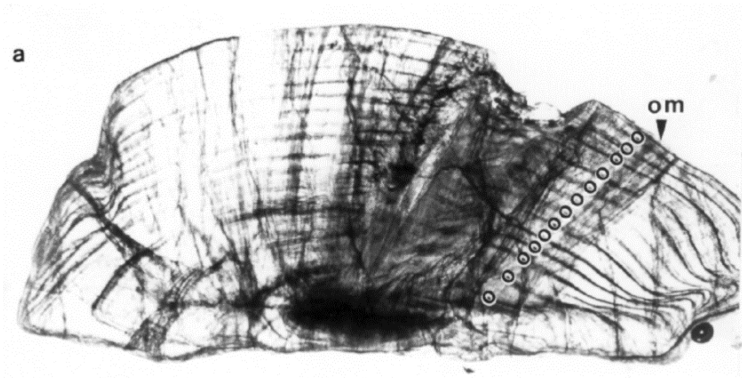

Figure 2.5: Photomicrographs of sagittal otoliths from 231 mm TL, 14-year-old *Coptodon rendalli* from Lake Chicamba, Mozambique. Note the opaque margin (om) on the otolith. (after Weyl (1998).

The length-mass relationship of the selected fish species was established by applying the standard power curve:

$$W = aL^b \quad [3]$$

Where W = Live mass (g) and L = in this case is total length (cm). Log transformation of the length and mass variables allows the parameters "a" and "b" to be determined through simple linear regression, as described in (Anderson and Neumann, 1996).

Determining natural mortality (M) of target species

Natural mortality (M; the number of fish. yr^{-1}) was estimated using the (Pauly, 1980) empirical equation;

$$M = -0.0066 - 0.279 \log_{10}(L_\infty) + 0.6543 \log_{10}(K) + 0.463 \log_{10}(T°) \quad [4]$$

where L_∞ (cm) and K are the von Bertalanffy growth parameters from Equation [2] and T° is the mean annual water surface temperature.

Jensen (1996) used the Beverton and Holt life history invariants (Charnov, 1993) to simplify the relationships between life history parameters and natural mortality. Using optimal trade-offs between reproduction and survival he showed that there was also a simple theoretical relationship between the von Bertalanffy *K* value and natural mortality

$$M = 1.5K \quad [4a]$$

a much simpler relationship than the one generated by Pauly (1980). Jensen re-evaluated Pauly's data and demonstrated that the simple relationship

$$M = 1.60K \quad [4b]$$

provides as equivalent a fit to the data as the Pauly equation. This simple relationship is close to the theoretical value (1.5K), suggesting that these relationships may provide a relatively sound method of estimating natural mortality.

Species diversity

Species numbers collected were used to establish population structures and biodiversity based on the Shannon-Wiener index (H') (Clarke and Warwick, 2001):

$$H' = -\sum_{i=1}^{k} p_i \log p_i \quad [5]$$

where k is the number of categories and p_i the proportion of observations found in category i. and species evenness (J') using (Zar, 1999):

$$J' = \frac{H'}{H'_{max}} \quad [6]$$

Catch rate

Catch per unit effort (CPUE) was determined for each sampling gear. In the case of gillnets, this was done for each mesh size. The overall CPUE was calculated as the biomass of fish collected for a given time, e.g. $net^{-1}.hour^{-1}$. Procedures outlined by Pollock et al. (1994) were used to provide estimates of catch-per-unit effort (CPUE) with the mean CPUE calculated as:

$$\overline{CPUE} = \frac{\sum_{i=1}^{n}\left(C_i / E_i\right)}{n} \quad [7]$$

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 et al., 1994). Effort units were standardized to 100 m net/hour. Catch data were analysed for significant differences by pooling mesh size and survey data. Preliminary analyses demonstrated that CPUE data did not meet the criteria for normality and homogeneity of variances required for the use of parametric tests. Differences between CPUE from surveys conducted at Flag Boshielo Dam were established using the Kruskal-Wallis test. Analyses were done using the R statistical software version 4.2.0 (R Development Core Team, 2020).

Net selectivity

Net selectivity (size at which fish are selected for by a particular gear) is an important measure in determining sustainable harvest strategies. All individuals caught in the experimental gillnet fleet were grouped into 10 mm length size classes by species and mesh size mi. Assuming that the retention probability is normally distributed, the selectivity of mesh mi is given by:

$$S_i(L) = \frac{\exp(-(L-\mu_i))}{2\sigma_i^{\,2}} \qquad [8]$$

with mean μ_i expressed as a linear function of mesh size m_i and the spread σ_i is assumed to be proportional to m_i such that $\mu_i = m_i k_1$ and $\sigma_i = m_i k_2$, where k_1 and k_2 are the scaling parameters for the selectivity curves, which are estimated from a log-linear Poisson model as described in detail by Millar and Holst (1997). These parameters were determined using an R script provided by Dr Henning Winker; Fisheries Scientist for the Department of Agriculture, Forestry and Fisheries (DAFF), South Africa.

<u>Application of the fisheries assessment models</u>

The YPR approach assumes that recruitment is constant and independent of spawner biomass. Due to the dependence of recruitment on spawner stock, scientists concerned with the management of fisheries are increasingly using spawner biomass-per-recruit models to make management recommendations; e.g. Weyl et al. (2005) and Richardson et al. (2009). The definition of a spawner-biomass target reference points (TRP) (FSB(x)) involves setting the fishing mortality to a level at which spawner biomass-per-recruit is reduced to x% of its pristine level. Although there is no conventional FSB(x) TRP, spawner biomass-per-recruit recommendations lie between 25% and 50% of unexploited levels Deriso (1987); Sissenwine and Shepherd (1987); Punt (1993a, b); Kanyerere et al. (2005); Weyl et al. (2005); Richardson et al. (2009). In the absence of information on the surplus production function or the spawner biomass-recruitment relationship, the FSB(x) TRPs are currently considered the most robust, allowing for the determination of a fishing mortality rate that will provide relatively high yields at lower risks (Clark, 1991; Punt, 1993b). In the case of *Labeo rosae* and *Oreochromis mossambicus* we recommend that SBR be maintained at above 25% of pristine levels.

<u>YPR and SBR analyses</u>

The fundamental assumption of all per-recruit analyses is that the stock is in a steady-state and that the parameters for recruitment, growth, and mortality are constant from one year to the next. The selectivity of each gear is assumed to be time-invariant, having the logistic form described in Equation [8]. Under these assumptions, the composition of the stock is then calculated by considering a cohort during its lifespan (Beverton and Holt, 1957). The relative proportion of fish at age a (Ňa) is defined recursively as:

$$\tilde{N}_a = \begin{cases} 1 & \text{if } a = 0 \\ \tilde{N}_{a-1} e^{-(M + S_{a-1} F)} & \text{if } 1 \le a < \max \\ \tilde{N}_{\max-1} e^{-(M + S_{\max-1} F)} \big/ (1 - e^{-(M + S_{\max-1} F)}) & \text{if } a = \max \end{cases} \qquad [9]$$

where Sa is selectivity at age (a), F is the instantaneous rate of fishing mortality on fully recruited cohorts, M is the instantaneous rate of natural mortality and max is the maximum recorded age.

In all per-recruit models, the weight-at-age is described by:

$W_a = a(La)^b$ [10]

where L_a is the length-at-age determined by the von Bertalanffy growth equation and a and b are parameters describing the length-age relationship, Equation [3]. To allow for the determination of a suitable initial fisheries management strategy for potential target species based on the biological reference point approach, the yield-per-recruit (YPR) and spawner-biomass-per-recruit (SBR) models as a function of fishing mortality (F) were used where:

$$YPR_F = \sum_{a=0}^{max} w_a S_a F \widetilde{N}_a \left[1 - e^{-(M+S_a F)}\right] / (M + S_a F) \Delta a$$ [11]

and

$$SBR_F = \sum_{a=0}^{max} \psi_a w_a \widetilde{N}_a \Delta a$$ [12]

All summations were conducted with a step size (Δα) of 0.10 of a year.

2.4 Results

2.4.1 Flag Boshielo Dam Fisheries assessment

Catch composition

Between February 2016 and April 2017, nine fishery assessment surveys were conducted at Flag Boshielo Dam. A total of 1376 specimens, from 11 species in six families, were captured using gillnets during this study (Table 2.4). The catch included two non-native species; common carp and largemouth bass. The Shannon-Wiener index was H' = 0.54 and the evenness J' = 0.5 over the study, which is considerably lower than those reported by Brits (2006). This discrepancy may be due to the assortment of gear used by Brits (2006). The dam level decreased drastically during the study and this proved problematic for establishing suitable sites for sampling using seine nets (see Figure 2.6). In addition, the receding dam levels resulted in a higher density of crocodiles and, therefore, it was decided not to deploy fyke nets for fear of causing mortalities among juvenile crocodiles.

Catch composition was dominated by native species; cyprinid, rednose labeo (59% of the biomass and abundance), cichlid, Mozambique tilapia (21% of the biomass and abundance), and mochokid, brown squeaker (12% of the abundance 6% of the biomass); see Table 2.4. The remaining species captured contributed approximately 15% of the total biomass captured. About 3% of the total catch (biomass and abundance) was damaged by crocodiles (Table 2.4). The results are similar to those of (Sara et al., 2017b). However, rednose labeo had increased from 37% to 59% of the catch and Mozambique tilapia from 16% to 21% of the catch. It is unclear whether these changes in the proportion of these two species in the catch is as a result of the low dam levels, and/or comparatively poorer recruitment by the other species, and/or difference in sampling techniques, and/or increased harvesting of the fish stock. Due to the rednose labeo and the Mozambique tilapia being the dominant species (abundance and biomass) in Flag Boshielo Dam, they were considered suitable target species for the establishment of an experimental fishery in Flag Boshielo Dam.

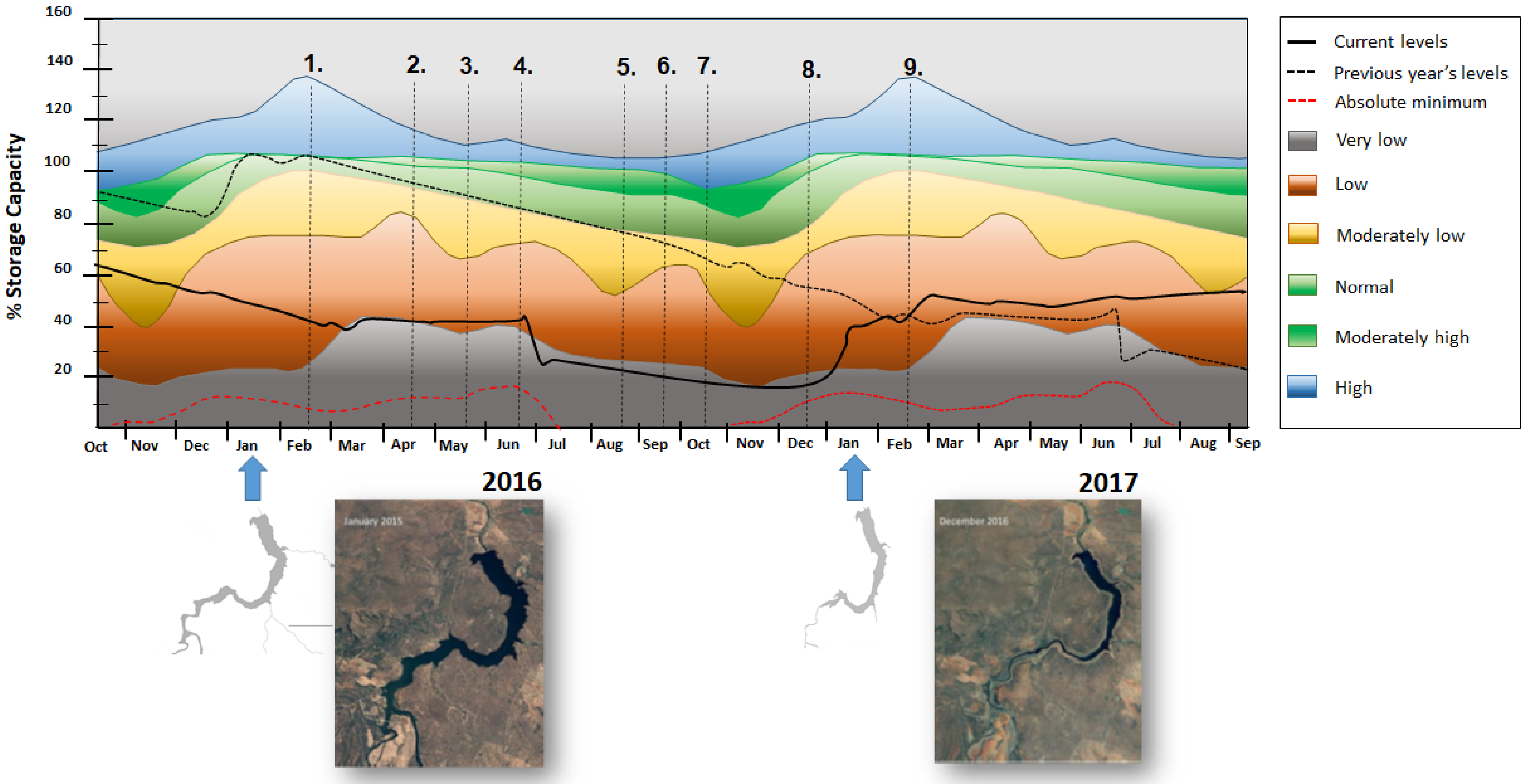

Figure 2.6: The change in storage capacity (%) of Flag Boshielo Dam between April 2016 and February 2017. January of 2016 and 2017 are indicated by the large blue arrows while the various surveys undertaken during this period are indicated by dashed black lines numbered 1 to 9. The continuous black line on the graph reflects the storage capacity (%) for a given month while the brown dotted line indicates the previous year’s level. (Source: https://www.dwa.gov.za/hydrology/weekly/percentile.aspx?station = B5R002; Accessed September 2016 and August 2017). The satellite photos of the impoundment were derived from https://www.google.com/earth/

Table 2.4: The abundance and biomass, expressed as a percentage (%), of fish species collected in Flag Boshielo Dam using gillnets during surveys conducted from February 2016 to February 2017. Abundant species above the 15% threshold considered for an experimental fishery are indicated in blue.

Family	Species	Common name	Abundance (n = 1376 fish)	Biomass (Total = 247.6 kg)
Centrarchidae	*Micropterus salmoides* (Lacepède, 1802)**	Largemouth bass	0.44	1.60
Cichlidae	*Oreochromis mossambicus* (Peters, 1852)	Mozambique tilapia	21.15	22.05
	Coptodon rendalli (Boulenger, 1896)	Redbreast tilapia	0.29	0.19
Clariidae	*Clarias gariepinus* (Burchell, 1822)	Sharptooth catfish	0.65	6.00
Cyprinidae	*Enteromius rapax* Guimaraes, 1884*	Papermouth	0.65	0.41
	Cyprinus carpio Linnaeus, 1758**	Common carp	0.44	0.44
	Labeo rosae Steindachner, 1894	Rednose labeo	58.72	58.69
	Labeobarbus marequensis (A. Smith, 1841)	Lowveld largescale yellowfish	0.44	0.24
Mochokidae	*Synodontis zambezensis* Peters, 1852	Brown squeaker	12.35	6.07
Mormyridae	*Marcusenius pongolensis* (Fowler, 1934)	Bulldog	0.87	0.48
Schilbeidae	*Schilbe intermedius* Rüppell, 1832	Butter catfish	1.09	0.53

(* indicates the genus previously known as *Barbus* see Skelton (2016) and ** indicates alien species

Biological parameters

The length-frequency data for rednose labeo demonstrate that the population distribution of rednose labeo was bimodal (Figure 2.7a), dominated by adult fishes with evidence of recent recruitment. The apparent lack of recent recruitment may be related to the low water levels in the impoundment, or the low river flow, limiting access to the spawning habitat in the river. During the raining season *L. rosae* migrate to the main channel of rivers to spawn on recently flooded plains (Skelton, 2001), and the low dam levels prior to and during this study, in combination with population exploitation and the sampling methods used, may have contributed towards the absence of juvenile rednose labeo in the nets. When water levels in Flag Boshielo Dam are below 30%, access to the main channel of the Olifants and Elands rivers is restricted by weirs that are flooded at higher water levels.

In contrast, Mozambique tilapia displayed a unimodal distribution (Figure 2.7b) with a peak occurring between 150- and 200-mm total length (TL), indicating poor recruitment in recent years. The lack of large individuals in the population may be indicative of fishing pressure and the use of illegal nets targeting larger more aggressive individuals. The length frequency profile does not appear to be indicative of a self-sustaining population driven by internal recruitment processes. However, the presence of largemouth bass in Flag Boshielo Dam may impact *O. mossambicus* recruitment. Bass breed in August and September while *O. mossambicus* breed from October onwards. Therefore, juvenile bass are large enough to feed on the tilapia fry/young when *O. mossambicus* breed.

The length-weight relationship for rednose labeo revealed positive allometric growth ($b = 3.24$; > 3) for the population in Flag Boshielo Dam (Figure 2.7c) indicating that the species becomes more spherical with age. This is higher than the value of 3.10 determined for *L. rosae* from Flag Boshielo Dam in 2013 by Lebepe et al. (2016) and the 3.03 determine for 2009 by Jooste et al. (2014). At the commencement of the study, the b value for *L. rosae* was 2.86 for a sample of 86 specimens measured in February 2016. This low value may be indicative of the extremely low water levels in the months before that survey, possibly indicating that the *L. rosae* population in the reservoir were stressed due to limited food resources. In contrast, Mozambique tilapia displayed negative allometric growth ($b = 2.59$; < 3) (Figure 2.7d). This is considerably lower than the value of 3.13 determined for *O. mossambicus* from Flag Boshielo Dam in 2009 by Addo-Bediako et al. (2014a). At the commencement of the study, the b value for *O. mossambicus* was 2.69 for a sample of 325 specimens measured in February 2016. These low values may be indicative that the *O. mossambicus* population in the reservoir were stressed due to the extremely low water levels in the months before the study, possibly due to limited food resources, but remained stressed through the study. For both species, the length-weight relationships explained more than 90% of the variation in the data; $R^2 = 0.93$ and 0.96 for *L. rosae* and *O. mossambicus*, respectively.

The parameters of the von Bertalanffy growth model, the proportion of sexually mature individuals (ψ; ϕ), the natural mortality rate, and total mortality determined for both rednose labeo and Mozambique tilapia from Flag Boshielo Dam (Table 2.5).

The von Bertalanffy growth models for rednose labeo and Mozambique tilapia are shown (Figure 2.8). The maximum ages recorded in this study were 8 years for rednose labeo and 10 years for Mozambique tilapia.

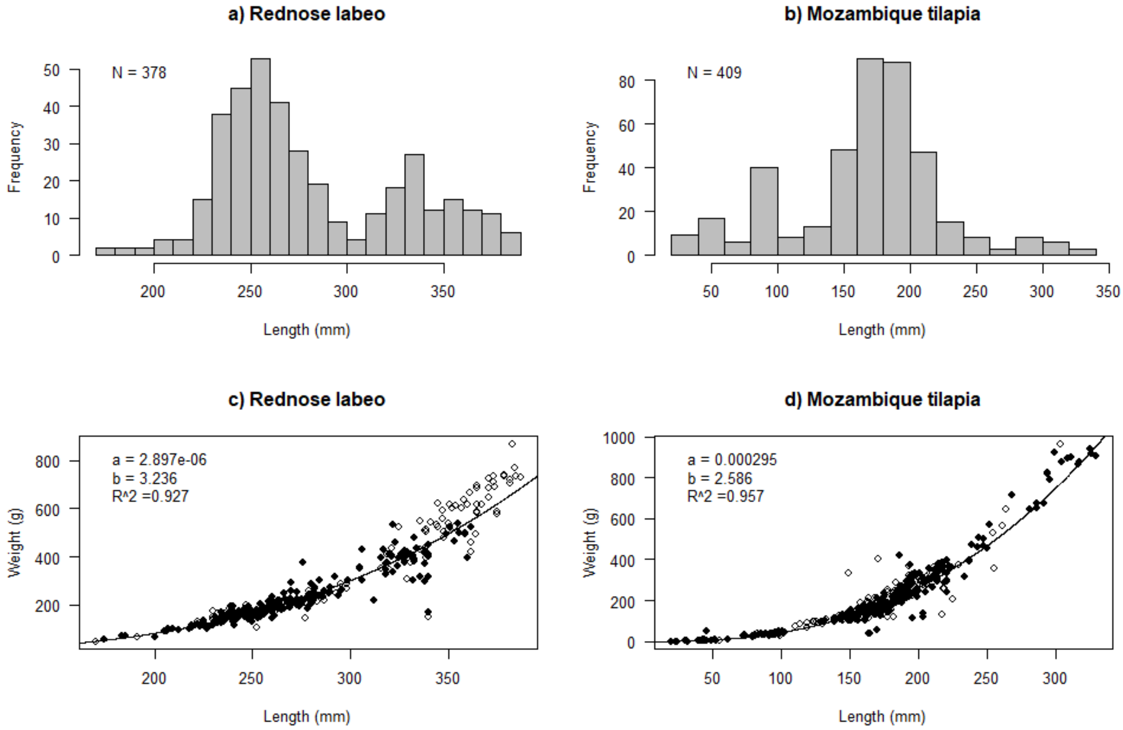

Figure 2.7: The length-frequency distribution for a) *Labeo rosae* and b) *Oreochromis mossambicus* and length-mass relationship c) *Labeo rosae* and d) *Oreochromis mossambicus* collected from Flag Boshielo Dam during surveys conducted from April 2016 to April 2017.

Table 2.5: The biological and fishery parameters established for *Labeo rosae* and *Oreochromis mossambicus* from Flag Boshielo Dam.

Parameters	*L. rosae*	*O. mossambicus*
L_∞ (asymptotic length; mm)	645.3	412.2
K (Brody growth coefficient; yr^{-1})	0.088	0.242
t0 (age of zero length; yr)	-2.174	0.164
a (length-mass parameter; mm)	2.90×10^{-6}	2.95×10^{-4}
b (length-mass parameter; $g.mm^{-1}$)	3.236	2.586
M (natural mortality rate; yr^{-1})	0.548	0.440
ψ (length-at-50% sexual maturity; mm)	234.3	171.5
δ (width of the logistic ogive)	70.2	55.73
ϕ (age-at-50% sexual maturity; yr)	3.35	2.64
σ_m (variance of logistic ogive)	0.292	0.242
t° (mean water temperature, °C)	21.1	21.1
max (maximum age considered; yr)	8.00	10.00
Pauly M (natural mortality rate; yr^{-1})	0.334	0.236
Jensen M (natural mortality rate; yr^{-1})	0.451	0.304

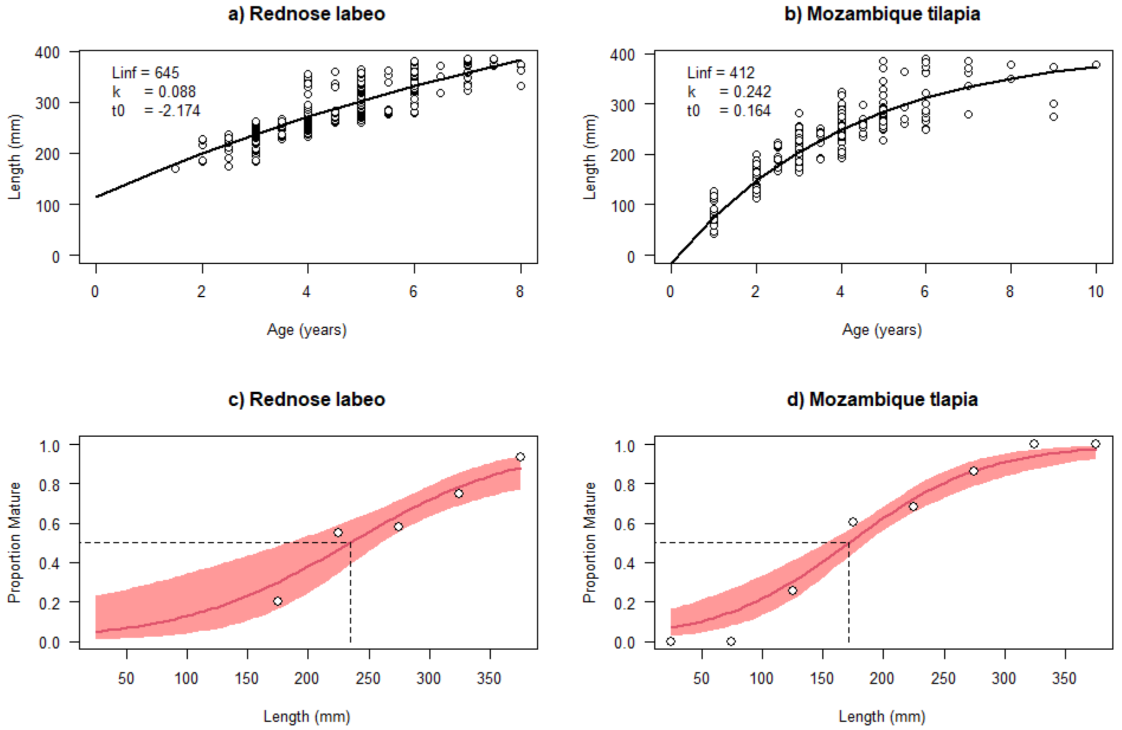

Figure 2.8: The von Bertalanffy growth model determined for a) *Labeo rosae* and for b) *Oreochromis mossambicus* and the female length at 50% maturity of ovaries for c) *Labeo rosae* and for d) *Oreochromis mossambicus* for surveys conducted in Flag Boshielo Dam from February 2016 to February 2017.

Rednose labeo prefers sandy stretches of larger perennial and intermittent rivers, especially warm pools (Gaigher, 1973). The species feeds on detritus, algae, and small invertebrates and reaches sexual maturity at approximately 150 mm TL (Skelton, 2001). All rednose labeo females from Flag Boshielo Dam examined in this study were greater than 170 mm and had at least developing ovaries indicating that they were sexually mature. However, the length at which 50% of the population had mature ovaries (Stages 4 and 5 of Table 2.3) was found to be 300 mm TL at an age of 3.2 years (Table 2.5, Figure 2.8). It should be noted that fish were examined throughout the year and not only in the breeding season. The L_∞ for rednose labeo was estimated at 645 mm, which is considerably greater than the 410 mm TL recorded in Skelton (2001). No rednose labeo greater than 400 mm TL was recorded at Flag Boshielo Dam, therefore, the overestimation of the L_∞ could be related to the lack of specimens smaller than 130 mm TL at this impoundment.

Mozambique tilapia thrive in standing water but are found in all but the fastest waters (Skelton, 2001). Their diet is dependent on their nutrient requirements and the resources available. Juvenile Mozambique tilapia shifts from carnivory to omnivory as they grow, becoming more planktivorous/detritivorous when adults. Adult Mozambique tilapia feed on algae, diatoms, macro-algae, macrophytes, and detritus with larger individuals displaying a dietary shift towards zooplankton, aquatic insects, other invertebrates, and small fishes. The dietary shifts allow this species to survive and thrive in diverse habitats and conditions (Skelton, 2001; Froese and Pauly, 2020). Mozambique tilapia is a euryhaline fish, tolerant of fresh and hypersaline environments (Jubb, 1967; Skelton, 2001) and can survive temperatures as low as 10°C, but prefers warmer conditions above 22°C, to a maximum of 42°C (Froese and Pauly, 2020). The smallest female Mozambique tilapia from Flag Boshielo Dam found with developing ovaries was 70 mm TL. However, the length at which 50% of the population had mature ovaries (Stages 4 and 5 of Table 2.3) was found to be 170 mm TL at an age of 2.6 years (Table 2.5, Figure 2.8). The L_∞ for Mozambique tilapia was estimated at 412 mm, which is consistent with the 400 mm TL recorded in Skelton (2001).

The natural mortality calculated for both species is considerably greater than the empirical values calculated for the aggregated Loskop-Flag Boshielo data using the equations developed by Pauly (1980) and Jensen (1996). For rednose labeo, the natural mortality was estimated to be 0.55 yr^{-1}, while the empirical estimates were nominally 0.45 yr^{-1}. Similarly, the Mozambique tilapia natural mortality was estimated to be 0.44 yr^{-1} while the Pauly and Jensen estimates were 0.24 yr^{-1} and 0.3 yr^{-1}, respectively. Both empirical estimates indicate that the populations of rednose labeo and Mozambique tilapia in Flag Boshielo Dam are being exploited to fishing mortalities of 0.1 yr^{-1} for rednose labeo and between 0.1 and 0.2 yr^{-1} for Mozambique tilapia. It is surprising that rednose labeo is being exploited at a higher rate than the considerably more highly prized Mozambique tilapia. This could be attributed to rednose labeo being harvested at higher rates in the winter months when Mozambique tilapia are scarce (Andre Hoffman, MPTA, pers. com).

Suggested parameters for experimental fishing

The overall mean catch-per-unit effort (CPUE) for rednose labeo was 5.5 kg/100-m net/hr and was significantly different (Kruskal-Wallis P = 0.002) between surveys (Figure 2.9a). The overall mean CPUE calculated for Mozambique tilapia was 1.7 kg/100 m net/hr but was not significantly different (Kruskal-Wallis P = 0.452) between surveys (Figure 2.9b). The post-hoc Dunn test found that the significant result for rednose labeo was as a result of significant differences between the September 2016 CPUE and those for August 2016, October 2016, February 2017 and April 2017, and between June 2016 and April 2017. The highest recorded catch for rednose labeo occurred in April 2016 with one net capturing fish at 64 kg/100 m net/hr, while the highest catches for Mozambique tilapia were recorded in October 2016 when one net captured fish at 8.5 kg/100 m net/hr.

Rednose labeo was recorded in all nets with the highest number of individuals of 170-360 mm TL (mean 256 mm TL, age = 3.6 years) retained in 60 mm mesh nets, 170-280 mm in 44 mm mesh nets (mean 227 mm TL, age = 2.8 years), 169-328 mm in 70 mm mesh nets (260 mm TL, age = 3.7 years), 180-370 mm in 100 mm mesh nets (261 mm TL, age = 3.7 years), and 291-365 mm TL specimens in 144 mm mesh nets (mean 318 mm TL, age = 5.5 years).

Mozambique tilapia was recorded in all nets with the highest number of individuals of 123-324 mm TL (mean 209 mm TL, age = 3.1 years) retained in 60 mm mesh nets, 16-260 mm in 44 mm mesh nets (mean 115 mm TL, age = 1.5 years), 125-374 mm in 70 mm mesh nets (219 mm TL, age = 3.3 years), 185-300 mm in 100 mm mesh nets (256 mm TL, age = 4.2 years), and 182-370 mm TL specimens in 144 mm mesh nets (mean 263 mm TL, age = 4.4 years).

Based on the CPUE for rednose labeo and Mozambique tilapia caught in the respective mesh sizes and their ages at maturity, we recommend that nets with mesh sizes greater than 144 mm are optimal to sustain a fishery for rednose labeo in Flag Boshielo Dam (Figure 2.10), whereas mesh sizes greater than 70 mm are optimal to sustain a fishery for Mozambique tilapia (Figure 2.10). However, based on the CPUE data for the respective mesh sizes, and considering that the estimated age at maturity for rednose labeo is an over-estimate because of the absence of fish smaller than 130 mm in the samples and that the species co-occur in the impoundment, it is suggested that a mesh size of 100 mm may be acceptable and the suitability tested for an experimental fishery in Flag Boshielo Dam targeting both rednose labeo and Mozambique tilapia.

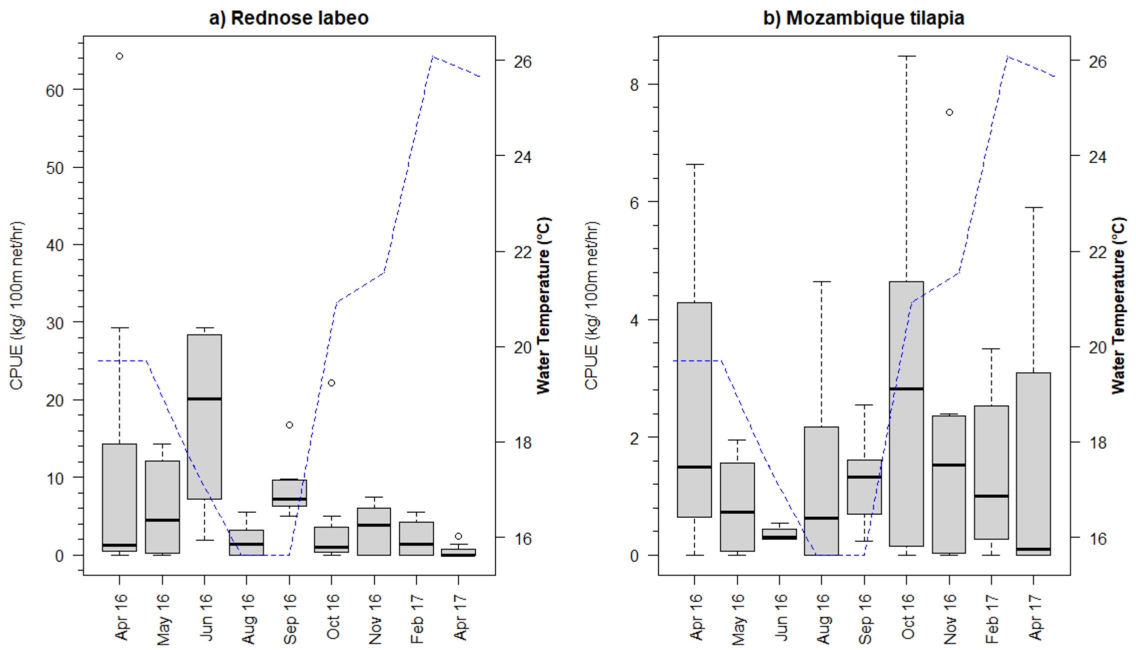

Figure 2.9: The catch-per-unit effort (CPUE) for a) *Labeo rosae* and b) *Oreochromis mossambicus* from Flag Boshielo Dam during surveys conducted from April 2016 to April 2017. The mean water temperature is indicated by the blue dotted line.

The low CPUE for both species in the 44 mm mesh size is a further indication of the lack of recent recruitment in the population, possibly due to a combination of low water levels, illegal netting and predatory fish in the impoundment. Excluding this mesh size, the CPUE for both target species is shown to decrease with an increase in mesh size (Figure 2.10). An outcome attributed to both species' populations being skewed due to the lack of large adult fish; a phenomenon caused when older mature specimens are being overfished. Using only the 100- and 144-mm mesh sizes, the CPUE for the fishery would be 0.324 kg/100-m net/hr for rednose labeo and 0.466 kg/100-m net/hr for Mozambique tilapia.

By-catch is an important consideration when considering the establishment of a fishery. Nine species were captured as by-catch in the surveys. In addition to the target species of rednose labeo and Mozambique tilapia, African sharptooth catfish *Clarias gariepinus*, silver catfish *Schilbe intermedius*, brown squeaker *Synodontis zambezensis*, papermouth *Enteromius rapax*, largescale yellowfish *Labeobarbus marequensis*, common carp *Cyprinus carpio*, redbreast tilapia *Coptodon rendalli*, Pongola bulldog *Marcusenius pongolensis*, and largemouth bass *Micropterus salmoides* were captured in the gillnet surveys.

Considering only the 100- and 144-mm mesh sized, four species recorded in this study would be caught as bycatch; African sharptooth catfish, brown squeaker, common carp, and largemouth bass. Common carp and largemouth bass are alien fish species in the Olifants River system and, therefore, of no conservation value. These two species are, however, of considerable importance to recreational fishermen who contribute to the economy of the area in numerous ways. Common carp is also one of the preferred target species of subsistence fishers that frequent the open-access banks of the lake. Other alien species known to occur in the lake, and captured in previous gillnet studies (Brits, 2006;

Sara et al., 2017b), but not recorded in the current study, are silver carp *Hypophthalmichthys molitrix* and grass carp *Ctenopharyngodon idella*, both alien species in the Olifants River system. Both species grow to a large size attaining more the 1 m in length (Skelton, 2001) and the silver carp has been abundant at times. However, mortalities of larger individuals have resulted in the local communities choosing not to eat this species because they think the mortalities indicate that there is something wrong with the species (Sara et al., 2018). Studies have not yet clearly identified the cause for the mortalities of the larger silver carp, but it is suspected that the productivity of the dam lake is not sufficient to support the larger individuals (Sara et al., 2018). Because catch rates for silver carp are low with the gear used in this study, there is scope to explore larger mesh sizes, or explore other capture techniques, to try and define the population structure of silver carp in Flag Boshielo Dam to determine whether it could support exploitation.

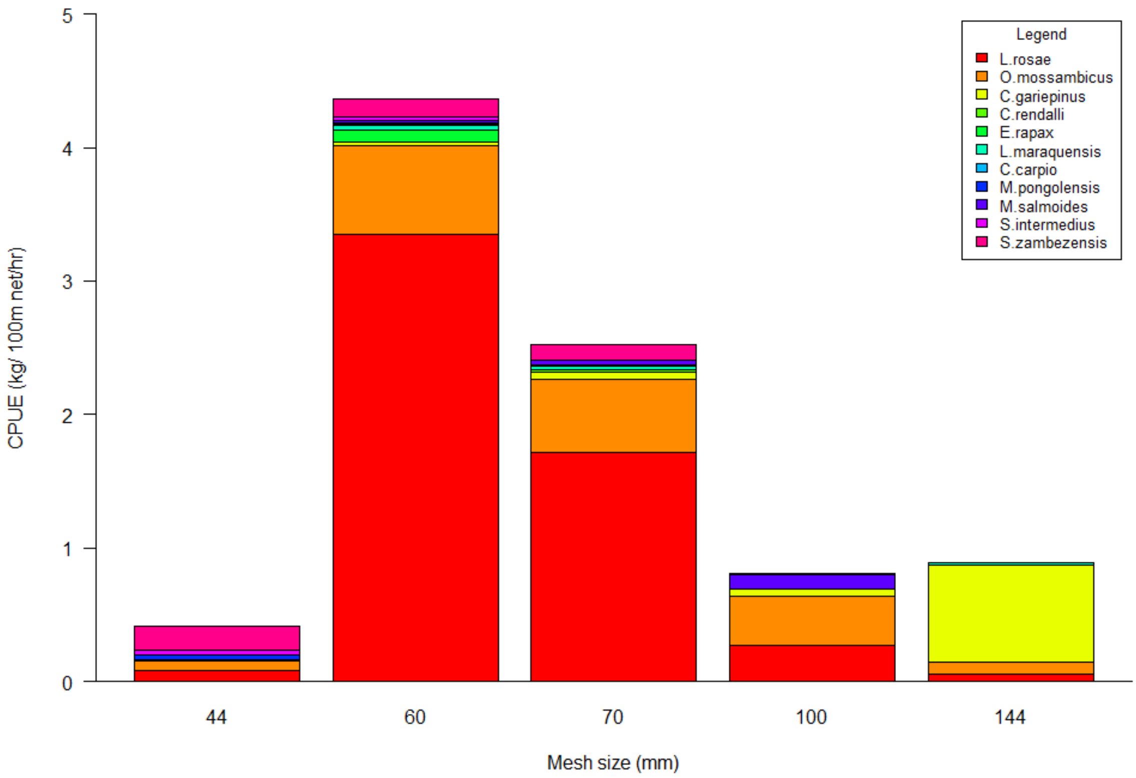

Figure 2.10: The catch-per-unit effort (CPUE) for target species, rednose labeo and Mozambique tilapia, and by-catch for the respective mesh sizes of the gillnets used in Flag Boshielo Dam.

The combined by-catch CPUE for the proposed mesh sizes is 0.917 kg/100-m net/hr, which exceeds the CPUE for the target species. The by-catch is dominated by African sharptooth catfish, the CPUE of which was 0.774 kg/100-m net/hr, in itself, equivalent to the combined CPUE for the two target species (Figure 2.10). The species constituted less than 0.7% of the abundance, but due to the large size of the individuals, the species made up 6% of the biomass of the total catches. Sharptooth catfish could form the basis of a fishery, but the current population levels are unlikely to support exploitation, and the species' population would require careful management, and possibly supplementation.

There are several native fish species whose populations in the impoundment may be threatened by the establishment of a fishery. In particular, the papermouth *Enteromius rapax*, smallscale yellowfish *Labeobarbus polylepis*, largescale yellowfish *Labeobarbus marequensis*, and leaden labeo *molybdinus* are of a similar size as the two target species and the larger adults of these populations may be harvested as by-catch in the fishery. There is clear evidence of the populations of all of these species declining from the population levels during the study conducted by Brits (2006), who collected his data between 1998 and 2000. By the time of the study by Sara et al. (2017), there was clear evidence that the populations of the aforementioned larger cyprinids were in decline. Of these four cyprinids, only small papermouth and largescale yellowfish were recorded in the current study. Neither smallscale yellowfish, leaden labeo, or redeye labeo *Labeo cylindricus* Peters, 1852 recorded by Brits (2006) and Sara et al. (2017), were recorded in the current study. While these cyprinids may have been considered to be of Least Concern in the most recent IUCN Red List assessment, papermouth populations are not reported frequently (Marr, 2017) and could be more at risk.

A second conservation issue that will need to be considered in establishing a fishery at Flag Boshielo Dam is the potential for conflict over the presence of crocodiles in the impoundment. The majority of the current gillnet fishers operating at Flag Boshielo Dam wade into the dam lake to set their nets. In addition, a small number of the nets set in the current study showed evidence of crocodiles feeding on the fish captured in the gill nets. Therefore, the nets deployed in this study were constantly monitored to reduce the risk of crocodiles becoming entangled when scavenging fish trapped in the nets. To reduce the accidental capture of crocodiles, only composite gill nets made with natural fibres should to be used and monitored when crocodiles are present.

2.4.2. Loskop Dam Fisheries assessment

Loskop Dam was surveyed intensively over two weeks during September/October 2017. Due to the profile of the impoundment, and the presence of a small population of crocodiles, gill, fyke, and seine nets were used. At the time of sampling, the dam level was at approximately 60% of full capacity. A total of 1392 specimens, consisting of 15 species belonging to six families, were collected using gill, fyke, and seine nets (Table 2.6). The total catch included two alien and invasive species; common carp and largemouth bass. However, the large number of bass collected in this study was in contrast to previous surveys (Andre Hoffman, MPTA, pers. com). For gillnets, a Shannon-Weiner diversity (H') of 0.81 and an Evenness (J') of 0.70 were calculated, for fyke nets an H' of 0.64 and a J' of 0.75, and for seine nets an H' of 0.44 and a J' of 0.04.

Catch composition

The catch composition in gill and seine nets was dominated by Mozambique tilapia (Table 2.6). The African sharptooth catfish dominated fyke net catches followed by Mozambique tilapia and rednose labeo (Table 2.6). Sharptooth catfish caught in fyke nets were predominantly large adult specimens that contributed considerably to the total biomass recorded. The Mozambique tilapia, followed by river sardine *Engraulicypris brevianalis* (Boulenger, 1908) was the most abundant species in the seine net treks, comprising 66.9%, and 21.3% of the catch, respectively. Because of their small size, river sardine only contributed 0.3% to the total biomass of the seine net treks. Based on the catch composition of all gears, rednose labeo and Mozambique tilapia were the species most abundant.

Table 2.6: The catch composition based on percentage (%) abundance and biomass of fish species collected using gill, fyke and seine nets during a rapid fishery assessment conducted at Loskop Dam in September/November 2017. Abundant species above the 15% threshold is indicated in blue.

Family	Species	Sampling Method Used					
		Gill Nets		Fyke Nets		Seine Nets	
		Abundance (n = 376 fish)	Total Biomass (297.58 kg)	Abundance (n = 44 fish)	Total Biomass (63.1 kg)	Abundance (n = 764 fish)	Total Biomass (79.9 kg)
Mormyridae	*Marcusenius pongolensis* (Fowler, 1934)	1.6	0.1	-	-	-	-
Cyprinidae	*Engraulicypris brevianalis* (Boulenger, 1908)‡	-	-	-	-	21.34	0.28
	Enteromius rapax Guimaraes, 1884*	3.5	0.6	2.3	0.0	0.13	0.01
	Enteromius unitaeniatus (Günther, 1866)	-	-	2.3	0.0	-	-
	Cyprinus carpio Linnaeus, 1758**	-	-	-	-	0.39	3.19
	Labeo molybdinus du Plessis, 1963	5.3	2.4	-	-	-	-
	Labeo rosae Steindachner, 1894	14.9	14.0	22.7	2.8	6.81	6.98
	Labeobarbus marequensis (A. Smith, 1841)	10.6	3.1	2.3	1.8	-	-
Alestidae	*Micralestes acutidens* (Peters, 1852)	-	-	-	-	1.57	0.07
Clariidae	*Clarias gariepinus* (Burchell, 1822)	5.3	14.6	34.1	80.8	-	-
Mochokidae	*Synodontis zambezensis* Peters, 1852	0.8	0.1	-	-	-	-
Schilbeidae	*Schilbe intermedius* Rüppell, 1832	13.3	3.6	4.5	0.5	-	-
Centrarchidae	*Micropterus salmoides* (Lacepède, 1802)**	1.6	2.0	-	-	0.26	6.63
Cichlidae	*Pseudocrenilabrus philander* (Weber, 1897)	-	-	-	-	0.65	0.01
	Oreochromis mossambicus (Peters, 1852)	40.2	57.4	31.8	14.1	66.88	79.92
	Coptodon rendalli (Boulenger, 1896)	2.9	2.2	-	-	1.96	2.90

‡ indicates the genus previously known as *Mesobola sensu* Riddin et al. (2016); * indicates the genus previously known as *Barbus* see Skelton (2016) where ** indicates alien and invasive species.

Biological parameters
The length-frequency analysis of rednose labeo gillnet catches demonstrated the population to be bimodal in its distribution, dominated by specimens 200-300 mm TL (Figure 2.11). Signs of limited recruitment for this species was evident as individuals sampled in fyke and seine nets were reported to have a mean TL of 186 (SD ± 113) mm and TL of 135 (SD ± 94) mm, respectively. An outcome possibly attributed to the period when the survey was done as one can expect to find juveniles in the various sampling gear used during early and late summer after the species have successfully spawned. The population distribution of labeo from Loskop Dam can be categorised as casual with recruitment dependent on inflowing rivers. All but one of the rednose labeo were captured at one site, the Olifants River inlet to the dam lake. The concentration of rednose labeo close to the Olifants River inlet likely indicates a staging of the population for a spawning migration into the river habitats and onto sandy flats in the dam. This aggregation of rednose labeo increases the risk that the population being targeted at migration staging areas, or on their spawning migrations, potentially irrevocably harming the population. Reports of migrating cyprinids being targeted at fishways in the north of Limpopo (Paul Fouché *op. cit.*) and spawning aggregations of smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822) being targeted at the inlets of Sterkfontein Dam (Yellowfish Working Group *op cit.*) highlight that the practice of targeting staging or migrating fish could be widespread in South Africa.

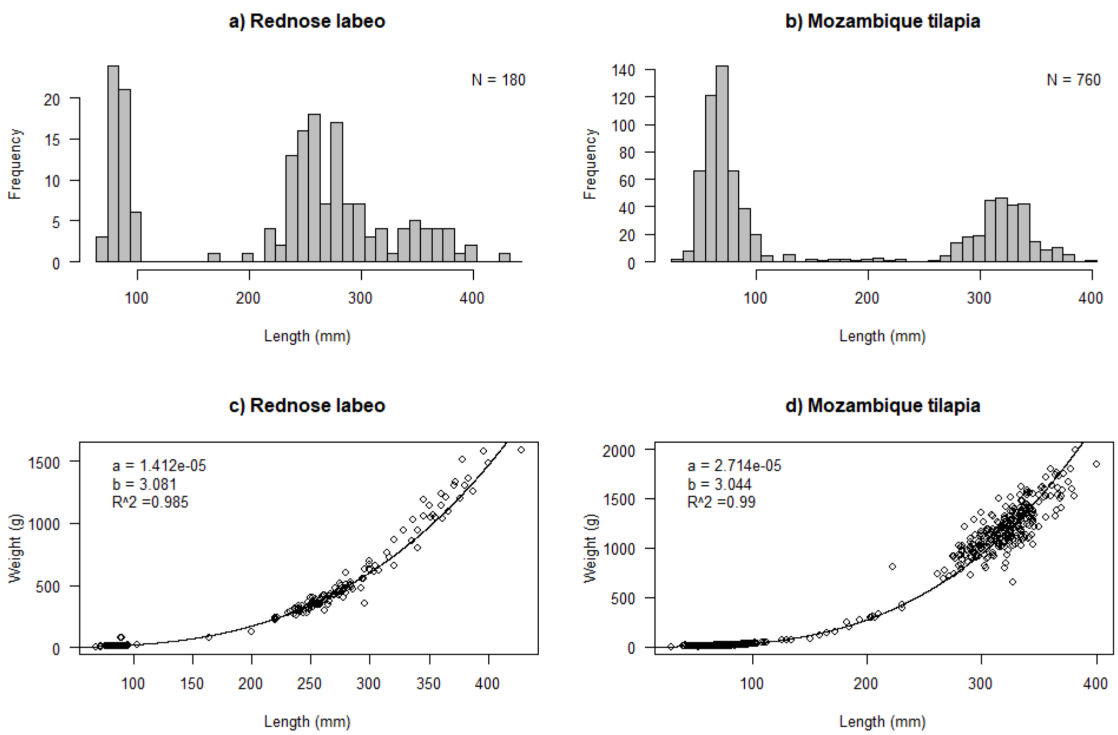

Figure 2.11: The length-frequency distributions for a) *Labeo rosae* and b) *Oreochromis mossambicus* and length-mass relationships for c) *Labeo rosae* and d) *Oreochromis mossambicus* determined from specimens sampled during a rapid fishery assessment conducted in Loskop Dam during September/November 2017.

The population structure of Mozambique tilapia based on all catches revealed the species distribution is dominated by a high number of large individuals of 300-400 mm TL and even a greater number of small individuals (Figure 2.11b). A large number of juvenile Mozambique tilapia with a mean TL of 114 (SD ± 91) mm captured in seine nets is evidence of a self-sustaining population driven by internal recruitment processes. Mozambique tilapia was found at all five sites surveyed in Loskop Dam. Mozambique tilapia do not have spawning migrations and breed in still or slow-flowing reaches of pools. In impoundments, Mozambique tilapia breed in the shallower margins.

The relationship between the length and the live mass of rednose labeo and Mozambique tilapia from Loskop Dam provided an $R^2 > 0.97$ for both species (Figure 2.11). The length-weight relationship for rednose labeo revealed positive allometric growth (b = 3.08; > 3) for the population in Loskop Dam (Figure 2.11c) indicating that the species becomes more spherical with age. This is considerably higher than the value of 2.82 determined for rednose labeo from Loskop Dam in 2013 by (Lebepe et al., 2016). Mozambique tilapia also displayed positive allometric growth (b = 3.04; > 3; Figure 2.11d). This is lower than the value of 3.12 determined for *O. mossambicus* from Loskop Dam in 2013 by (Lebepe et al., 2020a). Larger adult rednose labeo and Mozambique tilapia were recorded for Loskop Dam than in Flag Boshielo Dam. This can be attributed to Loskop Dam being a more established impoundment with lower water level fluctuations and higher primary productivity than Flag Boshielo Dam, in addition to Loskop Dam falling within a conservation area with limited public access and where fish harvesting is prohibited. Moreover, the consumption of Mozambique tilapia from Loskop Dam is discouraged because the risk associated with humans consuming fish affected with pansteatitis is currently unknown.

The parameters of the von Bertalanffy model for both rednose labeo and Mozambique tilapia from Loskop Dam are presented in Figure 2.12 and Table 2.7. The maximum ages recorded for rednose labeo and Mozambique tilapia from Loskop Dam were 10 and 11 years, respectively. Female rednose labeo from Loskop Dam reach sexual maturity, the length at which 50% of the population had mature ovaries (Stages 4 and 5 of Table 2.3), at 4.5 years and 180 mm TL (Table 2.7), which was much older and smaller than the 300 mm TL at 3.2 years found for Flag Boshielo Dam. This is also considerably larger than the approximately 150 mm TL at reaching sexual maturity reported by Skelton (2001). The largest immature specimen was 131 mm and the smallest specimen displaying any stages in the development of the ovaries was 276 mm, possibly explaining the large uncertainty in the estimation of the length/age at sexual maturity.

The L_∞ for rednose labeo was estimated at 545 mm, which is also considerably greater than the 410 mm TL recorded in Skelton (2001). Very few rednose labeo greater than 400 mm TL were recorded at this impoundment, therefore, the overestimation of the L_∞ could be related to the lack of specimens 130 to 230 mm TL range in the surveys. For Mozambique tilapia in Loskop Dam, sexual maturity is obtained in individuals 2.4 years old having 124 mm TL (Table 2.7; Figure 2.12d). The L_∞ for Mozambique tilapia was estimated at 451 mm, which is higher than the 400 mm TL recorded in Skelton (2001).

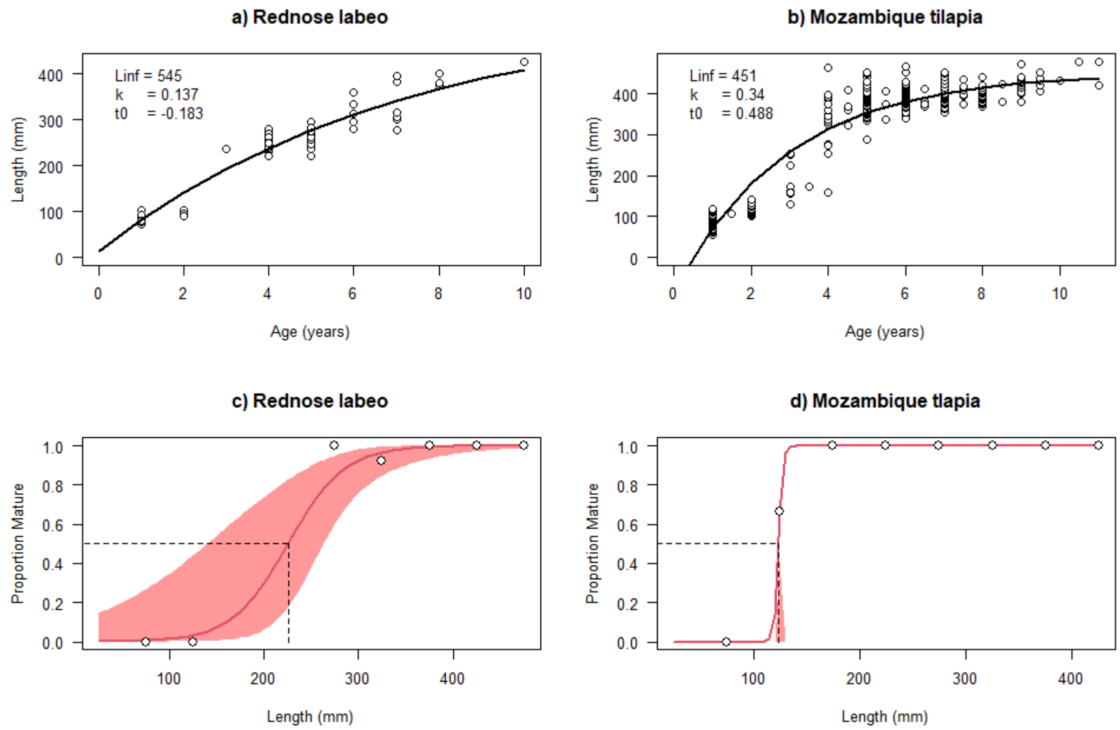

Figure 2.12: The von Bertalanffy growth model determined for a) *Labeo rosae* and for b) *Oreochromis mossambicus* and the female length at 50% maturity of ovaries for c) *Labeo rosae* and for d) *Oreochromis mossambicus* for surveys conducted at Loskop Dam during October/November 2017.

Table 2.7: The biological and fishery parameters established for *Labeo rosae* and *Oreochromis mossambicus* from Loskop Dam.

Parameters	*L. rosae*	*O. mossambicus*
L_∞ (asymptotic length; mm)	545	451
K (Brody growth coefficient; yr^{-1})	0.137	0.340
t_0 (age of zero length; yr)	-0.183	0.488
a (length-mass parameter; mm)	1.412×10^{-5}	2.714×10^{-5}
b (length-mass parameter; $g.mm^{-1}$)	3.081	3.044
M (natural mortality rate; yr-1)	0.440	0.401
ψ (Length-at-50% sexual maturity; mm)	225.5	123.6
δ (width of the logistic ogive)	29.9	1.98
ϕ (age-at-50% sexual maturity; yr)	4.50	2.35
σ_m (variance of logistic ogive)	0.568	1.32
t° (mean water temperature, °C)	21.5	21.5
max (maximum age considered; yr)	10.00	11.00
Pauly M (natural mortality rate; yr^{-1})	0.334	0.236
Jensen M (natural mortality rate; yr^{-1})	0.451	0.304

For rednose labeo, the natural mortality was estimated to be 0.44 yr^{-1}, while the empirical estimates were 0.45 yr^{-1} based on the equations developed by Pauly (1980) and Jensen (1996) for the aggregated Loskop-Flag Boshielo data. Similarly, the Mozambique tilapia natural mortality was estimated to be 0.40 yr^{-1} while the Pauly and Jensen estimates were 0.24 yr^{-1} and 0.30 yr^{-1}, respectively. The empirical estimates suggest that the Loskop Dam populations of rednose labeo are healthy, while the health and survival of Mozambique tilapia are potentially being impacted by pollution and pansteatitis to the level equivalent to a fishing mortality of 0.1 yr^{-1}.

For the most part, anglers who frequent this impoundment practice a policy of capture and release. In addition, the high numbers and larger specimens may be as a result of a large section of the river zone near the Olifants River inlet being cordoned off to the public, with entrance to this area strictly controlled by MTPA staff. This area provides a haven for fish to spawn during the breeding season.

Experimental fishing

Based on the population structure of both rednose labeo and Mozambique tilapia, there is evidence suggesting recruitment failure of both species over one or more seasons; evidenced by a gap in the size structure of both populations. This suggests that both species have ageing populations. The size structure of rednose labeo above 200 mm displays a Poisson like distribution indicating regular recruitment to the population in previous seasons. Similarly, for Mozambique tilapia, the majority of the population is between 280 and 400 mm, with very few individuals between 100 and 280 mm. Both species show evidence of being ageing populations with protracted recruitment failure (possibly 3 to 4 successive years). Exploitation of such populations could easily result in the extirpation of these populations at Loskop Dam and, therefore, we recommend that no exploitation of either species at Loskop Dam be considered without clear evidence of consistent annual recruitmen**t**. The results of the experimental fishery at Loskop Dam are presented here for completeness and because the Loskop Dam data were used to augment Flag Boshielo Dam experimental fishery data to estimate the dynamics of an unexploited fishery for the two species under consideration.

The overall mean catch-per-unit effort (CPUE) for rednose labeo at Loskop Dam was 10.1 kg/100-m net/hr. The overall mean CPUE calculated for Mozambique tilapia was 28.4 kg/100 m net/hr. These CPUE values are considerably higher than those obtained for Flag Boshielo Dam. The reason for the disparity between the two impoundments could be related to the Loskop Dam populations of both species being protected within a conservation area while there is considerable exploitation of the Flag Boshielo Dam populations of both species. Rednose labeo were only captured in gill nets at one site in the transition to the riverine section at the Olifants River inlet to the dam lake. This could be an indication that the fish sampled were staging for a spawning migration into the riverine habitats, while the juveniles were in a different habitat, as indicated by the abundance of young-of-year and juveniles captured using fyke and seine nets. Overall, the CPUE for both target species shows an increase with an increase in mesh size (Figure 2.13). An outcome attributed to both species' populations being skewed towards an abundance of large adult fish; a result of the protection of the fish populations from exploitation in the conservation area and putative recruitment failure for an extended period. Using only the 100- and 144-mm mesh sizes, the CPUE for the fishery would be 6.907 kg/100-m net/hr for rednose labeo and 27.138 kg/100-m net/hr for Mozambique tilapia. However, we reiterate our strong recommendation that no fishery be considered for Loskop Dam since a more comprehensive understanding of the recruitment dynamics for both species is needed and because Loskop Dam is located within a conservation area.

Rednose labeo was recorded in all nets with the highest number of individuals of 276-439 mm TL (mean 344 mm TL, age = 7.1 years) retained in 70 mm mesh nets and 338-469 mm in 100 mm mesh nets (415 mm TL, age = 10.3 years), 199-242 mm in 44 mm mesh nets (mean 220 mm TL, age = 3.6 years), 330-347 mm TL in 60 mm mesh nets (mean 340 mm TL, age = 7.0 years), and 370-584 mm TL specimens in 144 mm mesh nets (mean 469 mm TL, age = 14.2 years).

Mozambique tilapia was recorded in all nets with the highest number of individuals of 334-480 mm TL (mean 398 mm TL, age = 6.8 years) retained in 144 mm mesh nets, 79-160 mm in 44 mm mesh nets (mean 128 mm TL, age = 1.5 years), 158-380 mm in 60 mm mesh nets (271 mm TL, age = 3.3 years), 78-453 mm in 70 mm mesh nets (290 mm TL, age = 3.5 years), and 83-449 mm TL specimens in 100 mm mesh nets (mean 359 mm TL, age = 5.2 years).

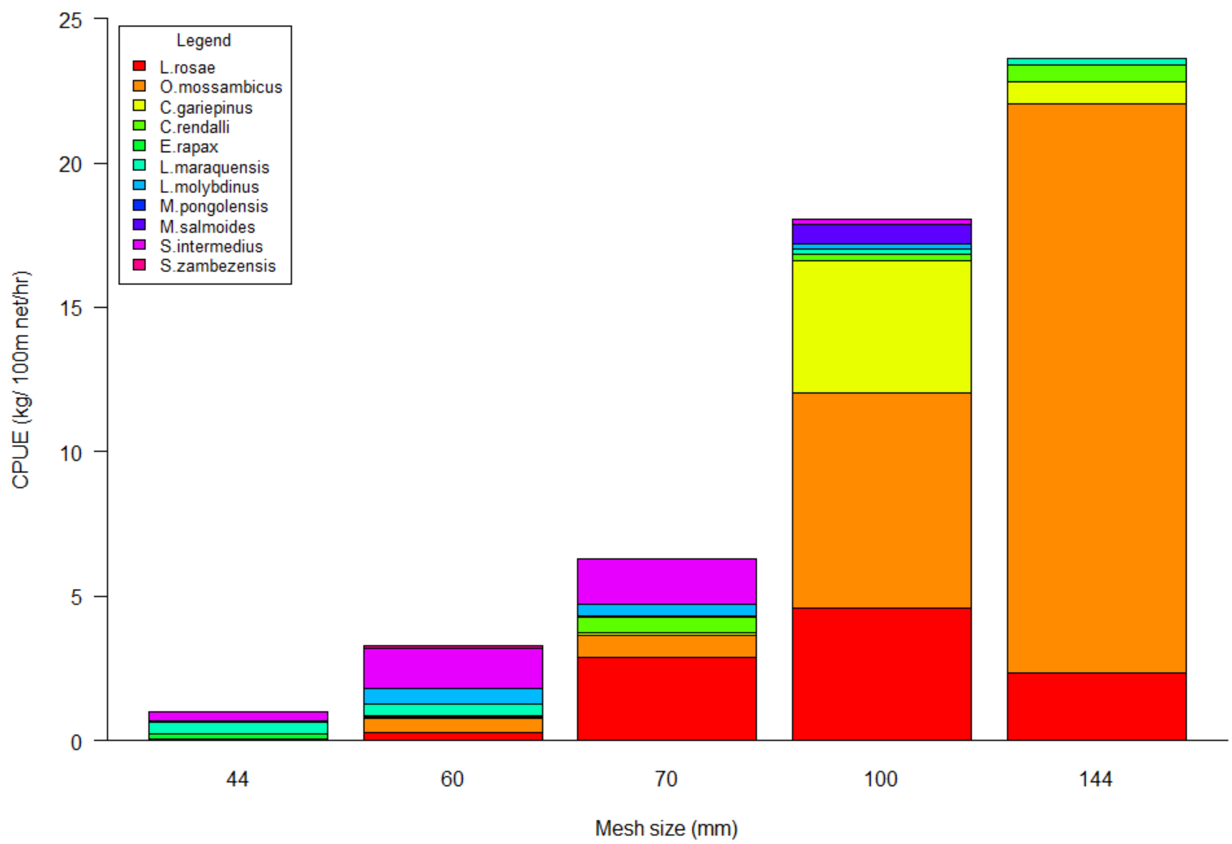

Figure 2.13: Experimental catch-per-unit effort (CPUE) for target species, rednose labeo and Mozambique tilapia, and by-catch for the respective mesh sizes of the gillnets used in Loskop Dam.

The experimental CPUE (kg/100 m – net/hr) for a hypothetical fishery targeting rednose labeo and Mozambique tilapia stocks in Loskop Dam increases with increased mesh size (Figure 2.13), although, there is a drop off in CPUE from the 100- to 144-mm mesh size. This is due to the body depth of the two species, with Mozambique tilapia having a deeper body than rednose labeo. In this scenario older specimen contribute the most towards the total biomass whereby smaller mesh sizes, e.g. 44, 60, and 70 mm are to be excluded to allow for fish stock populations to recover from fishing pressure.

Nine species were captured as by-catch in the gillnet surveys. In addition to the target species of rednose labeo and Mozambique tilapia, African sharptooth catfish, silver catfish, brown squeaker, papermouth, smallscale yellowfish, leaden labeo *Labeo molybdinus*, redbreast tilapia, Pongola bulldog, and largemouth bass were captured in the gillnet surveys. Considering only the 100- and 144-mm mesh sized, six species recorded in this study were caught as bycatch; viz. African sharptooth catfish, silver catfish, largescale yellowfish, leaden labeo, redbreast tilapia, and largemouth bass. Common carp and largemouth bass are listed as alien and invasive fish species and are known to occur in Loskop Dam. The gillnet surveys did not detect the presence of common carp, although this species was captured using seine nets. Although these two alien species are of considerable importance to recreational fishermen, who contribute to the economy of the area in numerous ways, conservation authorities recommend that these species be removed from the aquatic environment when caught.

The combined by-catch CPUE for the 100- and 144-mm mesh sizes is 7.624 kg/100-m net/hr, which exceeds the total CPUE for all mesh sizes for the target species in Flag Boshielo Dam. The by-catch was dominated by African sharptooth catfish, the CPUE of which was 5.397 kg/100-m net/hr (Figure 2.13), in itself, equivalent to the total CPUE for the combined catch of two target species in Flag Boshielo Dam. The species constituted less than 0.7% of the abundance, but due to the large size of the individuals, the species made up 6% of the biomass of the total catches. Sharptooth catfish could form the basis of a fishery, but the current population levels are unlikely to support the exploitation and the species' population would require careful management.

2.4.3. Pongolapoort Dam fisheries assessment

The survey of Pongolapoort Dam was conducted in November 2017. During the survey, the conditions on the water were difficult with strong winds generating precarious conditions on the lake some of the days. The lake is very deep and all but one of the sides has steep drop-offs, making the deployment of the gill- and fyke nets difficult. This particularly in the gorge section of the dam where the drop-off along the water margin is steep. The lake also has considerable populations of crocodiles and hippos; the hippos in particular are renowned for their aggressive nature towards motorboats. The conditions and short duration of the fisheries assessment of Pongolapoort Dam did not provide a representative assessment of the fish stocks of the impoundment.

From Pongolapoort Dam, a total of 40 specimens, 4 species from 3 families, were captured using gill, fyke, and seine nets. During the assessment, five tigerfish with a mean TL of 197 mm and a mean mass of 49.52 g were captured using gill nets. In addition, 35 specimens (4 species) were caught using fyke nets. Catch composition based on the percentage biomass for fish caught in fyke nets was 77% for tigerfish (n=27), 9% for Mozambique tilapia (n=3), 8% for redbreast tilapia *Coptodon rendalli* (n=3), and 6% for the tank gobby *Glossogobius giuris* (Hamilton-Buchanan, 1822) (n=2).

2.4.4. Initial harvest strategy for Mozambique tilapia and rednose labeo in Flag Boshielo Dam

Net selectivity

Based on the combined length-frequency data the population distribution of rednose labeo is shown to be unimodal and dominated by individuals between 180 to 220 mm TL (Figure 2.14). There appears to be limited recruit and the absence of large individuals is evident. Conversely, Mozambique tilapia displays a full population structure having a distinct tri-modal distribution with peaks occurring at 150, 200, and 400 mm total length (TL), indicative of a self-sustaining population driven by internal recruitment processes (Figure 2.15). A clear distinction between rednose labeo size and the mesh used was noted (Figure 2.14). The highest relative retention was established for 180-220 mm TL individuals using 60 mm stretch mesh gillnets. No retention of specimens was observed in nets having mesh sizes of 44 and 144 mm. An overlap between Mozambique tilapia size and mesh size occurred (Figure 2.15). Mozambique tilapia was recorded in all nets with the highest number of individuals of 120-180 mm TL retained in 60 mm mesh nets, 180-220 mm in 70 mm mesh nets, and 370-420 mm TL specimens in 144 mm mesh nets.

Per recruit analysis

Yield-per-recruit (YPR) and spawner biomass-per-recruit (SBR) models were used to recommend initial harvest strategies for *Labeo rosae* and *Oreochromis mossambicus* to maximise yield (from a per recruit perspective) while minimising the risk of stock collapse through maintaining SPR to at least 25% of unfished levels. To provide generalised input parameters for the models' biological datasets derived from the two separate assessments were aggregated into a single biological dataset. This is realistic as the two reservoirs are close to one another, less than 80 km apart, lie in similar climatic areas, and biological estimates for growth and maturity were similar for the two target species in the two localities (See sections 2.4.1 and 2.4.2).

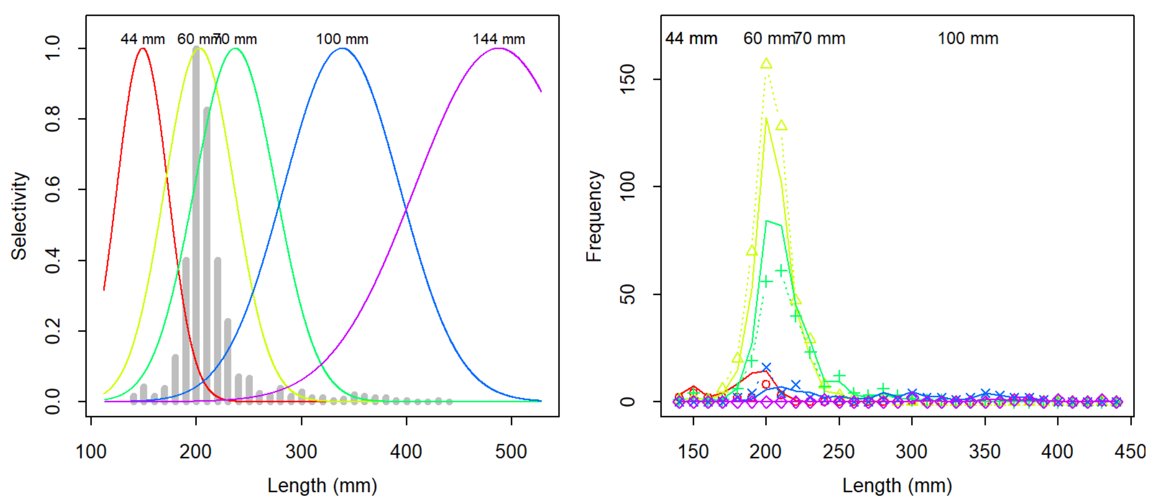

Figure 2.14: The net selectivity and frequency with total length (mm) for *Labeo rosae* based on aggregated data from Flag Boshielo and Loskop dams.

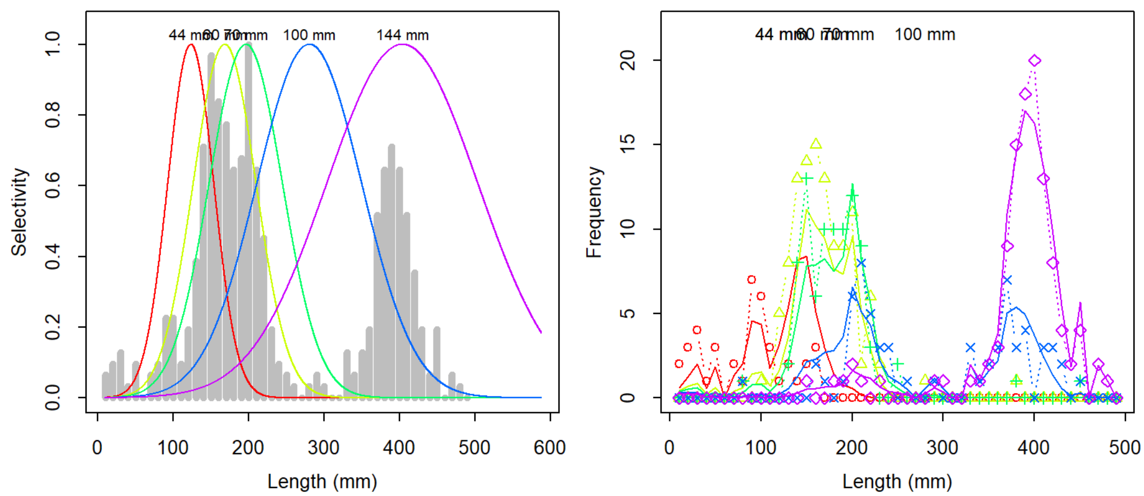

Figure 2.15: The net selectivity and frequency with total length (mm) for *Oreochromis mossambicus* based on aggregated data collected from Flag Boshielo and Loskop dams.

The aggregated parameters of the von Bertalanffy model for both rednose labeo and Mozambique tilapia from Loskop and Flag Boshielo dams are presented in Figure 2.16 and Table 2.8. The maximum ages recorded for rednose labeo and Mozambique tilapia were 10 and 11 years, respectively. Female rednose labeo reach sexual maturity at 3.4 years and 238 mm TL (Table 2.8; Figure 2.16c). The largest immature specimen was 131 mm and the smallest specimen displaying any stages ovary development was 170 mm. The L_∞ for rednose labeo was estimated at 403 mm, which is equivalent to the 410 mm TL recorded in Skelton (2001). Very few rednose labeo greater than 400 mm TL were recorded in this study, therefore, the estimate of the $L_\infty$from the combined data appears to represent maximum length for this species.

Table 2.8: The biological and fishery parameters established for *Labeo rosae* and *Oreochromis mossambicus* from aggregated data from Flag Boshielo and Loskop dams.

Parameters	*L. rosae*	*O. mossambicus*
L_∞ (asymptotic length; mm)	403	539
K (Brody growth coefficient; yr^{-1})	0.282	0.188
t_0 (age of zero length; yr)	0.062	0.266
a (length-mass parameter; mm)	2. 713 x 10^{-5}	1.819 x 10^{-4}
b (length-mass parameter; $g.mm^{-1}$)	2.963	2.689
ψ (Length-at-50% sexual maturity; mm)	236.4	169.1
δ (width of the logistic ogive)	52.9	48.4
ϕ (age-at-50% sexual maturity; yr)	3.384	2.803
σ_m (width of the logistic ogive)	0.305	0.484
t° (mean water temperature, °C)	21.5	21.5
max (maximum age considered; yr)	10.00	11.00
Pauly M (natural mortality rate; yr^{-1})	0.334	0.236
Jensen M (natural mortality rate; yr^{-1})	0.451	0.304
Mean M (natural mortality rate; yr^{-1})	0.39	0.27

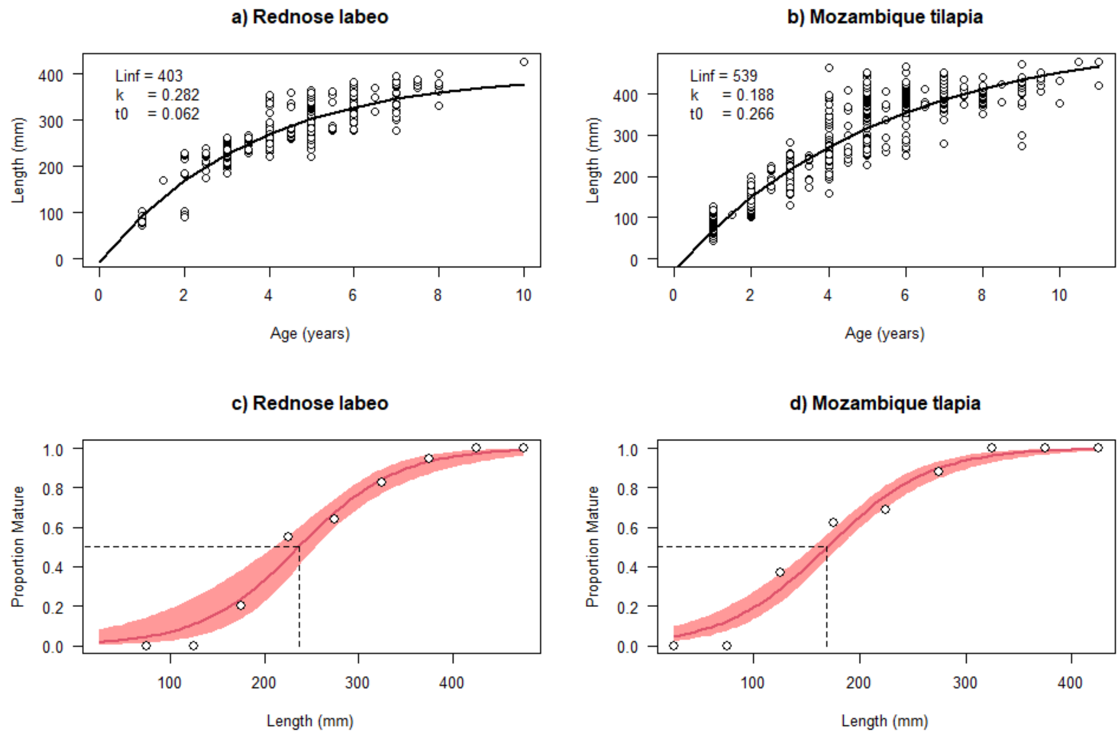

Figure 2.16: The von Bertalanffy growth model determined for a) *Labeo rosae* and for b) *Oreochromis mossambicus* and the length (mm) at maturity determined for c) *Labeo rosae* and for d) *Oreochromis mossambicus* based on aggregated data collected from Flag Boshielo and Loskop dams

The L_∞ for Mozambique tilapia was estimated at 539 mm and sexual maturity for Mozambique tilapia was estimated at 169 mm TL and 2.8 years (Table 2.8; Figure 2.16d). The largest immature specimen was 250 mm and the smallest specimen displaying any stages in the development of the ovaries was 107 mm.

For rednose labeo, the natural mortality was estimated to be 0.44 yr^{-1}, while the empirical estimates were 0.34 yr^{-1} and 0.45 yr^{-1} based on the equations developed by Pauly (1980) and Jensen (1996) for the aggregated Loskop-Flag Boshielo data. Similarly, the Mozambique tilapia natural mortality was estimated to be 0.40 yr^{-1} while the Pauly and Jensen estimates were 0.24 yr^{-1} and 0.3 yr^{-1}, respectively. To incorporate uncertainty between models the means of the two empirical M estimates were used in the YPR and SBR models.

YPR and SBR analyses

The results of YPR and SBR analyses (Figure 2.17) demonstrate that both species YPR is maximised at fishing mortalities exceeding 0.3 yr^{-1} and at ages of selection exceeding 3 years. The SBR analyses demonstrate that SBR is reduced rapidly even at low fish mortalities when fish are selected at ages below maturity. At fishing mortality (F) approximating those necessary to maximise YPR, SBR is maintained at above 25% of pristine SBR if fish are selected at the ages of 4 years or older. At ages of selection of 5+ years, SBR is maintained even at very high fishing mortalities. As a result, if a fishery were to be initiated for *L. rosae* and *O. mossambicus* in these impoundments, initial mesh size restrictions of 100 mm would be required to minimise the risk of stock collapse. While this would maximise catch rates from Loskop Dam (Figure 2.14), the use of 100 mm mesh sizes would result in low catch rates at Flag Boshielo Dam (Figures 2.10). As there are indications that the current informal gill net fishery has already depleted the larger fish, the size and shape of the informal gill net fishery would have to be assessed before further development is planned. This is required because there is a relatively high risk of stock collapse at relatively low F (and subsequently effort levels).

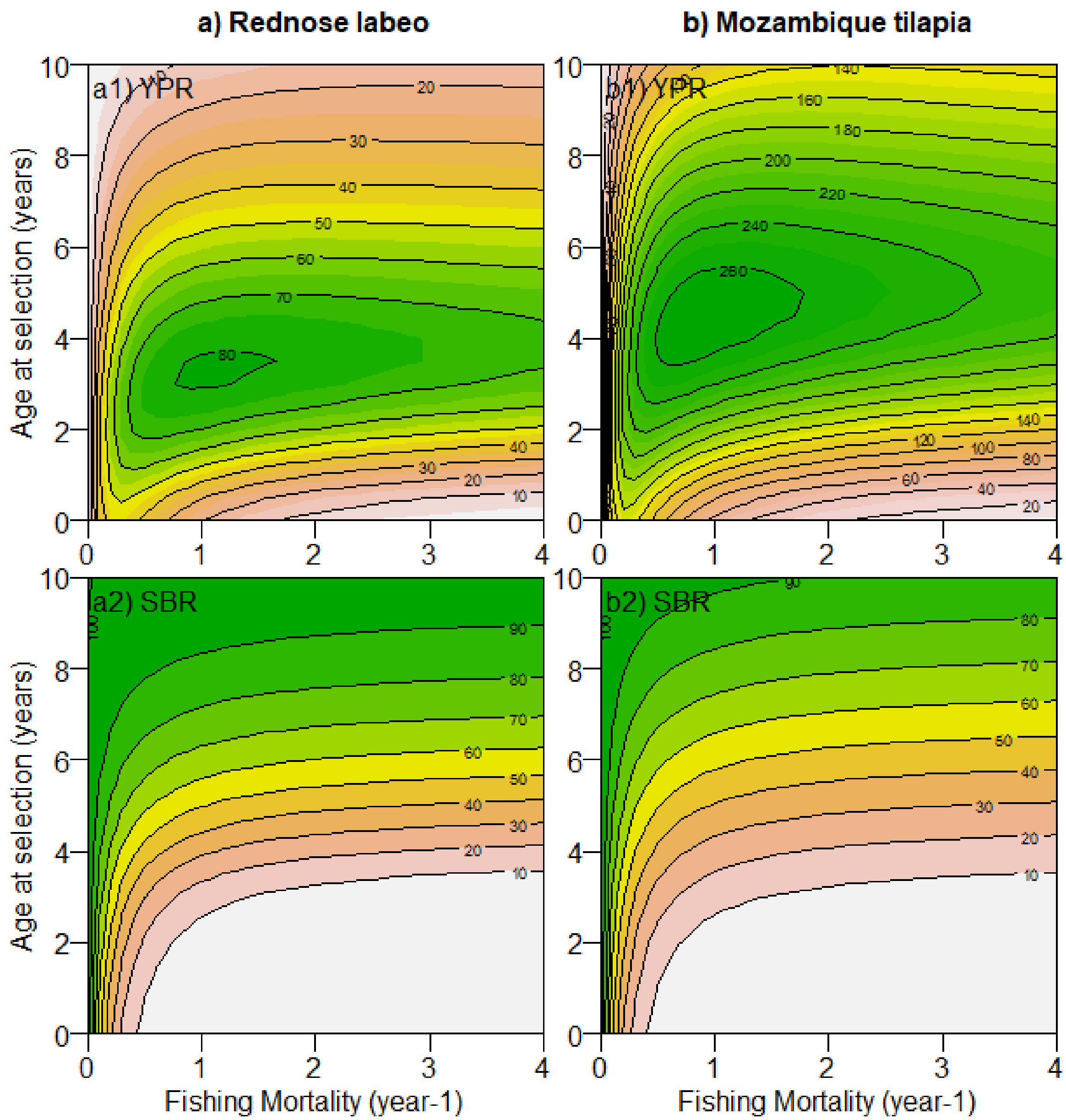

Figure 2.17: The yield-per-recruit (YPR) and spawner biomass-per-recruit (SBR) isopleth plots for fish varying in age for a) *Labeo rosae* (a1 and a2, respectively) and b) *Oreochromis mossambicus* (b1 and b2, respectively) based on aggregated data from Flag Boshielo and Loskop dams.

2.5. Discussion

The ultimate goal of fisheries management is to sustainably maximise human benefits from a fishery. In the South African context, such benefits can be either social (food security) or economic (either through service provision or via small scale fisheries). Ideally, fisheries should be managed such that yields are maximised without compromising the long-term sustainability of the fishery and the conservation of vulnerable species (Tweddle et al., 2015). In most fisheries, this requires management of the larger, high-value fish species; in particular see Weyl et al. (2010); Tweddle et al. (2015); Froese et al. (2015). This is because these larger fishes are generally slower growing, later maturing, and longer-lived than small fishes; see King (2013). Their populations are, therefore, more stable but require more time to rebound once overfished (Adams, 1980). In this context, it is also important to incorporate behavioural aspects of the target species. Labeos, for example, have not been able to support large fisheries in African impoundments because they are vulnerable to overfishing during spawning migrations into rivers; e.g. Booth and Weyl (2004). In South Africa, as is the case in many countries, the lack of directed catch and effort data constrains the assessment of lacustrine fisheries. In addition, there are often insufficient length- or age-based catch data and other biological data pertinent to the application of age-based models. When available, data is often imprecise and temporally disjunct of little quantitative value. Therefore, stock assessment methods, such as the surplus production model (Schaefer, 1954; 1957), *ad hoc* tuned Virtual Population Analysis (Pope and Shepherd, 1985; Butterworth et al., 1990; Punt, 1993a) cannot be applied. For these reasons, fisheries managers in developing countries have focused on the application of the yield-per-recruit (YPR) model, which is an abbreviation of the full dynamic-pool model (Beverton and Holt, 1956; 1957), in the management of both marine and lacustrine fisheries; e.g. Weyl et al. (2005); Kanyerere et al. (2005); Richardson et al. (2009). Application of the YPR models allows for the evaluation of the response of the YPR of a single species to changes in fishing mortality and age-at-50%-selectivity in a single fishery.

In an attempt to define optimum fishing mortality from a per-recruit perspective, the use of target reference points (TRPs) has become common practice in fisheries management (Clark, 1991; Punt, 1993b; Punt and Butterworth, 1993; Caddy and Mahon, 1995; Griffiths, 1997). The yield-per-recruit approach allows for the determination of at least two commonly used TRPs: firstly, the fishing mortality which corresponds to the maximum of the yield-per-recruit curve (F_{max}) and secondly, the marginal yield or $F_{0.1}$ strategy (Boerema and Gulland, 1973; Deriso, 1987), which is the rate of fishing mortality at which the slope of the YPR curve falls to 10% of its value at the origin. In most marine fish, the stock-recruitment relationship is density-dependent, but data are typically so few or so variable that the form of the relationship has not been determined objectively (Shepherd, 1982; Sissenwine and Shepherd, 1987). Models that have been used to describe the stock-recruitment relationship suggest either that recruitment approaches an asymptote at high stock densities (Beverton and Holt, 1957) or that recruitment reaches a maximum before decreasing at higher levels of stock abundance (Ricker, 1954; 1969; 1975). Although no spawner biomass-per-recruit (SBR) relationships have been determined for fish species in African reservoirs, many of the target species in these fisheries exhibit reproductive behaviours that imply that a density-dependent spawner biomass-recruitment relationship exists (e.g. nest guarding and mouthbrooding in cichlids). The use of TRPs that ignore the density dependence between spawner biomass and recruitment should, therefore, be used with caution. The F_{max} strategy maximises YPR without regard to whether sufficient spawner biomass is conserved to ensure sufficient recruitment in the future (Deriso, 1987; Sissenwine and Shepherd, 1987; Clark, 1991). While the $F_{0.1}$ strategy is more conservative than the F_{max} strategy, the $F_{0.1}$ fails to take into account the effects of fishing on the spawning stock and subsequent recruitment (Clark, 1991; Punt, 1993b).

The research presented here focussed on developing management recommendations for inland fisheries in the aforementioned impoundments. This was achieved by either conducting a long term or rapid appraisal of the fisheries potential of impoundments using empirical approaches and various fishing gear. (Barkhuizen et al., 2016) collated the first complete database of commercial fisheries yields in South Africa between 1979 and 2014. The results were surprising. Despite the issuing of licenses to operators on several water bodies, only 9 036 tonnes of fish were harvested by commercial fishery enterprises operating sporadically in seven impoundments. Commercial fisheries yields were dominated by Bloemhof Dam (73%) and Kalkfontein Dam (23%) with sporadic attempts to develop commercial fisheries at the five other impoundments contributing only 4% to the total yield over the 35 years. Interestingly, only two commercial ventures operated continuously at one impoundment (Bloemhof Dam) for more than 32 years. The success of these operations was attributed to prior knowledge, skills, experience, and, most importantly, a pre-existing and self-initiated market.

Fish composition and abundance varied between the impoundments studied here. When comparing species richness based on gillnet catches; Loskop Dam was reported to have a higher species diversity than Flag Boshielo Dam. Fish production and catch yields in Loskop Dam were considerably higher than those reported for Flag Boshielo Dam, largely due to the difference in the ecology and management strategy at the respective dams. For example, when using the same fleet of nets and soaking time, a total of 584 specimens from Loskop Dam were captured within two weeks whereas a total of 1376 specimens from Flag Boshielo Dam were obtained after a year of conducting monthly, three day, surveys. For a gillnet fishery in Flag Boshielo Dam, only nets with mesh sizes 100 mm and greater are to be considered to protect the spawner stock. Selectivity results indicate that *L. rosae* caught in a 100 mm mesh net will on average be 300 mm in TL and 450 g in live mass. Similarly, for *O. mossambicus* specimens retained by a 100 mm mesh net are predicted to have an average TL of 310 mm and a body mass of 719 g. Both these species are reported to reach sexual maturity around 210 mm TL and imposing restrictions on capturing fish less than 300 mm will reduce the risk of stock collapse.

Fish sampling by members of the team on Flag Boshielo (source, Joseph Sara)

Members of the team dissecting fish samples from Pongola Dam (source, Joseph Sara)

Ensuring the sustainability of small formal fisheries in Flag Boshielo Dam may not be feasible. The management of the fishery will have to ensure sustainable utilisation of fish stocks over time, to promote the economic and social well-being of the harvesting fisheries (Hilborn and Walters, 1992) and should, therefore, be a top priority for provincial administration. Moreover, potential conflicts between existing users (recreational and subsistence anglers) and crocodiles need to be considered. In addition, is dependent on access to the rivers feeding the impoundments for spawning and aggregate in staging areas in preparation of spawning migrations. Protection of these staging areas in the impoundment from the indiscriminate harvest is vital for the sustainability of a fishery based on this species, Although *L. rosae* grows comparatively larger than most other riverine species, this fish is not normally targeted by the rural populace due to the flesh of *L. rosae* becoming quickly rancid if not treated soon after landing. By comparison, the texture and white flesh of *O. mossambicus* make this species highly desirable to consumers (Jooste et al., 2015a).

Loskop Dam is a popular venue for recreational bass anglers and coarse anglers, the latter targeting *O. mossambicus*, *L. rosae*, common carp and sharptooth catfish. Annually angling competitions are held at Loskop Dam; two targeting *O. mossambicus* and separate competitions targeting bass, labeos and sharptooth catfish, respectively. The tourism value of this venue is considered high due to the water sports undertaken and the recreational fishing value of the dam. Due to its large size, this dam is capable of yields that might sustain a commercial fishery but may appear to be a conflict with the well-established tourism industry and conservation interests surrounding this impoundment. The yields obtained in Loskop data reveal the benefits of having systems that are well managed within a conservation framework that have restrictions imposed as to where one is allowed to catch fish, etc. Pongolapoort Dam on the other hand requires further investigation to establish the cause for the extremely low CPUE recorded during the rapid assessment.

Significant by-catches were recorded for both Loskop and Flag Boshielo dams. At both impoundments, the by-catch exceeded the catch of the target species for the mesh sizes recommended for the fishery at Flag Boshielo Dam. The establishment of a fishery will have significant knock-on effects on non-target fish species, some of which are in decline in the Olifants River system. Clear guidelines are required outlining permissible gear, operating and reporting procedures, and monitoring/utilisation of by-catch to avoid potential conflicts with crocodiles and reduce the risk of crocodile mortalities. Given that crocodiles are listed as CITES II animals, the Flag Boshielo population is not only protected, it is the only viable population in the Olifants River outside a formal conservation area. This population serves as an apex predator in the middle reaches of the Olifants River.

Of concern about impoundments within the Olifants River System is that the Olifants River has been systemically impaired by acidification and industrial, agricultural, and domestic pollution and is now one of the most polluted river systems in South Africa, particularly the Upper Olifants River sub-catchment (Heath et al., 2010; Ashton and Dabrowski, 2011). Although most metals naturally occur in the biogeochemical cycle, many are released into the environment as industrial, mining, agricultural, and domestic effluents containing complex mixtures of chemicals, many of which do not occur naturally at measurable quantities in aquatic ecosystems and are toxic even at low concentrations; e.g. Cd, Pb and Hg (Davies and Day, 1998; Dallas and Day, 2004). Metals not degrading in the environment, rather they accumulate in sediments (di Toro et al., 2001) or are assimilated into aquatic food webs (Chapman and Wang, 2000) through biota absorbing pollutants from the environment and their food (Chen et al., 2000; Warren and Haack, 2001). Consequently, concentrations of pollutants increasing up the aquatic food chain, posing a toxicity risk to organisms higher up the food chain such as predatory fish, piscivorous birds, and humans (Goodyear and McNeill, 1999). Therefore, people who regularly consume contaminated fish are at risk of genotoxic, carcinogenic, and non-carcinogenic health impairment due to long-term exposure from the toxins consumed (du Preez et al., 2003).

Several studies have highlighted that both Loskop Dam and Flag Boshielo Dam are subjected to pollution events that could adversely impact the biota present in these impoundments; see Oberholster et al. (2011, 2012a, b), Dabrowski and de Klerk (2013), Dabrowski et al. (2013, 2014b, 2015), Oberholster et al. (2017). In addition, pansteatitis has been recorded from crocodiles and Mozambique tilapia in Loskop Dam; see Botha et al. (2011), Dabrowski et al. (2014a, 2017) and recently in Mozambique tilapia from Flag Boshielo Dam (Sara et al., 2020a). Two recent Water Research Commission reports, Jooste et al. (2015a) and Sara et al. (2020b), and several recent peer-reviewed papers have discussed the issues relating to metal concentrations in the fish muscle tissue from Loskop and Flag Boshielo dams; see Addo-Bediako et al. (2014a, b), Jooste et al. (2014, 2015b), Marr et al. (2015), Lebepe et al. (2016), Sara et al. (2017a, 2018), Lebepe et al. (2020a). These studies found that during wet climatic cycles, the concentrations of metals in fish muscle tissues is of levels that could exceed the safe levels for long-term consumption, whereas during dry climatic cycles the concentrations of metals in fish muscle tissue are generally at levels safe for long-term consumption (Sara et al., 2020b). While (Sara et al., 2020b) proposed mechanisms for this outcome, these hypotheses require validation. The human health risk assessments, in the aforementioned studies, reveal that, under specific conditions yet to be fully defined, certain metals, viz. lead, antimony, and chromium, in Mozambique tilapia, rednose labeo, sharptooth catfish and silver catfish exceed international levels for safe consumption such that adults consuming a modest 150 g fish portion once a week may be placing themselves at a serious health risk. Should the trend of increasing pollutions levels in the Olifants River continue to increase, the risks to human health posed by the consumption of contaminated fish will increase (Marr et al., 2015). Considering that the local rural population is expected to increase, impoverished individuals within the community are increasingly likely to supplement their dietary requirement for protein by consuming fish from the impoundment. This is of great concern because of the potential health impacts on children and adults in rural areas (Marr et al., 2015).

In contrast to metals, pesticides and persistent organic pollutants (POP) have received less recent attention. Most studies conducted, especially those before 1980, primarily focused on pesticides through localised once-off surveys. van Dyk and Greeff (1977) detected concentrations of and endosulfan, dieldrin, and DDT in water samples from the Levubu, Letaba, Olifants, Sabie, and Crocodile rivers in the Kruger National Park while Pick et al. (1981) analysed fish fat from the Olifants, Crocodile, and Letaba rivers for the presence of organochlorine insecticides. Nearly all samples contained residues of one or more of the selected insecticides, namely DDT, DDE, endosulfan, dieldrin, and benzenehex-achloride (BHC). Even though these studies have shown that a variety of pesticides do occur in water resources, it is difficult to determine the extent of impacts because of a lack of relevant ecological effect assessments in the laboratory and the field (Ansara-Ross et al., 2012). More recently, Bollmohr et al. (2008) evaluated agricultural pesticides in the upper Olifants River, including the Elands River that flows into Flag Boshielo Dam and Verhaert et al. (2017) investigated the trophic transfer of persistent organic pollutants (POPs: PCBs, PBDEs, OCPs and PFASs) at selected sites in the Olifants River through trophic magnification factors. Verhaert et al. (2017) found that POP levels in surface water, sediment, and biota were low. Only ΣDDTs levels in fish muscle were highlighted. Significant positive relationships between relative trophic level and PCB, DDT, and HCH concentrations were observed, indicating biomagnification of all detected POPs. Verhaert et al. (2017) concluded that the fish species of the Olifants River can be consumed with a low risk of POP contamination. Moreover, Bangma et al. (2017) revealed that healthy Mozambique tilapia from Loskop Dam had a higher overall burden of PFAS than pansteatitis-affected individuals.

In conclusion, there is potential to establish a fishery at Flag Boshielo Dam targeting rednose labeo and Mozambique tilapia, although the harvest potential may be limited. There are, however, risks involved that include stock collapse, significant by-catch, human health impairment from consuming contaminated fish, and conflicts related to crocodiles. A comprehensive assessment of the current informal exploitation of the Flag Boshielo Dam fish stocks is required and the establishment of a formal fishery at this locality should incorporate the participants in the current informal fishery.

2.6. Acknowledgements

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CHAPTER 3. USING MARKET VALUE CHAINS TO ENHANCE THE CONTRIBUTION OF INLAND FISHERIES TO RURAL LIVELIHOODS IN SOUTH AFRICA

Edwin Muchapondwa, Mafaniso Hara and Barbara Tapela

3.1 INTRODUCTION

The African Union has identified inland fisheries as a priority investment area for poverty alleviation and regional economic development (NEPAD, 2005). Working through the framework of the Comprehensive Africa Agricultural Development Program (CAADP) and the Rural Futures Program, the NEPAD Agency has been spearheading a continent-wide effort to maximize the contribution of fisheries to Africa's food and nutrition security, well-being and wealth (AUC and NPCA, 2014).

In South Africa, inland fisheries have largely remained invisible and under-valued (Turpie, 2008; Weyl et al., 2007; Rouhani & Britz, 2004; Van der Waal, 2000; Andrew et al., 2000; Heeg & Breen, 1982). This is despite inland fisheries' great potential to contribute to the livelihoods, food security and employment of many rural women and men in South African informal economies (Tapela et al., 2014; Jaganyi et al., 2008). There is a need to understand the value of the inland fisheries and the role they play in the economy.

With increasing pressure for government to effectively address the persisting challenge of rural poverty, inequality and unemployment, the need to unlock the socio-economic potential of South African inland fisheries has become more urgent. Including inland fisheries in national policy statements and programs can prove beneficial to promoting economic and social growth for the poor, preventing further poverty, and achieving Sustainable Development Goal (SDG) 1 and other SDG targets, especially those related to food security (Lynch et al., 2017). The management of the fishery to ensure sustainable utilisation of fish stocks over time, to promote the economic and social well-being of the captured fisheries (Hilborn and Walters, 1992), should therefore be a top priority.

There is a concomitant interest in developing the economic and social opportunities offered by inland capture fisheries. The creation in 2009 of an inland fisheries mandate within the restructured Department of Agriculture, Forestry and Fisheries (DAFF) has significantly facilitated the promotion of these objectives through inland fisheries.[1] DAFF objectives resonate with the Value Chain Framework for Agrarian Transformation,[2] which seeks to meet basic human needs, develop rural enterprises and promote linkages between rural light industries, markets and credit facilities.

[1] However, the management mandate for inland fishery resources is currently delegated to the provincial environmental and nature conservation authorities, while the DWS and various authorities regulate activities on dams (Britz et al., 2015).

[2] This framework is implemented by the Department of Rural Development and Land Reform (DRDLR).

Inland fishers (men and women) ought to participate in Market Value Chains (MVCs) as extended chains could yield greater product value because there is greater value addition along the chain and/or there is a market participant who places greater value on the product. MVCs which include urban and/or global players are likely to be the kind of extended chains which bring greater value to rural fishermen and fisherwomen. Therefore, linking rural inhabitants into such MVCs could provide a means for them to overcome challenges of unemployment, poverty and inequality. There is a need to integrate rural fishers into mainstream agro-food systems and other coordinated commodity chains to help them pull their weight in tackling own challenges.

The agrarian transformation taking place within South Africa's rural spaces raises a number of policy questions. Grounded upon national aspirations to effectively address unemployment, poverty and inequality, the key policy questions relate to issues of ecological resilience, governance, and gender equity. Accordingly, this project maps and analyses MVCs associated with South African inland fisheries, which are transitioning from informal subsistence to formal commercialized activities, while taking full cognizance of their linkages with governance and gender to guide efforts to enhance the contribution by inland fisheries to rural resilience. This is explored in the context of inland fisheries in Flag Boshielo dam (Limpopo Province), Pongola dam (KwaZulu-Natal Province) and Voëlvlei dam (Western Cape Province) in South Africa.

Knowledge of the economic value of inland fisheries allows for appropriate decisions about these resources in national policy. As inland fisheries are part of natural capital, they would deserve more protection their greater they are valued. Furthermore, they would get more protection the greater they play a role for society particularly the poor and disadvantaged members of society.

The MVC concept is often used to get an idea of who exactly interacts with the resource and at what stage. Analysis of MVCs is used widely today as an instrument of development by major donor agencies. Two main reasons explain its popularity since the end of the 1990s: (i) the sustained evidence of a link between private sector driven economic growth and poverty reduction; and (ii) the fact that the integration of trade and production at the global level through value chains transmit the pressures of global competition to domestic markets in developing countries thereby stifling local firms (Gereffi, 2013). Donors have typically used the value chains framework to guide interventions. There has been mainly four different objectives of interventions: strengthening the weakest link to address potential bottlenecks in a value chain; improving flows of knowledge and resources to make all firms in the value chain more productive; working on specific links between firms to improve efficiency of the value chain; and creating new or alternate links in the value chain to promote diversified outcomes (Gereffi, 2013). In light of the foregoing, there is a need for clear understandings of MVCs and the attendant governance and gender issues associated with inland fisheries in South Africa. The MVCs include both those directly relating to the subsistence, recreational and commercial exploitation of fish species, as well as those relating to commercial enterprises associated with inland fisheries. The latter include recreational tourism and fish processing and marketing, among others.

The possibility of improving the welfare of communities through sustainable inland fisheries will be investigated through the upgrading concept in MVCs. This concept focuses on the strategies used by stakeholders to maintain or improve their positions in the MVC (Gereffi, 2013). Thus, the challenge of economic upgrading in a MVC is to identify the conditions under which communities can climb the value chain from basic assembly activities using low-cost and unskilled labour to more advanced forms of full package supply and integrated manufacturing (Gereffi, 2013). Within the MVC framework, four types of upgrading have been identified (Gereffi, 2013): (i) Moving into more sophisticated product lines; (ii) Transforming inputs into outputs more efficiently by reorganizing the production system or introducing superior technology; (iii) Acquiring new functions (or abandoning existing functions) to increase the overall skill content of the activities; and (iv) Movement of firms into new but related industries.

The question is thus how to integrate economic agents such as firms and households in value chains in a way that allows for incorporation of a growing number of the workforce and increasing levels of productivity and outcomes (Altenburg, 2007). This calls for a balanced approach which takes both competitiveness and equity issues into account. Accordingly, this research interrogated the conditions under which participation in inland fisheries MVCs can contribute to both economic and social upgrading in the study area.

3.2 Background on the South African Inland Fisheries Sector

This section briefly presents the South African inland fisheries sector and its potential role in economic livelihoods. Current users of inland fish resources are mainly small scale fishers (including subsistence fishers) and recreational anglers (Tapela et al., 2013; Weyl et al., 2007) while (large-scale) commercial fishers have historically plied their trade in selected impoundments. Even though small-scale fishers from local communities are generally regarded as having a legitimate claim to fish, in the absence of a supporting rights-based governance framework, their activities are usually illegal, unmanaged and often unsustainable. Recreational angling is by far the most developed, but access rights to the social and economic benefits from this sub-sector largely remain the prerogative of historically privileged racial classes (Tapela et al., 2013; Hara & Swarts, 2014). Commercial inland fisheries are undeveloped as a result of a history of limited access to resources, low demand for fresh water fish, the lack of an inland fisheries policy and unclear fisheries management objectives (Weyl et al., 2007). The peculiarities of each of the three categories of fisheries will be discussed in turn below.

Very little published information is available on the scale and livelihood contribution of small-scale fishing in rural communities, as it is largely an informal activity with no established system for stakeholder representation or data gathering. Britz et al. (2015) analysed at 64 case studies of a selection of fishing communities to characterise current small-scale fishery use in South African dams. Subsistence fishing activity was recorded on 77% of dams, recreational fishing on 69% and artisanal/small scale commercial fishing on 40%. Small-scale fishing on most water bodies was not rooted in indigenous fishing traditions, however, but was found to be an adaptive livelihood strategy to modern socio-economic circumstances. Most small-scale fishers were poor, but the role of fishing in their livelihood strategies was diverse, ranging from a part-time subsistence activity to a full-time artisanal occupation.

Small-scale commercially orientated artisanal fishers were largely resource-poor and unemployed men and women from rural local communities around the dam. It was not clear to what extent landlessness and/or joblessness, which were generally rife in many rural communities, contributed to the ranks of these fishers. The fishers used various types of nets, including beach seine nets, gill nets and other home-made nets. Some of the fishers used both nets and fish traps, as well as canoes and rafts. Both men and women fishers were involved in 'illegal' net fishing practices. While seine nets were mostly used by men, women fishers often used bunched up dry sisal cords, basket traps made of chicken wire and/or plastic netting, which they put into the water to trap fish. Small-scale commercially-orientated net fishers relied on informal markets along local roadsides, at road intersections and within local communities (Britz et al., 2015).

South African inland fisheries are predominantly used by recreational anglers who utilise the fish resource primarily for leisure purposes (Weyl et al., 2007). Through the utilisation of tourist facilities and associated services along inland waterways, recreational anglers contribute significantly to the regional economy (Du Plessis and Le Roux, 1965; Le Roux, 1965; Cadieux, 1980; Leibold and van Zyl, 2008; Du Preez and Lee, 2010). In some countries this economic contribution exceeds that of commercial fisheries (Stage and Kirchner, 2005; TCW Economics 2008). The few assessments of the economic impact of recreational angling in South Africa all indicate that this impact is considerable.

Recreational angling in South Africa can be broadly subdivided into two categories: the formal sector, which comprises individuals/members affiliated to or belonging to an organised body such as a club, and the informal sector that comprises social anglers that are not linked to any organised body (Pledger, 2010). Formal angling organisations are important partners in long term planning and policy development around the utilisation of fisheries. Nationally there are more than 19,000 recreational anglers that are affiliated to various angling associations (Pledger, 2010). Some 7,400 of these are affiliated to associations that only use inland waters. Britz et al.'s (2015) review of the recreational angling sector revealed that it has a substantial participation rate (estimated to be of the order of 1.5 million participants) and a significant economic impact associated with the tourism sector and angling services and supply value chains. Recreational angling was recorded on 69% of dams surveyed. The recreational angling disciplines are diverse, including bank angling for carp, yellowfish and catfish, artificial lure angling for bass and other species, flyfishing for trout, boat angling and informal recreational/subsistence angling.[3]

Commercial fishing in the form of single licences is only permitted on a limited scale on a few dams (e.g. the Gariep, Bloemhof and Moletedi Dams) (Weyl et al., 2007). Although commercial fisheries remain largely undocumented, historically commercial fisheries operated on a few impoundments including the Kalkfontein Dam, Bloemhof Dam (Orange/Vaal River system) and Darlington Dam (Sundays River system) (Anon., 1982; Merron and Tomasson, 1984; Potts, 2003). Despite these attempts to develop commercial fisheries on larger impoundments in South Africa,

[3] Angling is organised as a sporting code, affiliated to the South African Sports Confederation and Olympic Committee (SASCOC), under the Sport Anglers and Casting Confederation (SASACC). Recreational angling is a poplar activity on state dams and is supported by the DWS policy of promoting recreational activities on state dams. The management of recreational fishing activity on state dams was in the process of being formalised by the DWS, through the compilation of Resource Management Plans for major state dams. Despite its economic impact and ability to create rural livelihoods and decent jobs, recreational angling is not recognised or represented as a fishery sub-sector by the DAFF. Recreational anglers were concerned about sustainability issues, growing gill net fishing, and conflicts with small-scale fishers. The organised sports angling community was in the process of approaching the DAFF to obtain recognition of a proposed fisheries sub-sector association representative of all anglers, both informal and organised, in order to develop appropriate governance and management arrangements, and to realise the economic potential of the industry (Britz et al., 2015).

and despite a number of studies on the fisheries potential of these dams for the establishment of capture fisheries (e.g. Koch and Schoonbee, 1980; Hamman, 1980, 1981; Allanson and Jackson, 1983; Cochrane, 1987, Andrew, 2001), the commercial viability of these enterprises has been marginal (Britz et al., 2015).

There have been numerous attempts to develop formal small-scale commercial fisheries in rural communities (e.g. Jackson, 1980; Schramm, 1993; Andrew, 2001). Unfortunately, few fisheries developed or remained operational after the initial project interventions. The reasons for this lack of success are unclear, but have been attributed to: the perceived low value of the resource; the lack of historic involvement in fishing; the limitation of artisanal and subsistence fishing to the former homeland areas under the Apartheid era; a cultural resistance to fishing (Andrew, 2001); and the concerns by management authorities that the support of small-scale and commercial use may threaten fish populations (Andrew et al., 2000; Britz et al., 2015).

The overriding reason for the lack of development of commercial inland fisheries is probably economic. Recent estimations on profitability of various commercial fisheries options on Lake Gariep (Potts et al., 2004) and Darlington Dam (Weyl et al., 2010) found that the low fish price (ZAR 6-10/kg) coupled with the absence of a formal marketing system for inland fish precluded the economic viability of even small commercial enterprises in these water bodies. In addition, they showed that employment possibilities in commercial fisheries were relatively low, and pointed out that commercial fisheries would result in considerable conflict with other users of the resource. As a result, employment gains from commercial fisheries were likely to be countered by employment losses from tourism at sites where recreational fisheries were well established (Britz et al., 2015).

3.3 Materials and Methods on Valuation and Value Chains

3.3.1 The Valuation Framework for Inland Fisheries

Valuation of inland fisheries is linked to the concept of Ecosystem Services. Ecosystem services refer to the benefits that people obtain from ecosystems. These include: provisioning services (e.g. food, fibre, fuel, water); regulating services (benefits obtained from ecosystem processes that regulate, e.g. climate, floods, disease, waste and water quality); cultural services (e.g. recreation, aesthetic enjoyment, tourism, spiritual and ethical values); and supporting services necessary for the production of all other ecosystem services (e.g. soil formation, photosynthesis, nutrient cycling) (Millennium Ecosystem Assessment, 2005). The appropriate valuation framework for inland fisheries takes into account social, economic, market and ecological values. This study will focus on the economic value of inland fisheries. The results should be consumed with care as they leave out social and ecological values.

In economic terms, biodiversity and ecosystem services can be considered as contributing to different elements of “Total Economic Value‟, which comprises both use values (UV) (including direct use such as resource use, recreation, and indirect use from regulating services) and non-use values (NUV), e.g. the value people place on protecting nature for future use (option values) or for ethical reasons (bequest and existence values) (Krutilla, 1967; Krutilla and Fisher, 1975; Peters, Gentry and Mendelsohn, 1989; Kolstad, 2000; De Groot et al., 2006; Bennett and Thorpe, 2008;

TEEB, 2010). UV from an inland fishery is the economic value of products extracted that are either directly utilized (e.g. for consumption or processing, used as aquaculture broodstock or seed material, or for ornamental purposes) or extracted for sporting/recreational purposes. The economic importance of most of these values can be measured in monetary terms, with varying degrees of accuracy, using various techniques (including market pricing, shadow pricing and questionnaire based) (TEEB, 2010). This study focuses on monetary valuation and therefore ignores non-monetary valuation.

A major gap in knowledge is the actual and potential value of inland fisheries to society measured in terms of economic value, food security, jobs and welfare gains.[4] This information is essential to inform policy and planning and the investment in capacity by governments to support the sector's development. Some estimates show that inland capture fisheries and aquaculture contribute over 40% to the world's reported finfish production from less than 0.01% of the total volume of water on earth (Lynch, Cooke et al., 2016). They make a substantial contribution towards preventing increased poverty and, in some cases, alleviating poverty (i.e. addressing Sustainable Development Goal [SDG] 1: No Poverty) (Lynch, Cowx et al., 2017). In a recent global review, Thorpe and Zepeda Castillo (2018) estimate the marketed use value (MUV)[5] of inland freshwater fisheries catches from reported "official" data to be approximately US$26 billion. It is acknowledged that a significant proportion of the inland catch is "hidden" and unreported. Adding an imputed value for the hidden harvest results in a new estimate of the MUV of inland freshwater fisheries catches of US$38.53 billion. The value of capture fisheries is somewhat dwarfed by the values generated by recreational fishing – called non-marketed use value (NMUV).[6] Excluding Africa and using limited data from Asia and Latin America, the 2015 NMUV of recreational fishing was estimated to be at least US$64.55 billion. Aggregating the UV of inland capture fisheries and the NMUV of inland recreational fisheries indicates that the total use value (TUV) of the inland fishery sector is worth at least US$108 billion.

The global review suggested that the 2015 TUV of the inland fishery in Africa was US$8.51 billion, including a hidden harvest of US$2.7 billion and no NMUV from recreational fishing.[7] The current study will estimate the MUV, NMUV and TUV for South Africa (see Section 4) to demonstrate the significance of inland fisheries and as motivation for a detailed study of the chain that this value typically follows in relation to water bodies adjacent to poor rural fishers.

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[4] This is a global problem, and Cowx and Gerdeaux (2004) point out that fisheries tend to be poorly- or under-valued in multiple aquatic resource user scenarios.

[5] MUV refers to the capture and sale of fish and fish products through local, national and international markets, whether for food or ornamental purposes. More correctly, as Cowx et al. (2004) and Tuan et al. (2009) indicate, MUV is a net value, and so the cost of extraction should be deducted from the gross fishing income, in order to identify the resource rent.

[6] NMUV refers to fish caught for self-consumption, as baitfish, or for sporting or recreational purposes (Bennett and Thorpe, 2008).

[7] The transformation of fish into a fish product (through drying, smoking, processing, transportation, etc.) also generates additional value, which can be directly attributed to the underlying extracted resource. For example, Chimatiro (2012) suggested that these "substantial market-based gains" raised African fish rent resource generation from USD 2 billion to USD 3.8 billion. De Graaf and Garibaldi (2014) In total, the gross value added of African inland fisheries in 2011 was estimated to reach to USD 3 186 million (2 415 + 767 + 3.64), or USD 6 275 million if these findings were extrapolated across the whole continent. However, for now, we concentrate on the value of inland fisheries at point of first sale value (FSV).

3.2 Market Value Chain (MVC) Analysis

This study uses value chain analysis to assess the level of competitiveness within the value chain and to identify a possible link for fishers to integrate with the mainstream economy. Over the years, a number of different concepts have been used that overlap with the concept of value chains.[8] The different value chain analysis emanating from the concepts are based on the same underlying aspect – the flow of the physical product, from input suppliers, to the final consumer. The major differences relate mainly to the focus of attention of the user. Value chain analysis is used for a wide variety of applications (Jordaan and Grové, 2012). According to Webber and Labaste (2010), the value chain approach is used to 'guide and drive high-impact and sustainable initiatives focused on improving productivity, competitiveness, entrepreneurship, and small and medium enterprise (SME) growth'.

The importance of using the value chain analysis approach to contribute to enhancing the level of competitiveness of an industry is evident from the number of studies, including those by Webber and Labaste (2010), FIAS (2007), Lusby and Panlibuton (2007), Francis (2004), Fundira (2003), Fitter and Kaplinsky (2001) and Neves et al. (undated), which compiled guides and research frameworks to enhance the level of competitiveness of the industry under consideration; and Boonzaaier (2009), Darroch and Mushayanyama (2008), Madevu, Louw, and Kirsten (2007), Madevu (2006), Hardman, Darroch and Ortmann (2002) and Esterhuizen, Van Rooyen, and D'Haese (2001), that investigated the competitiveness of agricultural industries in South Africa. We refer the interested reader to Jordaan and Grové (2012) for an extensive review of these studies.

One of the major constraints faced by inland fishers is lack of market access. Value chain analysis is also used to help producers gain market access. Schmitz (2005) shows how value chain analysis can be useful for identifying points along the chain where producers can access the market and hence link with the mainstream economy. Allied international studies include Schipmann (2006) and Van der Meer (2005) while Khaile (2012), Van der Merwe (2012), Ortmann and King (2010), Cloete (2010), Baloyi (2010), Van der Heijden (2010), Boonzaaier (2009) and Magingxa (2006) include local equivalents. Also see Jordaan and Grové (2012) for extensive reviews.

The framework used by this study to examine MVCs in inland fisheries is derived and adapted from the Greater Access to Trade Expansion (GATE) Project (see Gammage et al., 2009). The GATE project integrates a gender and pro-poor analysis that aims to uncover the economic, organizational, and asymmetric relationships among actors throughout the chain and recognizes that power differentials among actors may influence outcomes along the chain. The GATE project has analysed value chains from a distributional perspective to explore opportunities to improve market outcomes; raise productivity and wages; decrease gender inequalities; and foster pro-poor growth. The types of conclusions and recommendations that emerged from the GATE Project approach to value chain analysis focused on how to improve the terms and conditions of employment and exchange for poor men and women in the chain. As a result, GATE methodology presents a different approach to analysing power, distribution, and segmentation in value chains, by income level and sex.

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[8] Some of those concepts include, amongst others, Porter's value chain, supply chain, global commodity chain, French filière, global production network, and commodity chain. See Jordaan and Grové (2012) for an elaboration of these concepts.

To date the GATE value chain analyses have demonstrated that the most vulnerable actors in the value chains occupy the least secure employment, and have limited opportunities to upgrade their production or change the terms and conditions of their labour and product exchange. Women are not visible in many activities even though their labour may be critical for particular nodes or segments of the chain. Women (and children) may be concentrated in the more flexible and insecure nodes of the value chain. Furthermore, insecurity in the chain is likely to be equated with low incomes and a greater vulnerability to poverty. The position of women could be further diminished by the growth of global production networks which have been linked to rising levels of income inequality, within and between countries, mainly due to the dynamics of rents in global value chains, which are increasingly determined by intangible assets (such as copyrights, brand names and design) as more tangible barriers to entry in manufacturing have tended to fall (Gereffi, 2013).

3.2.1. Value chain mapping

One of the first tasks to complete towards market value chain analysis is to construct a map of the chain. A value chain map enables the tracing and tracking of relationships between different actors, such as producers, intermediaries, processors and exporters, as well as the flow of inputs, services, and credit through the chain. A value chain map can also help to clarify the rationale behind the actors' decisions regarding their interaction with value chains. A good map reflects significant analysis of the value chain (Gammage et al., 09). In accordance with the GATE approach (Ibid.), the value chain map should estimate the number of firms involved in various functions and, where possible, provide estimates of employment in the chain. A flow chart is used for this. The various boxes and circles represent one or more organizational unit of varying complexity. The map of the value chain can indicate the type and size of these units graphically, and depict the flows of inputs, goods or services between the nodes. The actors in each specific market value chain can be grouped according to function and/or role. Actor groups could include, for example, ‘input suppliers’ (e.g. natural resource harvesters, community-engaged conservation agencies, savings and credit facilities, agro-chemical firms, extension and training service providers, etc.), ‘producers’ (e.g. crafters, farmers), ‘processing units’ (e.g. processing plants/exporters and producer-processors-exporters) and ‘marketing agents’ (e.g. buyers, transporters, brokers, supermarkets and other retailers). The emerging economic structure and other attributes of actor groups can subsequently be analysed to indicate the institutional arrangements governing actor relationships, gender structure of employment, and distribution of costs and returns in the chain, among other things. Value chain mapping can also be shaped to reflect main characteristics of production and exchange, such as relative size of productive unit by profit or return and by gender structure of employment within the value chain or productive unit (total or by gender).

Much of the research on value chain analysis considers only those agents who are directly involved with the primary product. Roduner (2007) argues for a systemic view of value chains that integrates three important levels within a value chain network, namely, value chain players, influencers and supporters. Value chain players are directly involved with transforming the physical product into the final product. Value chain influencers influence the operations within the chain by providing the regulatory and administrative conditions that have to be met by all players within the value chain. Value chain supporters provide information, training, promotions and support to value chain players to meet all the rules and regulations specified by the influencers. Thus, a systemic view of the value chain allows for the discovery of opportunities and bottlenecks within these levels, as well as in the dynamic interactions between the levels.

Accordingly, the value chain analysis approach taken in this study also considers the regulatory framework that influence the behaviour of the actors who are directly involved with moving the physical product along the chain, and also the support services that are available to support the value chain players to comply with the rules and regulations specified by the value chain influencers. While analysing the contribution of water use in agricultural value chain, Jordaan and Grové (2012) showed that the bulk of all of the water that was used along the value chain was used at farm level to produce the food products. They therefore suggested that enforcement by water institutions had a major role to play in improving water use efficiency at farm level. Similarly in our case, enforcement and support institutions could influence the nature, structure, extent and worthiness of fish MVCs.

As suggested by Jordaan and Grové (2012), a comprehensive analysis of the value chain is required to determine the degree of accessibility of the different marketing channels that are available in the value chain. The attributes of the product (i.e. quality) are major determinants of which marketing channels can be accessed. Fishers who do not use high paying marketing channels (i.e. retail stores) may not have access to them because of the attributes of the product. In such a scenario the seemingly sub-optimal decision may actually be an individual optimal choice. Thus, a comprehensive understanding of the attributes of the product and the requirements of the different marketing channels is necessary to know what specific marketing channels fishers should target.

3.2.2. Distributional analysis

Distributional analysis explores the value added, as it is generated along the chain, and examines the returns to labour and capital and to the different actors that participate in the chain. All data gathered and analysed are intended to be disaggregated by sex and gender in order to identify, from an economic perspective, returns to men and women (as well as the youth, disabled and/or indigent among these) for participating in the chain. Where possible we also examine the poverty rates and livelihood strategies of different actors in the chain.

3.2.3. Multipliers and spillovers

An analysis of multipliers and spill-overs provides an estimate of the role that the sector plays in stimulating other economic activities. This analysis is important to understand the actual and potential contribution of the value chain to poverty reduction or stimulating economic growth. The methodology suggested by the GATE Project and used herein is based on an approach outlined in Miller & Blair (2003).

The first step is to gather information on the origin of inputs and the proportion of costs that are comprised of products or services that are national or international in origin. Backward linkages represent the sum of all input purchases from other local and national industries by a particular sector expressed as a ratio of total sales, while forward linkages are the amount of purchases by other local industries from a particular sector. These forward and backward linkages can also be derived from input-output matrices if these exist at a sufficiently disaggregated level. Linkages can be derived from the Leontief matrix constructed from input-output tables.

In many of the sectors in developing countries, it is unlikely that such highly disaggregated input-output tables exist, so it is necessary to derive estimates of forward and backward linkages directly from the survey micro-data and key informant interviews. The multiplier analysis requires some simple coefficients derived from the backward linkages and the marginal propensity to consume. Multipliers measure the "ripple" effect in total national income of a unit change in some component of aggregate demand. They are frequently calculated as the ratio of the direct, indirect, and induced effects to the original direct change. Typically, larger economies have larger multipliers because they are more self-sufficient than smaller economies. Larger regions also have larger multipliers. The goal of this analysis is to capture the extent to which the sector links to other economic activities and secures spillovers that stimulate aggregate demand in other sectors.

3.2.4 Problem Tree Analysis

As in Jordaan and Grové (2012), after the comprehensive analysis of the value chains, problem tree analysis was used to investigate the stumbling blocks that constrain the fishers' ability to produce larger volumes of output, and their ability to maximise their income from selling their output. A problem tree is compiled by first identifying the main limitations that constrain the performance of the market participants under consideration. Participants are then asked to identify the causes for the specific limitations. This is to get a better understanding of the central problem and its causes. From this, some leverage points can be identified with the potential to overcome the limitations. Thus, the idea behind the problem tree analysis is to identify critical points where the chain faces limitations that constrain the performance of the participants within the chain. A problem tree analysis reveals the causes and effects of such limitations with the aim to identify potential solutions to overcome the limitations. Based on the problem tree analyses, some potential solutions were identified that may contribute to overcoming the stumbling blocks. The problem tree analyses were done based on discussions with key informants and fishers in the respective areas of study.

3.3 Data Collection and Study Area

The study used both primary and secondary data. Data collection methods included desktop research, participant observation, field surveys, semi-structured interviews with fishers and key resource persons, focus group discussions, questionnaires and stakeholder consultations. Site selection was based on findings of a recent baseline and scoping study by Britz et al. (2015). The key criteria for site selection included: productivity of fishery; presence of active fishing, angling and associated formal and informal fish markets and commercial enterprises, such as tourism; and diversity of ecosystem contexts.

3.3.1 Pongola Dam

Pongola dam (formerly known as Pongolapoort dam) or Lake Jozini dam is situated in a beautiful part of northern KwaZulu-Natal (KZN); on the western side of the Lebombo mountain range in an area characterised by bushveld, wildlife and subtropical weather. Situated on the Pongola River at the "Heart of the Zulu Kingdom", just outside the town of Pongola (30° 19' 3" S 30° 11' 3" E), the dam was completed in 1974 and covers an area of 13,276 ha. The dam is largely surrounded by game reserves, which support several tourist lodges. The reserve and game farms offer game drives, boat cruises, guided walks, rhino tracking, canoeing and recreational fishing charters for tiger fish. Pongola town and traditional communities from the surrounding areas use the water for drinking, washing and small-scale fishing.

3.3.2 Flag Boshielo Dam

Flag Boshielo dam (formerly Arabie Dam) (24°49’05”S; 029°26’39”E) is located within the Sekhukhune District Municipality of the Limpopo Province. The 1,288 ha dam is situated about 30 kilometres northeast of Marble Hall along the Mokopane – Marble Hall Road. Other surrounding villages and towns include Phetwane, Sevenstart, Mafisheng, Mokgalajana, Makgathle, Mmaphogo, Tsimanyane, Letebejane villages and Kromdraai, Groblersdal and Middelburg towns. The western shore of the Flag Boshielo Dam forms part of the Schuinsdraai Nature Reserve, a 9037 ha provincial nature reserve (Britz et al., 2015). The dam was built along the Olifants/Lepelle River and completed in 1987. The confluence of the Elands River with the Olifants River forms an important landmark at the inlet to the Flag Boshielo Dam.

3.3.3 Voëlvlei Dam

Voëlvlei Dam (33°20′15″S 19°2′1″E) is situated just off the R44 between Tulbagh and Hermon only 90 minutes from Cape Town. Voëlvlei Dam was commissioned in 1952 by impounding the natural Vogelvlei Lake near Gouda in the Drakenstein Local Municipality (DWAF, 2004). Additional water is obtained via canals from the Klein Berg River, and Vier-en-Twintig and Leeu Rivers (DWAF, 2004). Voëlvlei Dam is approximately 9 000 km^2 in size and has a storage capacity of 170 Mm^3 (DWAF, 2007). Voëlvlei Dam is predominantly used for recreational fishing and yachting, with very well organised local club structures managing access and activity on the dam under authorisation from the Department of Water and Sanitation. The lack of a dam resource management plan and policy on inland fishing has retarded a proposal to initiate a commercial fishery for carp and catfish, and the restricted public access to the dam raises issues of equity. The protected areas around Voëlvlei Dam include the Voëlvlei Nature Conservancy and Waterval Nature Reserve.

3.4 Valuation of Inland Fisheries in South Africa

3.4.1 Marketed use value for inland fisheries in South Africa

There are no national estimates for the economic value of inland fisheries for South Africa. Deriving such assessments would require valuations across the three subsectors: small scale fishing,[9] recreational fishing and commercial fishing. When considering the MUV, estimation needs to confront three major problems: establishing what has been caught; valuing what has been caught; and estimating the cost of catching the fish.

[9] For the subsistence fishing sector, the value of the fish should ideally be measured in terms of food security metrics including income, nutritional status, and welfare savings by the state.

Fouche et al. (2012) estimated that the harvestable yield of fish from large South African dams[10] could range from 10 to 200 kg per ha per year while McCafferty (2012) used a more conservative estimate of 40 kg per ha per year in average fish production. Therefore, South African water bodies could potentially yield 1000 to 2000 tonnes per year.[11] However, Weyl et al. (2012) estimated the potential productivity for inland fisheries on South Africa's major dams at around 15 000 tonnes annually, spread unevenly throughout the country, with the highest production being in the warmer areas of the country such as Limpopo, Mpumalanga, North West and KwaZulu-Natal. Using the continental average price[12] of US$2.10 per kilogram as reported by Thorpe et al. (2018), this yields an MUV of between US$2.1 million and US$31.5 million per year.

In Britz et al. (2015), income from fishing was largely context specific and depended on the orientation and investments by fisher. Generally, income varied from R250 to R550 per 25L bucket for livelihoods-orientated subsistence fishers, who fished a few times a week. Small-scale commercially-orientated fishers, who practiced semi-subsistence diversified fishing, generated incomes of between R150 and 250 per day and fished for 3 to 5 days per week, thereby earning between R1800 and 4000 per month during good fishing seasons.[13] Other better resourced and full-time small, medium and large-scale commercial fishers reported earnings of between R500 and R2500 per day, 6 days per week, which translated to between R12000 and R60 000 per month. A survey in 2000 estimated that there were about 30 000 subsistence fishers and about 28 000 households that depended on harvesting near-shore marine resources (Clark et al., 2002). However, Isaacs and Hara (2015) report that the latest estimated total number of small-scale and subsistence fishers in South Africa is about 8078. Assuming that they are all small-scale commercially-orientated fishers, this suggests that the MUV of South African inland fisheries ranges between R174 million (US$11.6 million) and R387.7 million (US$25.8 million).

Averaging out the results from the 2012 and 2015 studies, the MUV of South African inland fisheries can be estimated at about US$30 million per year. This compares well to the South African fisheries GDP of US$322.5 million (FAO, 2018).

3.4.2 Non-marketed use value for inland fisheries in South Africa

For the recreational fishing sector, the economic value of the resource needs to be measured in terms of the local economic impact generated by the tourism value chain and angling services and

[10] South Africa possesses over 700 public dams (these translate into about 800 000 hectares in surface area) and natural water bodies with inland fishery potential.

[11] Commercial and subsistence inland fisheries remain poorly developed despite several attempts dating back to the 1970s (Koch & Schoonbee, 1980; Allanson & Jackson, 1983; Jackson, 1980; Andrew, 2001).

[12] Monetizing the inland catch is equally, if not more, problematic as prices vary by time, place and species, reflecting local supply and demand factors. Price volatility is most acute in markets where the product (such as fish) is perishable, although this can be ameliorated when preservation opportunities such as drying, smoking, pickling or other forms of processing exist. Ideally, valuation methods should employ FSV (price at point of first sale, referred to variously as beach price (marine), farm-gate price (inland capture or culture), or ex-vessel price) as opposed to market prices – although the latter are often the easier to obtain (Thorpe et al., 2018).

[13] Survivalist fishers largely caught fish for their own consumption and therefore, for these, further research would need to determine income through proxy variables. For all types of subsistence (and artisanal) fishers, such incomes make critical contributions to the socio-economic status, food security and well-being of affected rural and local households. More in-depth research, however, is required to verify and refine these statistics, which were largely compiled through indicative appraisals of a few fishers and fisher households.

supplies such as accommodation, bait, guides, restaurants, equipment, food and so on. In terms of estimating economic value for "true" recreational fisheries, Thorpe et al. (2018) suggests that recourse to catch values will underestimate their true value. Instead, alternative valuation techniques are needed. One option is to use expenditure-based approaches: extracting information on the value of licences purchased and/or spent on fishing trips or, alternatively, estimating the turnover of the fishing tackle/bait industry and the recreational boating industry.

Economic assessments indicate that recreational fisheries contribute significantly to provincial and national economies (Cadieux, 1980; Brand et al., 2009; Du Preez and Lee, 2010; Leibold and Van Zyl, 2010). A non-peer reviewed study on the value of recreational fisheries in South Africa, commissioned by the South Africa Deep Sea Angling Association (SADSAA) in 2007, showed that the expenditure by freshwater anglers contributed significantly to the national economy (Leibold and Van Zyl, 2008). The study estimated that the average expenditure on angling related equipment and activities by anglers affiliated to angling clubs was ZAR 7 500 per angler per year, and that the total economic impact of these anglers, who represent about 10% of participants, was in the region of R900 million per annum.[14]

The economic survey by Leibold & Van Zyl (2008) indicated that recreational angling and sport fishing generate an NMUV of approximately R9 billion (US$600 million) per annum for South Africa. Tourism ventures associated with recreational fisheries, such as the trout fishery at Rhodes village and fishing charter operations on Pongola Dam, for example, support full time businesses. Other examples include the numerous privately-owned, state-owned and community-owned holiday resorts and fishing camps, which are found in the vicinity of many of the observed water storage dams across the country. With specific respect to dams that were constructed through public investments, it is worth noting that while such enterprises continue to derive significant financial benefits from utilizing state-funded infrastructure, recreational fishery benefits are not equitably shared with the impoverished rural communities, who occupy the backwaters of dam hinterlands. In essence, by retaining rather than distributing the huge financial turn-over generated by the recreational and sport angling sub-sector, these current beneficiaries 'capture' the value of public expenditure without paying other 'valid but marginalized' beneficiaries for their foregone use of such resources (Britz et al., 2015).

3.4.3 Total use value for inland fisheries in South Africa

It can be observed that the recreational value of inland fishing dwarfs the value of the inland small-scale fisheries' catch. The same scenario obtains at the global level where Thorpe et al. (2018) estimated an MUV of US$26 billion and an NMUV of about US$64.55 billion. Using the MUV and NMUV figures derived above, the TUV for South African inland fisheries can be estimated at about US$630 million per year. There is a need to find ways to allow the small scale fishers to tap some of the value from inland fisheries including recreational fishing. Such opportunities can be

[14] While up-calculations of this value for the unaffiliated anglers cannot be made with any confidence, the report demonstrates the economic contribution that the recreational sector makes to the national economy. Rural poor people communities however do not participate in many of the recreational fishing opportunities that offer social and economic benefits associated with, for example, ownership of fishing tourism enterprises such as accommodation, services and supplies (Britz et al., 2015).

investigated by looking at the inland fisheries value chains and identifying opportunities for upgrading small scale fishers.

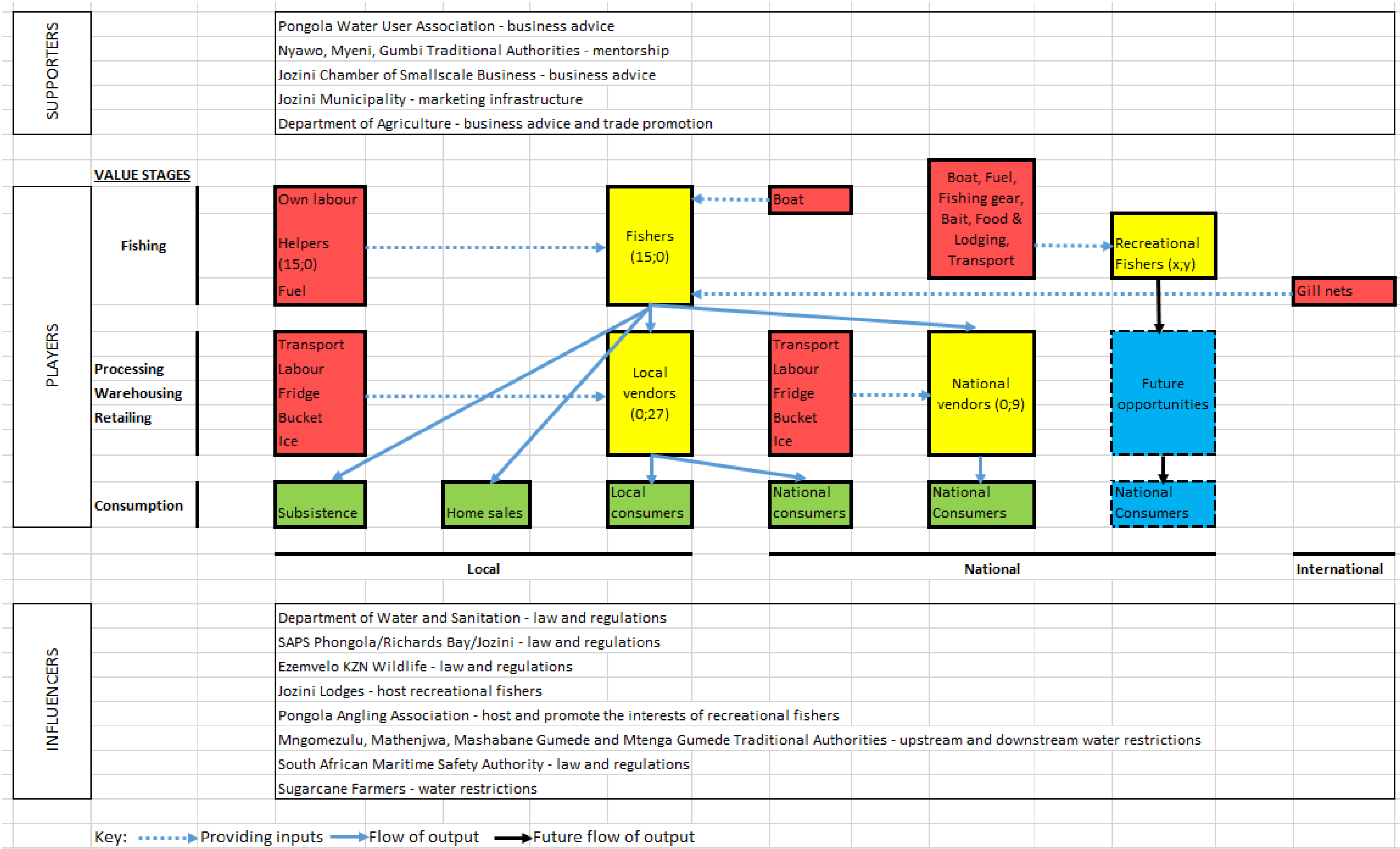
3.5 Mapping the Value Chain, Power and Governance

3.5.1 Mapping the value chain

One of the first tasks to complete towards market value chain analysis is to construct a map of the chain. A value chain map enables the tracing and tracking of relationships between different actors, such as producers, intermediaries, processors and exporters, as well as the flow of inputs, services, and credit through the chain. A value chain map can also help to clarify the rationale behind the actors' decisions regarding their interaction with value chains. A good map reflects significant analysis of the value chain (Gammage et al., 2009).

3.5.1.1 Pongola dam

Figure 3.1 presents the mapping of the value chain of Pongola dam fish. The Pongola dam fish value chain is composed of five functions: fishing, processing, warehousing, retailing and consumption. The first function is undertaken by artisanal fishers from the three traditional authority areas covering the dam (i.e. the Nyawo, Myeni and Gumbi) and recreational fishers from nearby towns and faraway places. The other traditional authorities on upper and lower dam areas are Mngomezulu, Mathenjwa, Mashabane Gumede and Mtenga Gumede. Fishing and eating self-captured fish is not a huge pastime for communities in the dam area hence the minimal involvement in fishing by the area's traditional communities. In fact, fishing seems to have been inspired in the area by formerly Mozambican immigrants, who have since become South African citizens. However, the few artisanal fishers who ply their trade in Pongola dam are quite reliant on the fish for their livelihoods (protein and income requirements). The area has high levels of unemployment and poverty. Recreational fishers usually come in large numbers during holidays or when there are organized fishing tournaments.



Source: Own formulation from field data

Figure 3.1: Pongola dam fish value chain

As recreational fishing is largely thought to be of the catch and release type, the processing, warehousing and retailing functions associated with Pongola dam fish are mainly done by local female vendors from Nyawo, Myeni and Gumbi traditional authority areas on fish supplied by the small-scale fishers. About nine of the local women regularly operated at the selling point in front of Inkunzi tavern in Jozini town while the rest sell at other unidentified local locations and outlying towns during the time of our visit in 2017. However, a limited amount of fish also finds its way to other female vendors who come from nearby towns such as Mtubatuba, Mkuze, Ndumo and Pongola. These outside women are usually only called when the harvests are good enough to satisfy the demand of the local vendors and leave a surplus.

There are therefore four general groups of actors in the Pongola dam fish value chain as depicted in Figure 3.1: input suppliers (for fuel, labour, transport, fishing gear, etc.); fishers (artisanal and recreational); vendors (local and external to Pongola (hence termed national)), and consumers (local and external to Pongola (hence termed national)). The shaded rectangles represent one or more organizational unit of varying complexity. The red rectangles represent input nodes, yellow rectangles represent output value addition nodes, green rectangles represent output terminal nodes and blue rectangles represent potential nodes. Where possible, the number of units at each node have been indicated. As this is a gendered value chain, the numbers of men (M) and women (F) participating at each node have also been provided, where possible. The dashed and solid arrows depict the flows of inputs and goods respectively between the different types of organizational units. The blue arrows represent the current situation while black arrows represent potential future flows.

The value chain supporters are Pongola Water User Association – business advice; Nyawo, Myeni, Gumbi Traditional Authorities – mentorship and community access rights; Jozini Chamber of Smallscale Business – business advice; Jozini Municipality – marketing infrastructure; and Department of Agriculture – business advice and trade promotion. The value chain influencers are Department of Water and Sanitation – law and regulations; SAPS Phongola/Richards Bay/Jozini – law and regulations; Ezemvelo KZN Wildlife – law and regulations; Jozini Lodges – host recreational fishers; Pongola Angling Association – host and promote the interests of recreational fishers; Mngomezulu, Mathenjwa, Mashabane Gumede and Mtenga Gumede Traditional Authorities – upstream and downstream water restrictions; South African Maritime Safety Authority – law and regulations; and Sugarcane Farmers – water restrictions.

In order to get greater insights from the MVC analysis, one has to view the full set of relevant functions and actors as defining a business organization. As the number of recreational fishers are difficult to pinpoint unless one has access to historical data from the relevant associations, the MVC analysis below will proceed on the basis of data gathered about the artisanal fishers. Given that there are 15 fishermen who had the means and permission to regularly go fishing, we considered them as representing 15 business organizations involved with the fishing function. This had been formalized as the maximum number allowed to fish on the dam. The number is based on those that had been actively fishing at the time this was being formalized by the Water User Association (WUA).

In the same way, we focus on the 27 local vendors who take over the fish from the fishermen as 27 business organizations involved with the processing, warehousing and retailing functions. In some ways, there is a vertical integration of functions by the fish vendors whereby processing, warehousing and retailing functions are carried out by the same business organization. Accordingly, the value chain depicts 27 fish processors, 27 fish warehouses and 27 fish retailers. The 15 fishing businesses, 27 fish processors, 27 fish warehouses and 27 fish retailers make use of services from outside the fishing sector. The fishers demand inputs to their business in the form of boats, fuel, nets, and labour. The fish processing, warehousing and retailing requires inputs such as transport, labour, fridge, buckets and ice. The sources of inputs required for these four functions may differ across business units.

The fishermen either buy fiberglass boats or take abandoned second hand ones from places such as iSimangaliso Wetland Park, a huge protected area along the coast in KwaZulu-Natal Province. The boats usually cost between R10,000 and R20,000 and fishers buy the boats either individually or in partnership. The 3-metre long average size boat has an average life span of about 5 years. There are three boats owned by the fishers that are currently operating on the dam.

All the artisanal fishers in Pongola use the 5 cm gill net minimum mesh size agreed upon and a 25 to 40 horse power boat with a petrol engine. Each fisher usually carries three nets. Nets are sourced from Mozambique. The usual net size is 10 m x 100 m. The net including accessories cost about R1,500 per set. These nets were said to last between 6 and 12 months of normal use. However, nets can be destroyed by crocodiles when they feed on fish caught in gillnets, or by hippos breaking through the set nets as they go across nets. In addition, speed boats belonging to recreational fishers do frequently get entangled and destroy artisanal fishers' gillnets.

Artisanal fishers rarely go out to the dam for fishing by themselves and they tend to go out in pairs as the conditions in the dam are quite risky and could be better managed with an extra hand on board. The boat owner does not charge the non-owner for sharing the use of the boat. In this context, sharing is viewed as a way of gaining safety and security from fellow fishers. However, the operational costs such as petrol are shared among the fishers sharing a boat. Fuel is sourced at local service stations. Petrol usage is estimated at about 20 litres/per return trip.

While artisanal fishers predominantly use own labour, some fishers use helpers (i.e. crew). Sometimes a helper goes out fishing in place of the net owner. Helpers are paid 30% of the net revenue (usually, after costs such as petrol have been deducted). Other costs are food for helpers and oneself (about R100/each/fishing trip).

The fishers, who comprise of a mixture of local (South African) and those originally from Mozambique (but largely naturalized), use the DWS General Permit for use of dams to access the dam waters. All the fishers fishing on the dam above the wall fish for commercial purposes. Even then, they do take some fish home for their own consumption after every trip.

The artisanal fishers mostly catch Redbreast tilapia (*Comptodon rendalli)*, catfish but occasionally also tiger fish. They land their catch at the slipway, unless the wind is too strong for them to come back. When the weather is too bad to come back home, the fishers try and land near to where they are fishing in order to avoid accidents and sell their fish there. The artisanal fishers land an average of 100 fish per person per trip even though on good days the harvest can be as much as 300 to 400 fish per person. The size of the fish in the catch ranges between 100 g and 1.5 kg. When fishers sell their fish to the fish vendors, prices depend on the mesh size, where small fish is sold for about R20-R30 per fish and the biggest fish is sold for R50-R60 per fish. A sample of artisanal fishers estimated that their gross revenue per trip averaged R3,000.

Artisanal fishers went out fishing 3 or 4 times a week with each fishing expedition taking them an average total of about nine hours. Currently, the fishing grounds that are productive are in Golela area close to the Swaziland border, which takes about 2 hours to reach and 3 hours to come back (when the boat is full of fish). Because of the distance, fishers set the nets, sleep in the boat and then haul out the nets after five 5 hours and then return home. Sleeping on the fishing grounds serves several purposes: saving time, saving petrol and guarding nets as, occasionally, some fishers do steal other fishers' fish from nets.

The women's business units mostly buy their inputs from local shops (e.g. fridge, buckets and ice). They use local taxis for transporting their wares, if necessary. There is an agreement (between the artisanal fishers and the WUA) that fishers should sell all their catch to the 27 local women belonging to the "women's cooperative for fish trading" that had been formed by the Jozini Municipality. This is to spread the benefits, instead of fishers integrating activities to add value to their catch by taking them on shore and selling to consumers rather than to the women. Giving some of these women the opportunity to sell fish keeps them away from involvement in illicit trade on things such as beer and dagga. In any case, the fishers are usually too tired to take up the next activities in the market chain by the time they come back from fishing. It is only once the needs of the women from the cooperative have been satisfied that the fishers can sell to other buyers.

Women fish traders from Sizabanthu cooperative selling fishing from Pongola Dam in Jozini Town (source – E. Muchapondwa)

Fishers communicate with the women by cellphone once they are bringing in the catch. The women buy the fish at the slipway. If the fish is more than they can carry on their own, the women hire a bakkie (at a fee of R10 per woman) to collect the fish. In the rare cases when a fisher arrives later than expected, the fisher delivers the catch to the women at their selling point outside Inkunzi tavern in the Jozini town. The fish is sold unprocessed to the women, and they gut the fish themselves. If they are unable to clean the fish they can ask for the fishers' help at a small fee. However, the women mostly gut their own fish.

The price charged by the artisanal fishers depends on the size of the fish. The price is initially based on the seller's visual assessment and determination, and then later through negotiation between the fisher and buyer. The fishers and buyers do at times agree as a group on the selling price of fish of specific size on the day. Usually though, this is negotiated between the individual fisher and buyer. The WUA tried to control the price that fishers sold the fish to the women, but this has not been enforced of late. The women said that they bought fish every time fish was landed, both to replenish their stock (even though they might still have fish in the deep fridge) and also as an obligation to the fishers in terms of maintaining business relations by buying the supplies/landed fish off them.

About nine of the local women regularly operated at the selling point in front of Inkunzi tavern in Jozini town while the rest sell at other unidentified local locations and outlying towns such as Mtubatuba, Mkuze, Ndumo and Pongola at the time of our visit. Some women specialized in selling big fish while others specialized in selling small fish. Most of the small size fish is apparently only caught below the dam wall in the river as there is largely only big fish above the dam wall. The women work individually, even though they belong to a "cooperative". The women use buckets and ice to sell their fish at their retailing points. The ice blocks are bought in one of the local shops in the town. They said that they used about 10 litres of ice per week (the price of a 5 kg packet of ice blocks was R13). Whatever fish was unsold at the end of the day is taken back home and put in a deep freezer and then taken out for sell next day. Thus, a freezer is one of the important investments for the women. The forthcoming Business Plan being developed by the DWS and WUA includes a freezer and a cooler box for each woman as the necessary investments.

The women estimated that they sold about 100 fish per week, i.e. the typical catch by fisher can be fully retailed within a week. However, the actual number of fish sold per day and the selling rate depend on the time of the month. Sells are higher and quicker around paydays or when people get social grants. There are times when trusted customers are given fish on credit, to be paid for after payday or after they get their social grants. Otherwise, the women's fish market opens at 7am and closes at 5pm every day, subject to the availability of fish.

The fish retailing prices outside the tavern in Jozini town range according to the size of the fish and also on how much the women bought each fish for. For a fish that is bought from the fishers for R10 they sell it for R20 per fish, this is the smallest fish that they have in their stock. The largest fish which they usually buy for R50 is sold for R90.[15] After selling a typical catch by fisher within a week, the women estimated that they earned a revenue of R6,000. Some women fry some of the fish that is unsold at the end of the day for sell as fried fish as a way of retaining its value. The women also use some of the fish for home consumption.

Even though the artisanal fishers get harassed by police officers, the women had never experienced such incidences. Since fishing now was being compromised because of the ongoing artisanal fishing rights issues in Pongola Dam during the time of this study, some women had reportedly left the fish selling business. Apart from the remainder of the women getting their fish from local artisanal fishermen, they seemed also to have been getting fish from other fishers of unknown origin. The new fish suppliers were more expensive, which forced the women to up their fish selling prices also. The ongoing artisanal fishing rights crisis in Pongola dam situation had negatively impacted on the artisanal fishers' livelihoods, fish-eating communities' welfare, and negatively affected the fish vending women's margins.

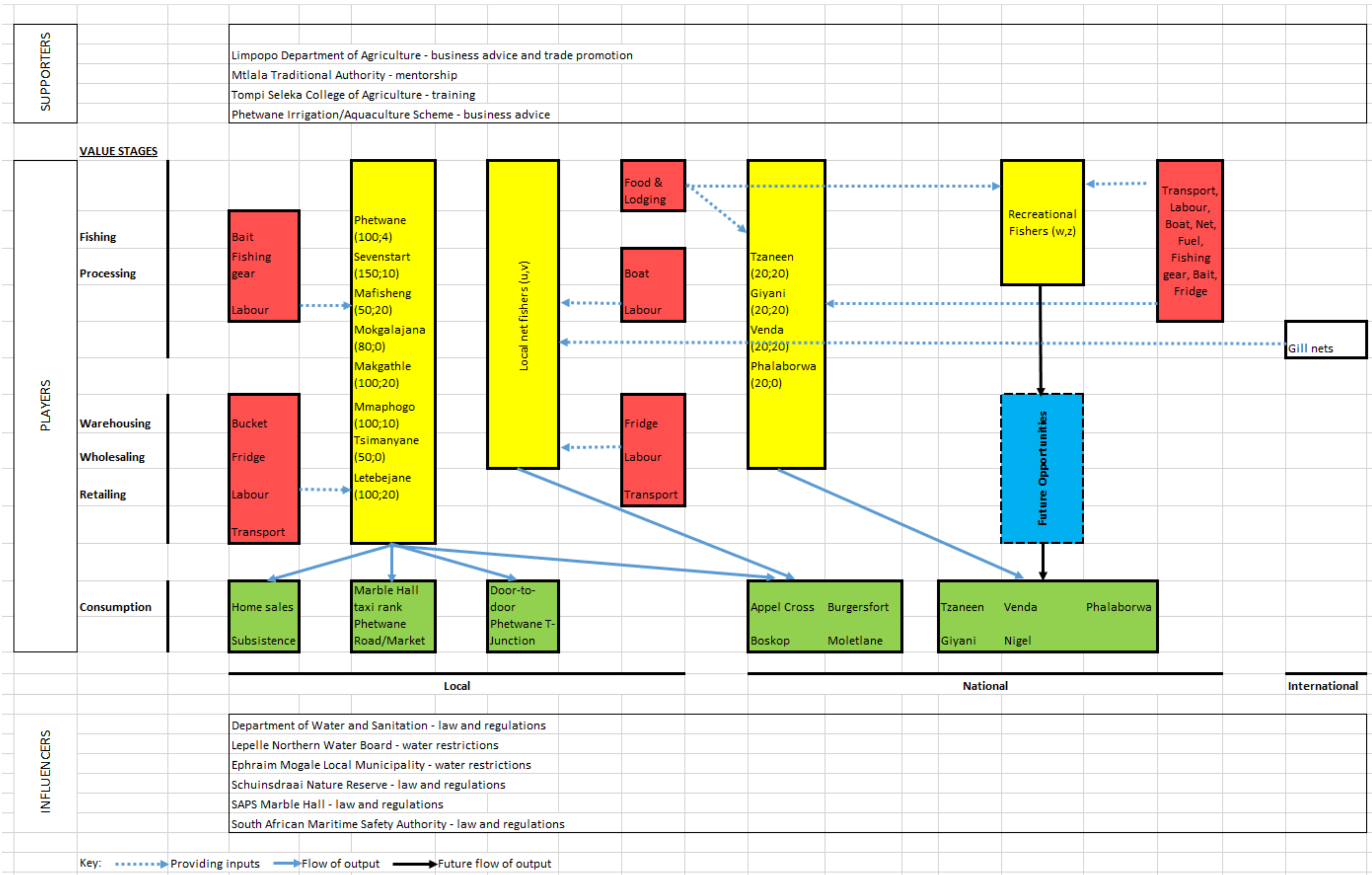
It was observed that most local guesthouses and restaurants did not have the local fish on their menus, and thus did not buy the local fish from the women or fishers. Even most shops (e.g. Shoprite, Spar, etc.) did not retail local fish. The fish they sold was mostly frozen marine fish, canned sardines and in a few cases frozen imported Chinese tilapia. One reason suggested for the lack of local fish in local restaurants and shops was that the amounts and the variations in catches were not conducive to fulfilling supply contract obligations. In fact, one of the interviewed artisanal fishers told of an example where he had been offered a contract to supply tiger fish to one of the guest houses, but could not fulfil it on a regular basis resulting in its cancellation.

[15] There have been changes in pricing since the scoping study by Britz et al. (2015). In that study, the price had increased to R10 for both sizes of fish while others sold 3 bream for R10 and large catfish for R30 (Britz et al., 2015).

3.5.1.2. Flag Boshielo dam

Fish species caught on the Flag Boshielo dam included carp (Common, Mirror, Grass and Chinese Silver), yellowfish (Large Scale, Small Scale and Papermouth), catfish (Sharp Tooth, Butter and Squeaker), tilapia (Blue, Redbreast, Nile, Vlei and Dwarf), eels (Giant Mottled, African Mottled and Longfin or Black), barbs (Papermouth, thee-spot bream, tail spot, Silver and Red fin), labeo (Muddies, Red Nosed, Leaden and Purple or Red-scaled), robbers (Dwarf Tiger and Silver), bass (Large Mouth) and Mormyrid (Churchill or Dolphin) (Britz et al., 2015).

Figure 3.2 presents the mapping of the value chain of Flag Boshielo Dam fish. Fishing was being undertaken by artisanal fishers from the eight villages adjacent to the dam (i.e. Phetwane, Sevenstart, Letebejane, Mafisheng, Mokgalajana, Makgathle, Mmaphogo and Tsimanyane), and informal and formal recreational fishers from nearby towns and faraway places. The value chain comprised of six functions: fishing, processing, warehousing, wholesaling, retailing and consumption. The value chain supporters were Limpopo Department of Agriculture – business advice and trade promotion; Mtlala Traditional Authority – mentorship and community access rights; Tompi Seleka College of Agriculture – training; and Phetwane Irrigation/Aquaculture Scheme – business advice. The value chain influencers are Department of Water and Sanitation – law and regulations; Lepelle Northern Water Board – water restrictions; Ephraim Mogale Local Municipality – water restrictions; Schuinsdraai Nature Reserve – law and regulations; SAPS Marble Hall – law and regulations; and South African Maritime Safety Authority – law and regulations.



Source: Own formulation from field data

Figure 3.2: Flag Boshielo fish value chain

Compared to the Pongola case, the Flag Boshielo value chain includes highly integrated community-based organisational units carrying out all the upstream functions including an extra one involving bulk sales to traders coming from far afield. Unlike in the Pongola case, fishing and eating self-captured fish is embedded in the culture of communities around the Flag Boshielo Dam. The artisanal fishers' livelihoods (protein and income requirements) greatly rely on Flag Boshielo Dam fish. The foregoing facts coupled with the reality of the area's high levels of unemployment and poverty explain the involvement in fishing by a significant proportion of the area's traditional communities.

Most of the artisanal fishers use line and hook while an unknown number use gill nets at night. In the sample of interviewees, there were at least four fishers who confirmed using gill nets. There is a perception among local fishers that most of the net fishers come from the Mafisheng RDP settlement. Due to the bulkiness of their catch, most net fishers predominantly sell their catch to traders in nearby larger towns. However, there are also limited instances when rod fishers also supply the same traders. The fishers either transport the fish themselves to the traders or wait for the traders to pick them up.

Hook and line fishers in Flag Boshielo Dam (E. Muchapondwa)

A gill net fisher setting his net in Flag Boshielo Dam (source – M. Hara)

There is a group of fishers which consider itself as informal recreational anglers without affiliation to any angling clubs and associations. They use store-purchased and home-made fishing rods, hooks and bait during day time. They reportedly come from places such as Tzaneen, Venda, Giyani, Nigel and Phalaborwa and engage in gill net fishing at night. Some of these informal recreational anglers also paid entrance fees to gain access to fisheries. Many of the informal recreational anglers took their catch home reportedly for sale. Their markets include larger towns, such as Tzaneen, Polokwane, Phalaborwa and Groblersdal, among others. Britz et al. (2015) reported that, when apprehended, these sorts of fishers were often caught with up to 5 to 6 nets that were 500 m long and catch between 400 and 500 fish each.

Formal recreational anglers were mostly white people, who were members of angling clubs and associations.[16] These anglers utilized many of the popular fishing areas around dam. They take part in numerous angling competitions and tournaments hosted in dams each year. Recreational anglers come from areas ranging from local farms and towns to places much further afield. They enjoy greater formal access to Flag Boshielo Dam fishery, through fishing permits, than members of rural local communities. They had better fishing gear and tackle, such as boats and flotillas, expensive fishing rods and specialized lures, among other forms of gear and tackle. They invested in high value related equipment such as vehicles, boat trailers, freezers, caravans, tents, gas appliances and outdoor furniture. Formal recreational anglers also had the financial resources to stay in formally registered resorts and camps, where there was greater security, electricity, water, ablutions and other facilities. They practiced catch-and-release techniques, often releasing some of the fish and taking a portion of their catch home. However, it was not clear to what extent recreational anglers consumed or sold their catch.

[16] Recreational anglers and angling clubs, such as Classics Spinfishing Society and others affiliated to South African Artificial Lure Angling Association, have been using the dam since its construction. Recreational fishers usually come in large numbers during holidays or when there are organized fishing tournaments.

Recreational anglers on Flag Boshielo Dam (source, M. Hara)

There were four general groups of actors in the Flag Boshielo Dam fish value chain as depicted in Figure 3.2: input suppliers (for fuel, labour, transport, fishing gear, etc.); fishers (artisanal, recreational and commercial); traders (external to Flag Boshielo (hence termed national)), and consumers (local and external to Flag Boshielo (hence termed national)).

As motivated earlier, the MVC analysis below will proceed on the basis of data gathered about the artisanal fishers. Given that there are reportedly 814 fishermen who have the means and permission to regularly go fishing, we consider them as representing 814 business organizations involved with the upstream functions. There is largely vertical integration of functions by the fishers whereby at least fishing, processing, warehousing and wholesaling functions are carried out by the same business organization. Accordingly, the value chain depicts 814 fishers, 814 fish processors, 814 fish warehouses, 814 fish wholesalers and 814 fish retailers. These business organizations make use of services from outside the fishing sector as elaborated on earlier in the Pongola case.

The artisanal fishers did not require a permit as long as they had access the dam from the community side of the dam waters. They used rods and hooks of varied quality but each tended to have several rods. The average fishing set was bought at a cost of R500 and each fisher used an average of three rods. They mostly caught tilapia, carp and catfish. The size of the fish in the catch ranged between 100 g and 2 kgs. When fishers sold their fish to the consumers, prices depended on the fish type and size but carp and tilapia ranged from R5-R30 while catfish ranged from R10-R50 per fish. As in Pongola, the price was initially based on the seller's visual assessment and determination, and then later through negotiation between the fisher and buyer. A sample of artisanal fishers estimated that their catch per trip averaged one 25-litre bucket (about 50 fish) which produced a gross revenue of R700.

Artisanal fishers went out fishing 3 or 4 times a week with each fishing expedition taking them an average total of eight hours. Fishing usually took place during summer months as it was reported that during May, June and July (winter months) fish goes into the deeper waters in the middle of the dam.

The gill net artisanal fishers used rowing dinghy boats with oars which they sourced from Marble Hall for about R1,700.[17] As in Pongola, they used the 5 cm minimum mesh size gill nets, but there were indications that homemade gill nets had smaller mesh sizes. Each fisher usually carried one net. Nets of variable sizes were sourced from Mozambique for about R1,200 per set including accessories for the usual net size of 10 m x 100 m. These nets were said to last 6 months of normal use but were under threat from crocodiles that fed on fish caught in the nets. There was a lower risk of speed boats belonging to recreational fishers getting entangled as artisanal fishers' gill nets were usually located along specific dam shore sections on the community side of the dam. Net fishers usually went out in pairs and only spent about 2 hours on their whole operation during the night as the nets stayed permanently in the water. A well-known net fisher estimated that their catch per trip averaged two 25-litre buckets (i.e. about 100 fish) which produced a gross revenue of about R1, 400. Depending on their calculation of enforcement probabilities, net fishers were prepared to go out every night. Net fishers constantly tried to evade being apprehended by environmental compliance and enforcement agencies, which patrolled the dam.

The fishers bought their inputs from local shops (e.g. rods, hooks, bait, fridge, buckets, etc.). As in Pongola, a freezer is one of the important investments for the fishers in Flag Boshielo where summer temperatures can reach over 30 degrees Celsius. Whatever fish stocks fishers had at the end of the day were stored in a deep freezer and then taken out for sell in buckets the next day. The freezers were used to produce the required amount of ice to preserve the fish during retailing. The marketing places varied from home sales, door-to-door, and specific locations in the area or nearby towns (Boskop, Moletlane, Burgersfort, Appel Cross, etc.). They used local taxis for transporting their wares, if necessary. Some fishers preserved and sold dried fish but fresh sales were most common. The fishers in the area used some of the fish for home consumption.

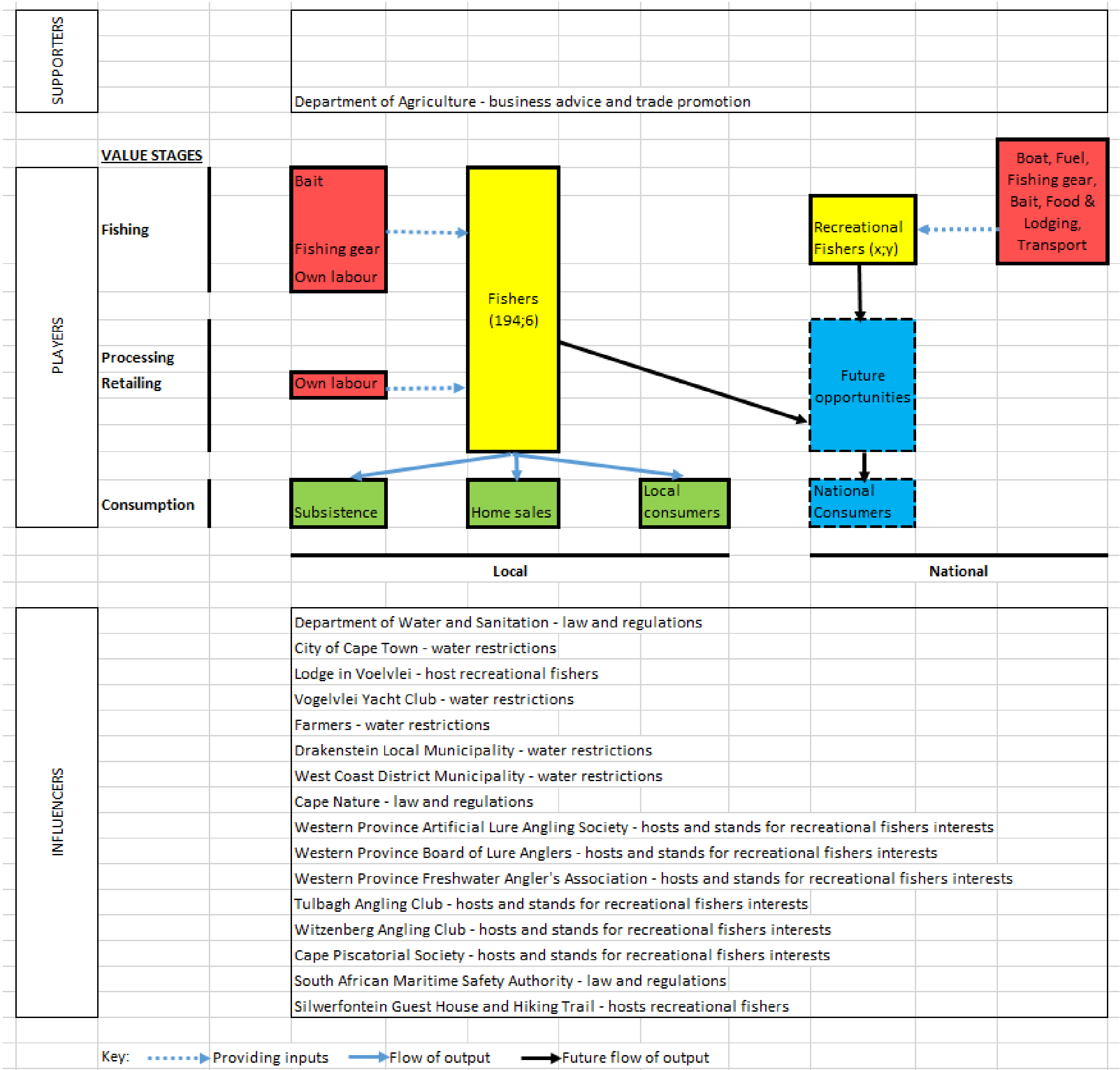
3.5.1.3 Voëlvlei Dam

The dam is a popular recreational angling site located close to the Cape metropolitan area. Smallmouth Bass are the main attraction.[18] Other fish species found in the Dam include carp, rainbow trout, catfish and Cape witvis (*Barbus andrewi*). Fishing can be done legally through a license that can be bought from the Receiver of Revenue or from the Post Office. Anglers are allowed two bass/day and are not allowed to sell the catch. The average size of Smallmouth range from 500 g-1,5 kg even though 2 kg ones are a distinct possibility. Most anglers practise catch-and-release. There is no control on fishing of alien species, especially carp and catfish, as these are viewed as being not good for the Dam because they are bottom feeders and thus discolour the water whereas the bass do not.

Figure 3.3 presents the mapping of the value chain of Voëlvlei dam fish. Fishing is undertaken by artisanal fishers from the neighbouring farms and rural town, Gouda. The value chain comprises of only four functions: fishing, processing, retailing and consumption. The value chain supporters are the Department of Agriculture – business advice and trade promotion. The

[17] The 2.5-metre boat has a life span of at least 30 years.
[18] The dam has been labelled as "The definitive South African Bass fishing site" (http://www.bigbass.catch.com/id5A7.12).

value chain influencers are Department of Water and Sanitation – law and regulations; City of Cape Town – water restrictions; Lodge in Voëlvlei – host recreational fishers and restrict public access to dam; Vogelvlei Yacht Club – restrict public access to dam and water restrictions; Farmers – water restrictions; Drakenstein Local Municipality – water restrictions; West Coast District Municipality – water restrictions; Cape Nature – law and regulations; Western Province Artificial Lure Angling Society – hosts and stands for recreational fishers interests; Western Province Board of Lure Anglers – hosts and stands for recreational fishers interests; Western Province Freshwater Angler's Association – hosts and stands for recreational fishers interests; Tulbagh Angling Club – hosts and stands for recreational fishers interests; Witzenberg Angling Club – hosts and stands for recreational fishers interests; Cape Piscatorial Society – hosts and stands for recreational fishers interests; South African Maritime Safety Authority – law and regulations; and Silwerfontein Guest House and Hiking Trail – hosts recreational fishers.



Source: Own formulation from field data

Figure 3.3: Voëlvlei dam fish value chain

Compared to the Pongola case, the Voëlvlei value chain includes highly integrated community-based organisational units carrying out all the upstream functions. Unlike in the Pongola case, fishing and eating self-captured fish is embedded in the culture of communities around the Voëlvlei dam. The small-scale fishers' livelihoods (protein and income requirements) greatly rely on Voëlvlei dam fish. The foregoing facts coupled with the reality of the area's low income levels explain the involvement in fishing. However, locals were selective on the fish species they consumed. In particular, they did not consume the increasingly abundant catfish for cultural reasons. They had instead found opportunities to earn an income through it as they find a ready market in immigrants from Malawi and Zimbabwe working in nearby farms.

All artisanal fishers used rod, line and hook. They use store-purchased equipment and bait. The fishers sell their catch almost immediately and avoid the need for warehousing. They also avoid transport costs by selling locally to community members or passers-by.

Formal recreational anglers were mostly white people, who were members of angling clubs and associations. These anglers utilized many of the popular fishing areas around the dam. Access to prime angling spots or launching a boat is reserved for members of the Western Province Artificial Lure Angling Society (WPALAS); the Western Province Board of Lure Anglers; the Western Province Freshwater Angler's Association; the Tulbagh Angling Club; the Witzenberg Angling Club and the Cape Piscatorial Society.

There are four general groups of actors in the Voëlvlei dam fish value chain as depicted in Figure 3.3: input suppliers (for fishing gear and bait); fishers (artisanal and recreational), and consumers (local to Gouda (hence termed local)). The MVC analysis below will proceed on the basis of data gathered about the artisanal fishers. Given that there were reportedly 200 fishers who had the means and permission to regularly go fishing, we considered them as representing 200 business organizations involved with the upstream functions. There was largely vertical integration of functions by the fishers whereby fishing, processing, and retailing functions were carried out by the same business organization. Accordingly, the value chain depicts 200 fishers, 200 fish processors, and 200 fish retailers. These business organizations made use of services from outside the fishing sector as elaborated on earlier in the Pongola case.

The artisanal fishers effectively do not require a permit as long as they are catching fish from the areas not frequented by anglers. They used varied rod and hook qualities but each tended to have up to three rods. The average fishing set was bought at a cost of R500 and each fisher used an average of two rods. They mostly caught carp and catfish. The fishers bought their inputs from local shops (e.g. rods, hooks, bait). Unlike with the other cases, a freezer was not important for commercial enterprise in Voëlvlei. Artisanal fishers went out fishing 3 times a week, usually during weekends (most are farm workers who do fishing during off days or after work), with each fishing expedition taking them an average total of four hours. Fishing usually took place during summer months as it was reported that fish does not bite during May to August (winter months).

The size of the fish in the catch ranged between 750 g and 1 kg due to the limited strength of their equipment. However, there were reports of anglers having caught catfish weighing 22 kg. When fishers sell their fish to the consumers, prices depended on the fish type and size but carp ranged from R20-R30 while catfish ranged from R30-R50 per fish. As in the other cases, the price was initially based on the seller's visual assessment and determination, and then later through negotiation between the fisher and buyer. A sample of artisanal fishers estimated that their catch per trip averaged 13 fish which produced a gross revenue of R300. Even though the fishers had fridges, these were mostly for storing their subsistence portion. The marketing of catfish was usually through word of mouth among regular contacts even though some fish was also sold along the nearby highway.

3.5.2 Governance and power relations within the value chain

The concept of governance in MVCs refers to the ability of lead organization units to organize the activities along a chain and their ability to control the distribution of resources (including labour) within it. Early literature used to identify the governance bearings in value chains by making a dichotomous categorization of the latter. On the one hand, in buyer-driven chains, retailers and marketers of final products exert the most power through their ability to shape mass consumption via dominant market shares and strong brand names. On the other hand, in producer-driven chains, power is held by final-product manufacturers and is characteristic of capital-, technology- or skill-intensive industries. However, as similar power relations could be found in aspects of both value chains, current typologies of governance structure include five different categories according to high or low levels of informational complexity, ease of codification of information, and supplier capabilities. The five network forms of governance identified are: classic markets, modular, relational, captive and hierarchies (see Gereffi et al., 2005 for more details). In these network forms of MVC governance, the lead firm exercises varying degrees of power through the coordination of suppliers without any direct ownership of the firms. Analyses typically explore monopoly or monopsony power[19] to set market prices, the power of bargaining between buyers and sellers, and sub-optimal contracting. In this study, qualitative methods were used to provide indications of the inequalities in bargaining power and the role that larger organizational units and intermediaries play in determining the terms of exchange.

Fish from Flag Boshielo, Pongola and Voëlvlei dams is not a unique product and is subject to competition. With competition comes loss of power. Thus, artisanal fishers and fish vendors are not leaders in the fish value chain. They operate in a classic market type of value chain governance where the degrees of explicit coordination and power asymmetry are low. In classic market value chains, market linkages do not have to be completely transitory, as is typical of spot markets; they can persist over time, with repeat transactions. The essential point is that the costs of switching to new partners are low for both parties.

[19] Monopoly refers to a market structure characterized by a single seller (or producer), who sells a unique product in the market and effectively controls market supply. The seller/producer (or a group of producers acting in concert) typically controls the supply of a product or service, keeps the prices high (to maximise profits) and prevents or highly restricts the entry of new producers. Monopsony refers to a market similar to a monopoly except that one large buyer typically inter-faces with a number of sellers (or producers), controls a large proportion of the market, dominates the price action and drives the prices down.

3.6. Gender Segmentation Analysis

The first step to examining gender relationships in value chains is to identify where men and women are located throughout the chain. An initial mapping should attempt to capture both the absence of women as well as their presence. The absence of women usually indicates strong gender-constraints (Gammage et al., 2009).

Analysis of sex segmentation involves a breakdown by gender of the number of people in various organizational units. The prevalence of gender segmentation by unit can be easily read from the resulting table. Tables 3.1 to 3.3 show the gender segmentation in the Pongola, Flag Boshielo and Voëlvlei dams fish value chains.

Table 3.1. Participation in the Pongola dam fish value chain

	Men	Women	Total	%Female
Fishing	30	0	30	0
Processing	0	27	27	100
Warehousing	0	27	27	100
Retailing	0	27	27	100
Total	**30**	**81**	**111**	**73**

Source: Own Computations from field data

Table 3.2. Participation in the Flag Boshielo dam fish value chain

	Men	Women	Total	%Female
Fishing	730	84	814	10
Processing	730	84	814	10
Warehousing	730	84	814	10
Wholesaling	730	84	814	10
Retailing	730	84	814	10
Total	**3,650**	**420**	**4,070**	**10**

Source: Own Computations from field data

Table 3.3 Participation in the Voëlvlei dam fish value chain

	Men	Women	Total	%Female
Fishing	194	6	200	3
Processing	194	6	200	3
Retailing	194	6	200	3
Total	**582**	**18**	**600**	**3**

Source: Own Computations from field data

It is clearly discernible from inspecting the proportions in Table 3.1 that the only function with a predominance of men in Pongola is fishing. Thus, women dominate the Pongola fish value chain. However, the above metrics only speak to the involvement in the stages of value addition rather than speak to whether women are getting most of the value in the chain. In many cases, women are required in several value addition stages but their rewards remain insignificant compared to men's. In the case of Flag Boshielo and Voëlvlei, the value chains are dominated by men.[20]

To date the GATE value chain analyses have demonstrated that the most vulnerable actors in the value chains occupy the least secure employment, and have limited opportunities to upgrade their production or change the terms and conditions of their labour and product exchange. Women are not visible in many activities even though their labour may be critical for particular nodes or segments of the chain. Women may be concentrated in the more flexible and insecure nodes of the value chain. Furthermore, insecurity in the chain is likely to be equated with low incomes and a greater vulnerability to poverty. The position of women could be further diminished by the growth of global production networks which have been linked to rising levels of income inequality, within and between countries, mainly due to the dynamics of rents in global value chains, which are increasingly determined by intangible assets (such as copyrights, brand names and design) as more tangible barriers to entry in manufacturing have tended to fall (Gereffi, 2013).

In a value chain, upstream refers to the actors and operators toward the initial stages of product development. When we consider the first five functions (fishing, processing, warehousing, wholesaling and retailing) of the value chain, men and women are in entirely different sectors or occupations in Pongola while they are jointly involved in Flag Boshielo and Voëlvlei. In Pongola, the functions undertaken by women are more labour intensive while those undertaken by men are capital intensive. Besides the traditional system of beliefs, this situation also demonstrates the combination of resilience and preferences between men and women. As with other occupations elsewhere, women vendors in Pongola are more insecure and liable as a result of upstream gender segmentation. While in other value chains women's insecurity is more likely to be as a result of being contracted under informal arrangements for lower wages, the fish vendors spend long days selling fish for which they will get little margins. Even though, there is participation by women across all functions in Flag Boshielo and Voëlvlei, the proportions are negligible and yet statistics show that there are more women-headed households than male-headed households in the area.

This study makes a finding similar to the value chain analysis conducted by GATE and others that women are often disproportionately located in the more insecure nodes of the chain. As a result, women are also more likely to earn lower returns and be more vulnerable to poverty. The efforts by the Water User Association in Pongola to provide resources under the forthcoming Business Plan, ring-fence the fish vending turf for the women, and regulate the cost of fish stock purchases to improve the women's margins are a step in the right direction. As indicated earlier, there is also a need to generate monopoly power for the women through an effective marketing cooperative accessing niche markets for them to further enhance the margins from the activities they are involved in. A complementary intervention would be the adoption of weight-based pricing of fish. As in Flag Boshielo and Voëlvlei, Pongola women must be given an opportunity to participate in fishing alongside men. This is likely to improve their incomes as the fishing function tends to generate higher value addition. In Flag Boshielo and Voëlvlei, there is a need to help more women participate in fishing. The required support in this case would be technical expertise and equipment.

[20] The analyses in this section can also be conducted using the Duncan Index (D), a summary statistic which allows for easy measuring of gender segmentation across the entire value chain (Blau et al., 2012; Hegewisch et al., 2010; Duncan, 1955).

Looking ahead, there are conceivable future threats to Flag Boshielo, Pongola and Voëlvlei dams' fish once the ongoing initiatives to enhance its value succeed. Highly valued fish will attract stakeholders who have not previously been involved in fishing. For example, if more men were to enter the fish value chain in response to lucrative prices without proper ecological training (and hence huge preference to use gill nets) then they could temper with the ecological thresholds and possibly degrade the fish resource in the dams. As many women currently rely on fish caught by men, a degraded resource could either pose a loss of income generating possibilities for women vendors or a reduction in affordable sources of protein.

Women remain marginalised within the small-scale fishing sector, both in terms of their fishing-related activities and their role in decision-making processes. A lack of access to credit, water and adequate sanitation, low levels of literacy, vulnerability to HIV/AIDS, low bargaining power, access to and management of the fishery resources, are just some of the effects of the marginalization of women in the sector. An underlying problem is that women are excluded from decision-making processes at all levels, from community level to state level.

3.7. Distributional Analysis of Gendered Value Chains

3.7.1 Costs and benefits in the value chain

The analysis of costs and benefits needs to be undertaken for each of the sets of actors to produce a rough estimate of the gross profit secured by each representative actor. Of special interest are the costs and benefits for the fishers and vendors. The study uses the average of figures collected from a sample of fishers and vendors. The financial cost of inputs were adopted from those respondents who reported market transactions. Tables 3.4 to 3.6 present the breakdown of the variable costs of representative actors in the sector in Pongola, Flag Boshielo and Voëlvlei.

Table 3.4. Breakdown of the variable costs of a representative actor in the Pongola fish value chain

	Financial Costs /fishing trip (R)	**Purchase Costs /unit (R)**	**Time Commitment /fishing trip (Hours)**
Inputs for Fishers			
Fuel/fishing trip	280	14/litre	
Own labour/fishing trip *or* Helper's labour/fishing trip	200 900	4,000/month min wage 4,000/month min wage	9 9
Food/fishing trip	100		
Gillnet/trip	25	1,500	
Boat/fishing trip	20	10,000-20,000	
Inputs for Fish Vendors			
Labour/fishing trip	1,000	4,000/month min wage	54
Buckets/fishing trip	10	35/bucket	
Cost of fish stock/fishing trip	3,000		

	Financial Costs /fishing trip (R)	**Purchase Costs /unit (R)**	**Time Commitment /fishing trip (Hours)**
Transport/fishing trip	130	10/taxi trip	
Fridge/fishing trip	10	4000/fridge	
Ice/fishing trip	180	13/5 kg packet	
Electricity/fishing trip	20	120/month/household	

Source: Own Computations from field data

Table 3.5: Breakdown of the variable costs of a representative actor in the Flag Boshielo fish value chain

	Financial Costs /fishing trip (R)	**Purchase Costs /unit (R)**	**Time Commitment /fishing trip (Hours)**
Fishing (Line)			
Own labour/fishing trip	200	4,000/month min wage	8
Fishing gear	2	500 per set	
Bait/fishing trip	30		
Fishing (Net)			
Own labour/fishing trip	200		8
Gill net/fishing trip	15	1,200 per set	
Boat/fishing trip	1	1,700 per set	
Processing			
Labour/fishing trip	40	4,000/month min wage	1
Warehousing			
Fridge/fishing trip	10	4000/fridge	
Electricity/fishing trip	20	120/month/household	
Wholesaling			
Transport/fishing trip	150		
Retailing			
Labour/fishing trip	200	4,000/month min wage	8
Buckets/fishing trip	10	35/bucket	
Transport/fishing trip	60		

Source: Own Computations from field data

Table 3.6: Breakdown of the variable costs of a representative actor in the Voëlvlei dam fish value chain

	Financial Costs /fishing trip (R)	Purchase Costs /unit (R)	Time Commitment /fishing trip (Hours)
Fishing (Line)			
Own labour/fishing trip	100	4,000/month min wage	4
Fishing gear	2	500 per set	
Bait/fishing trip	30		
Processing			
Labour/fishing trip	25	4,000/month min wage	1
Retailing			
Labour/fishing trip	100	4,000/month min wage	4

Source: Own Computations from field data

3.7.2 Value added in the value chain

The analysis of value added is designed to depict the distribution of returns throughout the value chain. The value added is the difference between the total revenue and the cost of bought-in (intermediate) raw materials, services, and components. The difference measures the value which actors have added to materials and services through a specific stage of production and/or processing.

3.7.2.1 Pongola Dam

Table 3.7 shows the value added calculations for selected actors across two different routes through which fishing takes place in Pongola Dam

Table 3.7: Breakdown of the value added of a representative actor in the Pongola dam fish value chain

Actor	Costs/trip	Revenue/trip	Value Added/trip
Route 1: Own Labour			
Fishers: Fishing	R 625	R3,000	R2,375
Vendors: Processing, Warehousing, Retailing	R4,350	R6,000	R1,650
Route 2: Helper's Labour			
Fishers: Fishing	R1,325	R3,000	R1,675
Vendors: Processing, Warehousing, Retailing	R1,650	R6,000	R1,650

Source: Own Computations from field data

In accounting sense, fishers in Pongola purchase inputs (excluding labour) worth R425 per fishing trip. In route 1, the fishers do the fishing themselves at a labour cost of R200 per fishing trip resulting in total input costs of R625 per fishing trip. Given that fishers make an average revenue of R3,000 per trip their value added is R2,375. At a rate of about three trips per week, fishers can potentially earn a monthly profit of R28,500, an amount which is seven times higher than the minimum wage[21]. In some ways, these statistics show how rural livelihoods can be improved through access to fish resources in inland fisheries. In the same way, they assist in showing how modest investments in building fish stocks in dams can change the face of poverty in rural areas across the country.

Route 2 reduces the value added for the fishers even though it also creates employment for other members of the community. The fishers sacrifice R700 from their valued added in order to create employment. At a rate of about three trips per week, helpers can potentially earn a gross monthly remuneration of R8,400, an amount which is double the minimum wage.

Regardless of the route taken by the fishers to catch fish, on average, the vendors put a mark-up of 50% on cost price and sell the fish to consumers at a gross revenue of R6,000 for an average stock of fish caught in a fishing trip by a typical fisher. The vendors incurred average inputs costs of R4, 350 in selling an average stock caught in a fishing trip by a typical fisher. Thus, on average, a vendor generated a value added of R1,650. On average, each vendor can handle stocks from four typical fishing trips every month thereby generating a monthly profit of R6,600 which is about one and half times the minimum wage. Considering that this amount is over their normal wage from fish vending, the fisheries contribute significantly to the livelihoods of fish vendors as well. It can however be noted that most of the value of fish currently rests with the fishers thereby justifying interventions by the Water User Association to prevent them from upstream functions so as to share the rents with the women in the communities adjacent to the dam.

The value added needs to cover for the factors of production used to produce it. In the case of the fishers and vendors, the major cost which needs to be accounted for is their human capital particularly entrepreneurship. There is evidence of a return on entrepreneurship across the two major categories of functions in the Pongola fish value chain namely fishing, and processing, warehousing and retailing. Compared to other business models, it seems that the value added of Pongola fish ought to be enhanced. Besides marketing, one strategy for capturing a greater proportion of the final price and increasing value added is to target niche markets such as lodges in Jozini or outlying towns with higher purchasing power.

3.7.2.2 Flag Boshielo

The value added for gill-net and line fishing in Flag Boshielo Dam are shown through the value added calculations for linefish and gillnet fishing actors in the dam as computed in Table 3.8.

[21] Effective 1st March 2020, the National Minimum Wage (NMW) for each ordinary hour worked was increased to R20.76 in terms of Government Gazette No 42965 of 22 January 2020

Table 3.8: Breakdown of the value added of a representative actor in the Flag Boshielo Dam fish value chain

Actor	Costs/trip	Revenue/trip	Value Added/trip
Line fishing			
Fishing	232	Integrated	
Processing	40	Integrated	
Warehousing	30	Integrated	
Wholesaling	0	Integrated	
Retailing	270	700	128
Gill net fishing			
Fishing	216	Integrated	
Processing	40	Integrated	
Warehousing	30	Integrated	
Wholesaling	150	1400	964

Source: Own Computations from field data

On the one hand, line fishing provides a revenue of R700 for an 8-hour fishing trip where a full 25-litre bucket of fish is caught and later sold during an 8-hour day. The total costs of the integrated firm are R572 and hence yield a total value added of R128. On the other hand, gill-net fishing provides a revenue of R1,400 for an 8-hour fishing trip where two full 25-litre buckets of fish are caught and later sold all at once to a trader. At a rate of about three trips per week, line and gill-net fishers can potentially earn a monthly profit of R1,536 and R11,568 respectively. The fishing business provides the gill-net fishers with three times the minimum wage whereas line fish provides less than a third of the minimum wage. Even though this can be viewed as a contribution to livelihoods and poverty reduction, however the sensitivity of the fish resource in Flag Boshielo (see chapter 2) entails that this is in fact a contribution to the fish resource degradation.

A fisher selling his catch from Flag Boshielo by the roadside (source; E. Muchapondwa)

3.7.2.3 Voëlvlei Dam

The value added for line fishing in Voëlvlei Dam is computed in Table 3.9 below.

Table 3.9: Breakdown of the value added of a representative actor in the Voëlvlei dam fish value chain

Actor	Costs/trip	Revenue/trip	Value Added/trip
Line fishing			
Fishing	132	Integrated	
Processing	25	Integrated	
Retailing	100	300	43

Source: Own Computations from field data

Line fishing provides a revenue of R300 for a 4-hour fishing trip where about 13 fish are caught and later sold during a 4-hour day. The total costs of the integrated firm are R257 and hence yield a total value added of R43. At a rate of about three trips per week, line fishers can potentially earn a monthly profit of R516. Thus, fishing is not yet an activity that small-scale fishers can rely on to serve their monthly financial income needs. Indeed, most fishers engage in the activity on a part-time basis. However, the possibility of expanding the dried fish markets for fish from the Western Cape into the Cape Metro area and across the country's borders holds promise for lucrative value chains for Voëlvlei fish.

3.7.3 Potential future routes for rents for communities

There are other routes which have not been addressed explicitly in this study. These are considered a sources of future opportunities for local communities to tap into the broader Flag Boshielo, Pongola and Voëlvlei fish value chains. For example, recreational fishing extracts rents from the fish resource in the three dams. Other ways in which local communities can benefit from them is through a strategy of sharing benefits from recreational fishing with all communities adjacent to the dams. There are various models for such benefit-sharing schemes: either the communities can benefit from the actual recreational fishing activity (e.g. a levy for utilizing the dam for recreational fishing) or from the broad rents generated when recreational fishers are hosted in adjacent town (e.g. a levy on all local revenues received from recreational fishers by lodges in the area). The estimated minimum daily expenditure for recreational fishing in the three dams is R5, 000. For fishing competitions that attract about 100 anglers, this translates to about R500,000 daily expenditure. A one percent levy on that would generate R5,000 which is enough to subsidize the local community with 10 fishing sets.

An analysis of multipliers and spillovers provides an estimate of the role that a sector plays in stimulating other economic activities. Backward linkages represent the sum of all input purchases from other local and national industries by a particular sector expressed as a ratio of total sales, while forward linkages are the amount of purchases by other local industries from a particular sector. This analysis is important to understand the actual and potential contribution of the value chain to poverty reduction or stimulating economic growth. However such analyses are data intensive and this study did not have the means to generate the necessary data. Nevertheless, it can easily be concluded that the linkages of this value chain with the national economy are currently very dense because the majority of inputs are made locally, a fact that magnifies the size of the multipliers.

3.8. Institutions for Pro-Poor Market Value Chains

3.8.1 Problem tree analysis

The problem tree analysis highlighted the factors affecting entry by rural women and men into lucrative inland fisheries MVCs. The main factors that constrain fishers from participating in lucrative inland fisheries MVCs are centred on their inability to assure quality standards and consistency of delivery.

Formal markets have stringent requirements in terms of grades, standards, business practices, prices and ownership. These markets will insist on high product quality and the associated high processing and safety systems. This is significant given the poor water quality concerns around a lot of the rivers feeding the dams where the fish is caught, e.g. documented poor water quality in Voëlvlei dam and the pollution in Loskop and Flag Boshielo Dams (Chapter 2).

Beyond quality requirements, fishers are generally unable to assure a consistent supply of the required volumes of fish. Fishers who have previously participated in formal markets had contracts cancelled due to the inconsistency of the volume delivery.

The factors contributing to the inability of fishers to assure quality standards and consistency of delivery are well documented (e.g. Jordaan and Grové, 2012). They include the small scale of operations, insecure fishing grounds and fishing rights, lack of access to credit, high transaction costs, and the lack of support around stringent grade, standards, business practices, prices and ownership requirements. However, some success stories have been documented by Hendriks and Lyne (2009), Louw et al. (2008), Louw, Vermeulen and Madevu (2006), Bediako and Debrah (2007), Ewert, Eva and Hamman (2006), and Sartorius and Kirsten (2002).

A number of key success factors were also identified and prove to have great potential to contribute towards the successful participation of rural women and men into lucrative inland fisheries MVCs. These factors include effective collective action among fishers and support to fishers; secure fishing grounds and tenure of fishing rights; and tailor made financing schemes.

3.8.1.1 Effective collective action among fishers and support to fishers

The results from this study show that fishers can substantially improve their cash flow positions by upgrading their positions in the fish value chain. There are several ways in which artisanal fishers and fish vendors can upgrade their positions in the fish value chain:

Niche markets

One of the ways to reap more benefits would be for the fishers and vendors to create monopoly power over their product and sell it to niche markets. With good marketing among the lodges and nearby towns, the fishers and vendors can become a strong force to reckon with. They can eventually become leaders in a supplier-driven value chain. However, there are several things which are needed for this to be realized. First, the fishers and vendors need to operate more collaboratively especially at the marketing stage. Such collaboration might also engender collaborations at the production stage. This would be ideal in as far as such collaborations help protect economic and ecological balance in the use of natural resources. The best form of collaboration could come through the establishment of a marketing cooperative or some form of Small, Micro to Medium Enterprise (SMME). This way, the fishers and vendors will sell their produce together and create the desired monopoly position. There is a platform for doing this in Pongola as fishers and vendors belong to the Sizabantu (i.e. helping people) cooperative. Such an arrangement would be difficult in Flag Boshielo and Voëlvlei because of the numbers involved. However, they could potentially be assisted to take over the space currently occupied by the informal recreational anglers from larger towns who are essentially exploiting the fish resource on a predominantly commercial basis.

Second, the fishers and vendors will need more corporate management skills to operate in the new dispensation as they have currently operated as individuals and with different objectives mainly led by subsistence motives. They need to be equipped to operate within an increased commercial setting. Examples of facilitation required include provision of cold storage facilities, advance payments made against fish in storage, liaison and contracting arrangements with niche buyers. In some ways, the forthcoming Business Plan for Pongola dam could assist with this.

Third, the fishers would need appropriate equipment to deal with the environmental sustainability of their fishing. While monopoly power potentially gives power to set extraction rates at sustainable levels there is also a need to make sure that any allowable harvest does not pose threats to the fish resource. The issue of boats and appropriate nets could be addressed through the forthcoming Business Plan for Pongola dam.

Weight-based pricing
Several differences were observed in fish samples obtained from the fishers and vendors. It was generally the case that any two samples with the same price from each fisher and vendor had different masses. One example recorded seven fish that were sold for R20 each with masses of 100 g, 110 g, 120 g, 150 g, 170 g, 180 g and 190 g. Similarly, it was generally the case that no two samples with the same price from different fishers and vendors were the same. From the mass differences, the study concluded that fishers and vendors are selling fish at different prices per kilo. A move to weight-based pricing therefore presents one way in which women can generate more revenue from their produce. As women move towards the concept of the marketing cooperative there could be standardization of prices.

3.8.1.2 Secure fishing grounds and tenure of fishing rights
Fishing grounds and fishing rights for rural inland fishers are highly contested.[22] A key success factor is the diffusion of challenges associated with that. Jordaan and Grové (2012) similarly suggest security of tenure as a key success factor in respect of emerging farmers' access to commercial agri-food value chains. Secure fishing grounds and tenure for fishing rights provide an incentive for inland fishers to invest in their fishing enterprises. Secure tenure also has some spin-offs that contribute towards overcoming factors affecting entry by rural women and men into lucrative inland fisheries MVCs. Secure fishing grounds and tenure of fishing rights may give fishers access to credit to supplement their cash flow. Accordingly, secure fishing grounds and tenure of fishing rights may enable fishers to intensify their fish production activities by deploying the most appropriate fishing effort. Secure fishing grounds and tenure of fishing rights will also allow enterprising fishers to expand the scale of their production by employing other fishers who do not want to invest in fishing heavily. Fishers who are merely interested in preserving their cultural fishing heritage and earn an income will therefore be able to take part in fishing by providing casual labour to local fishing enterprises.

3.8.1.3 Tailor made financing schemes
South African legislation bars the use of fishing nets in inland fisheries. Law enforcement has been strict with respect to infractions of this law at the three selected dams. The law however allows fishers to use rod, line and hook. Commercially-oriented rural fishers have complained about the limited business opportunities provided by line fishing. They have to invest huge amounts of effort in limited areas to derive tangible profits. This has led a lot of them to resort to breaking the law around the use of fishing nets. Almost all fishers at Flag Boshielo and Pongola dams making tangible profits were using fishing nets. The success factor related to the enabling environment in this respect would be the provision of tailor made financing schemes to give fishers access to credit to invest in productivity-enhancing fishing gear. The typical profiles of fishers make them ineligible for credit from financial service providers. It may be easier to create a tailor made financing product that suits the circumstances of fishers. It would be ideal if the credit is tied to investment in fishing gear.

The factors affecting entry by rural women and men into lucrative inland fisheries MVCs are very much integrated. An integrated approach needs to be followed to overcoming them. In many cases, the means to overcoming certain factors may reside in different institutions.

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[22] In contrast with South Africa's marine fisheries, which are governed by the Marine Living Resources Act, inland fisheries lack supporting legislation that is constitutionally aligned. The National Environmental Management Act (NEMA) provides for sustainable development and equity through natural resource access, but a policy on inland fisheries governance flowing from these principles is lacking. This is problematic, as fishing on inland waters is primarily governed as a recreational activity based on biodiversity considerations, while fishing rights for livelihood purposes are not provided for in existing legislation and policy (Britz et al., 2015).

Therefore, coordination of efforts would be necessary to provide holistic support to the rural women and men fishers.

3.8.1.4 Africa food shops as outlets

There are many African food shops in the Cape metropolis that sell fish and other products for the more than 100 000 immigrants in the Cape Town CBD. The shops are in areas such as Maitland, Mowbray, Observatory, Belleville, Salt River, Woodstock, etc. For example, in a two-kilometre stretch on Voortrekker Road in Maitland, there are four African food shops. The African food shops sell a variety of items including fish. The fish is either frozen or dried. There are both local and imported varieties. The local fish varieties are limited and usually consists of hake, red snapper, etc. They are always sold frozen. The local and imported fish varieties include catfish, stumpnose (According to the WWF sassi, the stumpnose is not considered saleable fish in South Africa due to its endangered status), tilapia, Thomson, maasbanker, Titus, mabundu, mackerel, angelfish, makayabu, etc. While varieties such as stumpnose are always sold frozen, catfish and tilapia are available in both frozen and smoked dried forms. The specialty of the shops seems to be the dried ones. The shops reported that they source the dried fish from Malawi, Zambia Zimbabwe and the Democratic Republic of Congo.

The immigrants in Cape Town have a per capita expenditure on African cultural food products of R5 000 per migrant per year with a market value of R500 million a year. The market remains undersupplied with the bulk of products entering SA as illegal cargo from Southern and Central Africa. The feasibility study collected data on African food items, including plants and fish products, to provide a clear indication of both the demand for products and the potential for local agriculture and fisheries to supply in the demand. The data indicated that fish protein comprises up to 80% of traditional animal protein intake and that the preference was to eat freshwater fish twice a week. The sales potential of these selected outlets was estimated to be between 25 to 30 tons a month.

The feasibility project caught Tilapia, Catfish, Carp from local dams using long lines, nets and electrode boat. These were processed into various traditional forms including brining, drying and smoking and sold on to the market via three Africa shops in Cape Town in order to assess the market dynamics on a small scale. The results suggested that the current market is not yet accustomed to fresh water fish in the frozen format, which is mostly consumed in either a fresh or preserved form. Similarly, carp as a species is not commonly found in Africa, though it has become readily available in the local market. The project subsequently focused on the supply of fresh tilapia, carp and catfish as well as traditionally smoked catfish.

Fresh catfish was popular in the target market. Catfish culturally is sold either live or in a smoked form. In the Western Cape it is illegal to transport catfish live. This provides for a limited market reach but still the market exists to absorb fresh catfish in large volumes of up to 50 tons per month. Smoked forms of catfish are the most popular form of fresh water fish product within in Southern and Central African regions. However, the project discovered that smoking of catfish does not always increase its value compared to the fresh product. The smoked catfish is used as a flavoured dish in the traditional stews that is prepared. Local shops have a problem securing a fresh and reliable supply of smoked fish. Products are often smuggled into the country with problems experienced in terms of poor food safety and quality standards. The shops also stock salted carp that is prepared according to traditional methods, similar as tilapia. The carp was mainly fish from local dams around Cape Town as entrepreneurs realized the market potential for such a product.

Currently there is no formal import avenue for traditional African fish produce, e.g. for smoked catfish. The supply chain is dominated by the informal trade and most supplies are smuggled over the border (Jimu, 2018; Ndofor Epo, 2018). The main reason for the illegal trade is that these products do not adhere to South African food safety standards. Imported products are sold per packet containing two fishes with a weight of approximately 400 g were selling at R25 per bag, whilst acquired at R17 a bag. The fish is wrapped in a small plastic bag and tied. The Project supplied fish ranging from R17 to R20 per bag. Larger fish of approximately 3kg live weight were sold at R35 per fish, which was a lower price (R12/kg) in terms of live weight compared to the smaller sized fish (R17/kg). Data showed that the fish lose up to 60% of weight during the traditional hot smoking process. This implies that the two smoked fish per bag with a combined weight of 400 grams, equates to a combined fresh weight of approximately 1 kg, with an equivalent retail value of R25/kg.

The market in South Africa is currently undersupplied with severe shortages of fresh water fish among these migrant cultural groups. This has led to the illegal importation of large quantities of freshwater fish products, often inferior in quality, in an effort to supply the market needs. This situation provides a unique opportunity to supply the market needs through the harvesting, processing and distribution of local freshwater fish species. The situation also provide a unique opportunity to establish sustainable local businesses linking rural fisheries resources to urban market demand, thereby creating job opportunities, improved food security and better livelihoods amongst disadvantages communities in South Africa.

The foregoing indicates that there is a market for fish which might be produced from Voëlvlei dam. However, the governance structures for small scale fishing will need to first be strengthened before the immigrant market can be tapped into, Going into the future, the institution needed to clear the path for rural fishers' entry into lucrative MVCs is an SMME similar to that proposed for Pongola dam. The enterprise needs to be capitalized through the facilitation of the Western Cape Department of Agriculture. The fishers and vendors would get shares in the enterprise and employment as well. Some of the women will need to be trained to start fishing. All members would be paid wages aligned with their performance in bringing fish stocks to the enterprise or marketing that fish for the enterprise. As the enterprise is set to generate better revenues through better linkages with lucrative MVCs especially those involving immigrants in South Africa and Africans in other countries, members will periodically get dividends which demonstrate the premium for following the SMME model. The Voëlvlei enterprise seems better geared towards carrying out value-addition activities and moving products to distant high-value locations in light of the results from the feasibility project. As the feasibility showed, line fishing alone would not generate enough revenues. Fish netting could be considered subject to prescription of the right mesh sizes. The need to manage the invasive alien species in Voëlvlei creates an opportunity to link rural fishers into lucrative MVCs. Indeed, among the key recommendations of the Voëlvlei Dam Resource Management Plan are the containment plan for invasive fish species and assessment of potential for commercial fishing or small scale fisheries.

3.9. Conclusion and Policy Implications

Contemporary international 'best practice' for dam development and 'good governance for Integrated Water Resources Management (IWRM) require dam authorities and/or governments to institute and implement fair and equitable benefit-sharing and compensation measures. The South African Constitution also requires the redress of results of past discrimination, which includes discriminatory access to benefits from recreational and other inland fisheries. There is therefore a valid case for tapping into ecosystem services and value chains of the recreational fisheries sub-sector as a means for enhancing rural livelihoods. Towards this end, this research sought to map and analyse existing value chains for inland fisheries in Flag Boshielo, Pongola and Voëlvlei dams and explore efforts to enhance the contribution by inland fisheries to rural resilience.

Inland fisheries are currently estimated to generate a monthly profit of R28, 500 for fishers and R6, 600 for fish vendors in Pongola; a monthly profit of about R1, 500 for line fishers and R11, 500 for gill-net fishers in Flag Boshielo; and a monthly profit of R516 for fishers in Voëlvlei. Obviously, the main value of the three inland fisheries is not just the commodity value of the landed tonnage, but lies in 1) the food security and sustainable livelihood benefits to rural communities and 2) the socio-economic benefits of the tourism and equipment supply value chains associated with recreational fishing. There are opportunities for benefit sharing schemes with local communities in respect of output or expenditures associated with recreational fishing. The fisheries policy needs to facilitate the recognition of all values associated with inland fisheries and craft mechanisms for sustainable inclusion.

Legal recognition of the use of inland fisheries for socio-economic benefit and the support of rural livelihoods is required. Inland fishery policy must take into account the historical inequity in access to inland fisheries and promote development interventions that empower disadvantaged rural communities. Furthermore, inland fishery policy needs to be based on a value chain approach in order to maximize the socio-economic benefits. The recreational fishing value chain linked to the tourism service sector is the most economically valuable component of inland fisheries. Subsistence fishing plays a vital food security role in certain rural communities. While the commercial fishing potential of fresh waters is limited, growing illegal fishing on a commercial scale has the potential to marginalise community and recreational fishers from value chain benefits. Public sector interventions that enhance the value of fish to local communities should thus be promoted; for example, equity of access to fishery resources for rural communities and capacity building to participate in all levels of the associated value chains.

Public sector interventions to optimise the socio-economic benefits of inland fisheries thus need to move beyond growing fish production through the promotion of primary fishing operations, to adopting a value chain approach to inland fishery development. This would include strategies for post-harvest value adding, and promoting employment and entrepreneurship opportunities in the tourism-linked recreational fishery sub-sector. The value of harvested fish should also be considered in terms of the welfare savings for the state generated by access to a secure, nutritious and sustainable supply of fish. Interventions which enhance the value of fish for local communities should thus be promoted; for example, equity of access to fishery resources for rural communities and capacity building to participate in all levels of the associated value chains.

There is a need to promote preferential treatment of marginalized groups – in providing services, and in instituting rights. In particular, women within small-scale fisheries should be empowered and encouraged to set up their own groups, organizations and networks. Measures to improve women's access and involvement in the entire value-chain should be implemented. In this regard, gender disaggregated statistics should be collected to better describe women's work in all aspects of the value-chain and to identify gender gaps in the sector.

Instead of viewing strict enforcement by provincial agencies as a barrier to participation in lucrative MVCs, fishers must adopt strategies that will allow them to overcome challenges they face in their existence and operations. Collective action through cooperatives or SMMEs has a major role to play. Fishers should institute own resource-friendly fishing rules that will improve collective action and enhance the sustainability of fishery resources in their area.

Fishers should consider ways of moving their product from the dam to places where they get high value for it. Some of the important markets for fishers at the selected dams were nearby and distant towns. There is a need to ensure that freshly-consumed products reach these places on time and processed products reach them in acceptable quality. Demand needs to be met consistently as there have been reports of lodges that had to cancel lucrative contracts with individual fishers because they could not supply the quantities as specified thereby disappointing expectant customers. The above requirements demand clean processing facilities, refrigerated storage, refrigerated transport and a critical mass of fishers targeting to sustainably satisfy demand at all times.

Fishers at the selected dams have mostly sold their fish fresh or frozen. Some research reviewed showed that there is a growing lucrative market for dried fish. More research and development in technologies for drying fish are required to allow fishers to reap greater benefits from their trade. The very nature of small-scale fishing (i.e. low levels of financial and human capital) means that fishers typically do not exhibit the necessary means to adopt new sophisticated technology. In the context of poverty alleviation, food security and rural development, government policy could play a facilitative role on this front.

Each of the selected dams has several stakeholders and the value chain maps have equally uncovered several regulatory and support influencers. There should be a high degree of coordination between the different stakeholders when implementing respective interventions aimed at helping fishers move into lucrative MVCs. Uncoordinated implementation of interventions may prevent fishers from achieving optimal benefits.

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CHAPTER 4. MANAGEMENT AND GOVERNANCE ARRANGEMENTS FOR SOUTH AFRICAN INLAND FISHERIES

Peter Britz and Mafaniso Hara

4.1. Introduction

In this chapter we evaluate the current governance and co-management arrangements for inland fisheries in the light of the project findings in respect of the production potential of inland waters, regulatory issues and market value chains. We make recommendations for future governance and management arrangements, paying particular attention to institutional requirements, and the current capacity of the public sector and stakeholder groups. The recommendations will contribute towards the implementation of the inland fisheries policy, which is ready for approval by cabinet and parliament (DAFF, 2016).

South Africa has committed to an ecosystem approach for the governance and management of its fisheries; which flows from the environmental right in the Constitution and the National Environmental Management Act (NEMA) (Act No. 107 of 1998); and which prescribes a sustainable development approach. The ecosystem approach incorporates the ecological, social and economic aspects of a fishery into the governance and management arrangements. This represents a major departure from the historic 'command and control' governance style that characterised environmental management before the democratic constitutional legislation was introduced. Changing the governance and management culture within state environmental institutions remains a work in progress as reconciling ecological, economic and social imperatives to implement a sustainable development approach is a challenge for staff within state environmental organisations who see their mandate primarily as ecological protection.

In the following sections, we outline the fundamental governance concepts underpinning the ecosystem approach followed by the present methodological approach.

4.1.1 Co-management (or co-governance)

Evidence worldwide shows that top-down state-run fisheries management schemes have not produced the intended goals of sustainable fisheries management, particularly for small scale fisheries. Such schemes tend to be costly to implement, especially for developing countries with limited resources. In addition, the autocratic nature of state-based management does not take users' perspectives into account resulting in systems that users do not accept or may even find illegitimate. Governance models based on user participation are therefore seen as providing a more viable alternative which fulfils the participatory criteria of the ecosystem approach to governance. Interest in user involvement in management is also related to resurgence of interest in grass-roots democracy, public participation, and local level planning; broadly referred to as 'co-management'.

A number of terms are used interchangeably to refer to co-management, for example, co-operative management, collaborative management, joint management, participatory management, multi-stakeholder management, etc. The governance approach uses the term ' co-governance' (Bavinck, et al., 2005). The widely accepted definition for co-management is one adopted by the IUCN World Conservation Congress, in October 1996, in Montreal which refers to co-management as:

> *"a partnership in which government agencies, local communities and resource users, non-governmental organisations and other stakeholders share, as appropriate to each context, the authority and responsibility for the management of a specific territory or a set of resources."*

Three arguments are used to justify increased adoption of co-management, visibly: 1) affected interests should be heard; 2) information from users could result in improved management decisions; and 3) that co-management would improve legitimacy of management systems, thereby reducing "transaction costs". In addition, there is growing recognition among managers and politicians that no management scheme will work unless it enjoys support *of those whose behaviour it is intended to influence.* Evidence also shows that if users willingly accept regulations as appropriate and consistent with their existing values, a regulatory framework will gain legitimacy with users and that regulatory schemes that have high legitimacy among users face reduced problems of non-compliance with the regulations. It is in this area of securing *legitimacy*, that co-management is viewed as a better resource management approach for fisheries than top-down approaches (Jentoft, 1989).

Meeting between members of the team and government officials from Mogale Municipality and Limpopo Provincial Government (source – M. Hara)

4.1.2 Governance of renewable natural resources

Governance has been defined as "the norms, institutions, and processes that determine how power and responsibilities over natural resources are exercised, how decisions are taken and how citizens secure access to, participate in, and are impacted by the management of natural resources" Campese (2016:7). Kooiman and Bavinck (2005:17) proposed the concept of 'interactive fisheries governance', which they defined as "the whole of interactions taken to solve societal problems and to create societal opportunities including the formulation and application of principles guiding those interactions and care for the institutions that enable them". The interactive governance concept proposes a shift from the conventional problem-solving approach to approaches that emphasize opportunity creation and the effective handling of the tensions that arise within a fisheries system (Kooiman et al., 2005). The approach also calls for the joint and interactive responsibilities of state, market and civil society. Thus governance should not be a prerogative of government or fisheries managers only, but rather calls for broader responsibility. Importantly, governance is broader than management in that whereas management is perceived as a technical exercise employing means to achieve specific goals (for example Maximum Sustainable Yield – MSY), governance includes also the deliberation and determination of basic relevant values and principles that should underpin the way those who govern and those that are governed define their tasks and roles, and interact (Kooiman and Jentoft, 2009).

Defined and understood this way, governance of renewable natural resources can be complicated and challenging due to multiple uses and users of natural resources, and the subsequent multiple actors involved, with multiple objectives, interests values, and principles. These actors may be located at different administrative levels (e.g. national, district, local and village levels). Both 'formal' and 'informal' institutions (referring to 'rules of the game' – North, 1990) affect the arrangements and performance of natural resource governance.

The introduction of new approaches to governance arrangements (e.g. introduction of Community Based Natural Resource Management (CBNRM) in protected areas, community forest management and fisheries co-management) are often top-down, led by line agency government departments or ministries, and in developing countries usually supported by donor-funded projects. This is inevitable, to an extent, given the size and scale the natural systems and the need for a uniform, equitable approach. In consequence, this does lead to problems in that not everyone who will be affected can be involved in designing and operating a would-be inclusive system and also, it becomes difficult to accommodate and take into account local context cannot.

New governance arrangements can be considered as institutions (i.e. rules of the game according to North, 1990). Unfortunately, when these are introduced, this does not happen in an institutional vacuum. There will usually be already many institutions that affect who can access and benefit from natural resources. Some of these institutions can be associated with natural resources directly (e.g. national and local rules and laws based on formal legislation) and some are not, such as kinship, power relations and gender norms and relations. In effect, new institutions associated with natural resource governance will usually be affected by pre-existing institutions. They may be affected by who gets involved, who takes over the governance and decision-making structures and whether there is acceptance, rejection or modification of the new institutions. The new institutions may exist and synergise with the pre-existing (sometimes referred to as 'institutional bricolage' – Cleaver, 2012). Over time, the same structures (e.g. co-management committees) introduced in different places will look and behave differently, with different outcomes for people and the natural resource depending on whether and how new institutions exist or cannot co-exist/integrate with the pre-existing institutions.

The introduction of CBNRM and collaborative approaches has in some cases been informed by 'common property theory', in particular the 'design principles' associated with Elinor Ostrom (Ostrom, 2008; 1990). The eight design principles were identified from research into collective governance arrangements and suggest how collective action for managing commons pool resources may best be developed and operationalised. These principles are: clearly defined boundaries, rules governing use or provision of the resource must be appropriate to local conditions, collective-choice arrangements, monitoring of rules and use: by users or accountable to the users, graduated sanctions, conflict resolution mechanisms, recognition of legitimacy and nested enterprises (where resources and structures are part of larger systems) (Ostrom, 1990).

4.1.3 Governability

Governability refers to the overall capacity for governance of a system. In the context of fisheries, it is a measure of how governable a particular fishery system is. The governability concept is based on the assumption that there are limits to how governable fisheries are and what level of governability can be achieved. According to Bavinck et al. (2013) and Kooiman (2008) governability *is* 'the overall quality for governance'. The quality of governance is supposedly situated in the *System-to be Governed* (SG) which in the case of a fishery system refers to the whole value chain and the actors/stakeholders in the value chain; the *Governing System* (GS) which refers to the institutions (North, 1990) and organizations that have a steering role in the fishery; and the *Governing Interactions* (GI), that is, how the GS and the SG are linked, interact and relate to one another (Bavinck et al., 2013; Kooiman et al., 2005; Bavinck et al., 2005;). Thus governability is a function of the SG and the GS and the interaction between these two systems. Interactive Governance Theory argues that the SG and GS must be compatible in order to be mutually responsive to one another (Jentoft and Chuenpagdee, 2013). The more proficient the GS, the more amenable the SG, and the more effective the interactions, the higher the quality of governance (i.e. the more governable the system will be). The interactive governance theory sees three opportunities for improved governability; empowerment of the SG, simplification of the GS; and changing the way the two systems interact so that they become more interactive and mutually responsive to each other (Bavinck et al., 2013).

4.1.4 Towards implementation of South Africa's draft inland fisheries policy

South Africa's draft inland fisheries policy is founded on the above principles of good governance and the ecosystem approach to fisheries which is facilitated by the South African constitution. The policy recognises two main categories in the freshwater wild capture fisheries sector, i.e. small-scale and recreational fisheries subsectors. The draft policy incorporates the principles of:

- Co-management/ co-governance
- Sustainable development
- Fisheries are an economic subsector
- Equitable access
- Transformation

- Precautionary approach
- Value chain approach

The policy development process was initiated by the Branch: Fisheries Management under the then Department of Agriculture, Forestry and Fisheries in 2016. In 2019, the fisheries function, inclusive of both marine and freshwater, was transferred to a newly established Department of Environment, Forestry and Fisheries. The draft policy has been subjected to two rounds of intergovernmental and public consultation processes, and has been supported by the Ministerial Technical Committee (MINTECH), and the Minister and the Members of Executive Council (MINMEC) fora.

At the time of writing, the draft policy had obtained Ministerial approval for tabling at National Economic Development and Labour Council (NEDLAC), to be followed by consultations with the Economic Sector, Employment and Infrastructure Development Director-Generals Cluster (ESEID DGs Cluster), the Office of Chief State Law Advisor (OCSLA). It will then go before Cabinet prior to its gazetting for implementation (Haider, 2020).

Following the gazetting of the policy, the governance challenge is the implementation of a completely new, developmentally orientated institutional arrangements to replace the existing provincial nature conservation based fishery governance arrangements which are based on pre-NEMA provincial legislation designed to govern recreational fishing. As the policy prescribes, this will by definition be a consultative process based on the principles of co-management/co-governance. Effective implementation will thus heavily rely on knowledge of the stakeholders, local conditions and appropriate institutional support. The case studies on stock assessment and fisheries potential, and market value chains presented in this report thus provides valuable insights into the conditions under successful implementation of the policy could be.

4.2. Methodology

The formulation and development of recommendations for effective governance and co-management of inland fisheries in South Africa is informed by the South Africa legislative and policy environment outlined above and in Chapter 1, the ecosystem approach to fisheries, previous recommendations on inland fisheries governance (Britz et al., 2015 and Tapela et al., 2015), the draft inland fishing policy (DAFF, 2016) and the present case studies.

4.3. Profile of South African Inland Fisheries

This section briefly characterises South African inland fisheries sector and their role in economy and livelihoods of people. The main sub-sector users of inland fisheries are small scale fishers (including subsistence fishers) and recreational anglers (Tapela et al., 2013; Weyl et al., 2007). In a few cases (large-scale) commercial fishers have historically plied their trade in selected impoundments. The key characteristics of each of the three sub-sectors are discussed in turn below.

4.3.1 Small-scale fisheries

Although small-scale fishers from local communities around dams are generally regarded as having a legitimate claims to fish, their activities are usually illegal in the absence of a supporting rights-based governance framework. The only specific legislative provisions governing the use of inland fish resources are rudimentary fishing "effort control" rules prescribed in the provincial environmental acts and ordinances, which have their origin in pre-democratic era policies. Their activities remain unmanaged and often unsustainable. Access rights to the social and economic benefits from inland fisheries largely remain the hands of historically privileged racial classes (Tapela et al., 2013; Hara & Swarts, 2014).

Very little published information is available on the scale and livelihood contribution of small-scale fishing in rural communities, as it is largely an informal activity with no established system for stakeholder representation or data gathering. Britz et al. (2015) looked at 64 case studies of fishing communities to characterise current small-scale fishery use in South African dams. The findings were that subsistence fishing activity was recorded on 77% of dams, recreational fishing on 69% and artisanal/small scale commercial fishing on 40% of the dams. Small-scale fishing on most water bodies was not rooted in customary fishing traditions, but was found to be an adaptive livelihood strategy to their prevailing socio-economic circumstances. Most small-scale fishers were poor. The role of fishing in their livelihood strategies was diverse, ranging from a part-time subsistence activity to a full-time artisanal occupation.

Value chains for freshwater fish were short, with no evidence of value adding. The fish were generally sold fresh informally, or consumed by the family. In certain localities, a significant daily income could be generated to cover family living costs. Rural community members also practised recreational fishing, but fish caught was usually consumed. Unresolved or growing user conflicts were present on certain water bodies, arising from a lack of recognition of customary common pool rights, and the lack of capacity of communities to participate meaningfully in existing governance institutions. Community narratives around inland fishery use often reflected unrestituted legacies of dispossession and marginalisation from customary resource access arising from Apartheid and Colonial era dam building, forced removals and land dispossession. Formal statutory and customary or informal resource governance systems existed side by side on many water bodies with varying degrees of cooperation. While small-scale fishing was often tolerated by the authorities, and in some instances actively supported, small scale fishers remained vulnerable to prosecution, and their activities were often marginalized by other resource users and stakeholders. Artisanal gill netting by outsiders with vehicles and boats was seen by local communities as inequitable and unsustainable. Gill netting by local community members was tolerated on most water bodies, although some concerns were expressed about the sustainability of the method (Britz et al., 2015).

Small-scale commercially orientated artisanal fishers were largely resource-poor and unemployed men and women from rural local communities around dams. It was not clear to what extent landlessness and/or joblessness, which were generally rife in many rural communities, contributed to the ranks of these fishers. The fishers used various types of nets, including beach seine nets, gill nets and other home-made nets. Some of the fishers used both nets and fish traps, as well as canoes and rafts. Both men and women fishers were involved in 'illegal' net fishing practices. While seine nets were mostly used by men, women fishers often used bunched up dry sisal cords, basket traps made of chicken wire and/or plastic netting, which they put into the water to trap fish. Small-scale commercially-orientated net fishers relied on informal markets along local roadsides, at road intersections and within local communities (Britz et al., 2015).

While there was a prevalence of "poaching" or gill net fishing activities by resource-poor commercially orientated fishers from local communities around many dams, respondents were reluctant to disclose the extent to which such practices were conducted by local fishers. The disclosed characterization was that such fishers conducted their fishing activities at night and brought home large catches of fish, which they sold within local communities and in small urban settlements nearby. Members of communities were also reluctant to mention the fishing techniques used by gill net fishers, save that they caught significantly more fish during the night time than all anglers did during daytime, and that they earned significantly high incomes from selling fish (Britz et al., 2015).

Small-scale commercially-orientated net fishers stated that they constantly tried to evade being apprehended by environmental compliance and enforcement agencies, which patrolled both dam shores and rivers. In some cases such as Nandoni, Makuleke, Phongola and Masibekela, where formal organisations were non-existent, invisible and/or ineffective, traditional leaders actively discouraged illegal gill net fishing practices. In the cases of Nandoni and Makuleke, this enforcement signified the emergence of a local common property regime. In the case of Flag Boshielo and various other dams in Limpopo Province, the environmental agencies operating under auspices of the Limpopo Economic Development, Environment, and Tourism's (LEDET) Community Outreach Programme had elicited the cooperation of various local communities in different districts and municipalities in the apprehension of net fishers from outside the rural communities. It was not clear to what extent local people also reported illegal net fishing by members of their own communities, nor the degree to which local people continued to collaborate with larger commercial fishers from further afield. Consequently it was also not clear whether or not the current endemic activities by small-scale commercially orientated artisanal fishers, indicated an increase in prevalence or simply an increase in the visibility of this practice (Britz et al., 2015).

Subsistence fishers in the Pongola Floodplain included both adult women and men. The fish species caught were bream, catfish and 'sardines'. Any tiger fish caught were thrown back into the water. The *imfonya* indigenous fishing technique was used in the drier areas with shallow, muddy water, mainly by women. Male fishers used techniques such as spears, (*induku*), hook and line and nets. Some of the male fishers claimed to have stopped using nets because of the law that prohibits the use of nets and the high risk of drowning. After one incident of drowning, fishermen had been told to only fish when given authority (licences). Indunas had told them about the licences. Licence fees were paid to the indunas and the amounts varied from one community to another, with the maximum being R1000. In communities subject to high licence fees, fishers were not happy with the arrangement and some had begun to fish at different places, far from the indunas' sight. They would put nets out at around 5pm in the afternoon then remove them the following day at 6am. Many fishers fished twice or thrice per week when there was need for food. Some fished around midday after attending to their fields (Britz et al., 2015).

4.3.2 Recreational Fisheries

Recreational angling is by far the most developed subsector. South African inland fisheries are predominantly used by recreational anglers who utilise the fish resource primarily for leisure purposes (Weyl et al., 2007). Recreational anglers "*access the resource by vehicle and sometimes receive a lift; they have permanent employment, use high technology gear consisting of a fibreglass or graphite rod, and a multiplying or spinning reel, and release, consume or sell a portion of their catch" (*Ellender et al., 2009). Through the utilisation of tourist facilities and associated services along inland waterways, recreational anglers contribute significantly to regional economies (Du Plessis and Le Roux, 1965; Le Roux, 1965; Cadieux, 1980; Leibold and van Zyl, 2008; Du Preez and Lee, 2010). In some countries this economic contribution exceeds that of commercial fisheries (Stage and Kirchner, 2005; TCW Economics 2008). The few assessments of the economic impact of recreational angling in South Africa all indicate that this impact is considerable. It is therefore important that recreational anglers are recognised as important stakeholders in South African inland fisheries and that their interests be recognised in future fisheries development.

Recreational angling in South Africa can be broadly subdivided into two categories: the formal sector, which comprises individuals/members affiliated to or belonging to an organised body such as a club, and the informal sector that comprises social anglers that are not linked to any organised body (Pledger, 2010). Formal angling organisations are important partners in long term planning and policy development around the utilisation of fisheries. Nationally there are more than 19,000 recreational anglers that are affiliated to various angling associations (Pledger, 2010). Some 7,400 of these are affiliated to associations that only use inland waters.

Britz et al. (2015)'s review of the recreational angling sector revealed that it has a substantial participation rate (estimated to be of the order of 1.5 million participants) and a significant economic impact associated with the tourism sector and angling services and supply value chains. Recreational angling was recorded on 69% of dams surveyed. The recreational angling disciplines are diverse, including bank angling for carp, yellow fish and catfish, artificial lure angling for bass and other species, fly-fishing for trout, boat angling and informal recreational/subsistence angling. Angling is organised as a sporting code, affiliated to the South African Sports Confederation and Olympic Committee (SASCOC), under the Sport Anglers and Casting Confederation (SASACC). Recreational angling is a popular activity on state dams and is supported by the DWS policy of promoting recreational activities on state dams. The management of recreational fishing activity on state dams was in the process of being formalised by the DWS, through the compilation of Resource Management Plans for major state dams. Despite its economic impact and ability to create rural livelihoods and decent jobs, recreational angling is not recognised or represented as a fishery sub-sector by the DAFF. Recreational anglers were concerned about sustainability issues, growing gill net fishing, and conflicts with small-scale fishers. The organised sports angling community was in the process of approaching the DAFF to obtain recognition of a proposed fisheries sub-sector association representative of all anglers, both informal and organised, in order to develop appropriate governance and management arrangements, and to realise the economic potential of the industry (Britz et al., 2015).

The economic value of recreational fisheries is substantial. A non-peer reviewed study on the value of recreational fisheries in South Africa, commissioned by the South Africa Deep Sea Angling Association (SADSAA) in 2007, showed that the expenditure by freshwater anglers contributed significantly to the national economy (Leibold and Van Zyl, 2008). The study estimated that the average expenditure on angling related equipment and activities by anglers affiliated to angling clubs was ZAR 7 500 per angler per year, and that the total economic impact of these anglers, who represent about 10% of participants, was in the region of ZAR 900 million per annum. While up-calculations of this value for the unaffiliated anglers cannot be made with any confidence, the report demonstrates the economic contribution that the recreational sector makes to the national economy. Rural poor communities however do not participate in many of the recreational fishing opportunities that offer social and economic benefits associated with, for example, ownership of fishing tourism enterprises such as accommodation, services and supplies (Britz et al., 2015).

Recreational fishing is sustainable as anglers extract a small tonnage of fish and catch-and-release fishing is widespread. Recreational fishing is recognised as a legitimate form of resource use in provincial environmental legislation with management control measures designed to protect biodiversity and prevent over-harvesting. However, national policies on primary industries (agriculture, forestry and fisheries) do not recognise the recreational fishing value chain as a sub-sector of fisheries which contributes to the economy through the creation of rural livelihoods, decent jobs, economic opportunities and food security. The consequences of this include:

- Potential development opportunities for rural communities associated with access to fishery resources with recreational fishing potential are overlooked.
- Resource managers tend to preferentially promote fishing for food security, and overlook the potential socio-economic benefits of recreational fishery development linked to the tourism value chain.
- Resource managers lack policy guidance and governance protocols to resolve resource use conflicts between recreational fishers and small-scale fishers. As a result recreational fishers on certain water bodies are deterred from participation by user conflicts and overfishing.

4.3.3 Commercial Fisheries

Generally, commercial inland fisheries are undeveloped as a result of a history of limited access to resources, low demand for fresh water fish, the lack of an inland fisheries policy and unclear fisheries management objectives (Weyl et al., 2007). Commercial fishing in the form of single licences has only been permitted on a limited scale on a few dams including Gariep, Bloemhof, Moletedi (Weyl et al., 2007), Kalkfontein and Darlington Dam (Sundays River system) (Anon., 1982; Merron and Tomasson, 1984; Potts, 2003). Despite a number of studies on the fisheries potential of state dams (e.g. Koch and Schoonbee, 1980; Hamman, 1980, 1981; Allanson and Jackson, 1983; Cochrane, 1987; Andrew, 2001), and attempts to develop commercial fisheries on larger impoundments, the commercial viability of these enterprises has been marginal with none still operating (Britz et al., 2015).

There have been numerous attempts to develop formal small-scale commercial fisheries in rural communities (e.g. Jackson, 1980; Schramm, 1993; Andrew, 2001). Unfortunately, few fisheries developed or remained operational after the initial project interventions. The reasons for this lack of success are unclear, but have been attributed to: the perceived low value of the resource; the lack of historic involvement in fishing; the limitation of artisanal and subsistence fishing to the former homeland areas under the Apartheid era; a cultural resistance to fishing (Andrew, 2001); and the concerns by management authorities that the support of small-scale and commercial use may threaten fish populations (Andrew et al*.,* 2000; Britz et al., 2015).

The overriding reason for the lack of development of commercial inland fisheries is probably economic. Recent estimations on profitability of various commercial fisheries options on Lake Gariep (Potts et al., 2004) and Darlington Dam (Weyl et al., 2010) found that the low fish price (ZAR 6-10/kg) coupled with the absence of a formal marketing system for inland fish precluded the economic viability of even small commercial enterprises in these water bodies. In addition, they showed that employment possibilities in commercial fisheries were relatively low, and pointed out that commercial fisheries would result in considerable conflict with other users of the resource. As a result, employment gains from commercial fisheries were likely to be countered by employment losses from tourism at sites where recreational fisheries were well established (Britz et al., 2015).

Britz et al. (2015) found that illegal commercial fishers in Limpopo Province were mostly male 'outsiders', who lived in places far away from dams and were either more affluent or better resourced than local small-scale commercial fishers. Their operations were mobile, organized with investment in dedicated gear. This comprised of fleets of gill nets, boats, freezers and vehicles. After fishing, the larger commercial fishers transported their catch in bakkies or four-wheel drive vehicles to distant urban markets. Markets include larger towns, such as Tzaneen, Polokwane, Phalaborwa and Groblersdal, among others.

4.3.4 Structural and regulatory frameworks on case study dams

4.3.4.1 Phongolo

The decision to allow gillnetting on Phongola Dam was taken by the Water User Association (WUA) in conjunction with Department of Water and Sanitation (DWS) and Department of Agriculture, Forestry and Fisheries (DAFF). The decision was based on the view that gillnet fishing should be seen as a livelihood and developmental activity. There is also informal (without permits) commercial fishing by use of gillnets from the DWS slipway, which is the only legal public access to the dam. At the time of our fieldwork in 2017/18, a formal Business Plan was being developed to formalise the use of gillnets. There was no zoning of the dam to demarcate areas for artisanal gillnetting, recreational fishing, and subsistence line fishing. Zoning is thus one of the aspects being considered in the Business Plan. Recreational fishers (mostly not resident in the area) are not part of the WUA and were not part of the decision to allow gillnetting. In fact, the recreational fishers are against the use of gillnets on the dam because of problems such as getting gillnets entangled in their boats during sport fishing and the belief that gillnets are not an appropriate gear for fishing on the Dam.

The Ezemvelo KwaZulu-Natal Wildlife (EKZN Wildlife) which has historically been officially responsible for management of biodiversity on the dam, including fisheries, does not agree with use of gill nets either as they view them as destructive. EKZN Wildlife is viewed by locals as siding with recreational fishers who take things into their own hands, to the extent of confiscating artisanal fishers' gillnets and burning them. As a result of this antagonistic attitude towards fishers, EKZN Wildlife no longer had the mandate of monitoring of fisher activities on the dam (at the time we did the surveys in 2017 and 2018) as DWS did not renew its permit. Monitoring and enforcement is currently falls under DWS and the South African Police Service (SAPS).

In the absence of effective fishery governance structures and institutions, particularly formalised fishing rights and a fishery management plan, the situation is highly conflicted with the mainly white recreational sector actively involved in pursuing criminal sanctions against the gill net fishers from the community who they regard as 'poachers'. The community fishers feel dispossessed of their traditional land and right to make a livelihood from fishing (Britz et al., 2015).

Since fishing other than recreational is not legally recognized under the existing provincial legislation, which is the official legal framework for management of biodiversity on the Dam, there are no regulations for controlling the activities of artisanal fishers using gillnets and other equipment. SAPS use the issue of safety at sea to regulate the activities of the artisanal fishers. This takes the use of South Africa Maritime Safety Authority (SAMSA) regulations (e.g. boats that are not certified) or other safety issues (e.g. life jackets). As a consequence of SAPS' use of this approach, artisanal fishers complained that their boats were unfairly confiscated and sank in September 2016. Most artisanal fishers suspended fishing in the period soon after that incident. There was a belief among artisanal fishers that the SAPS officers being brought in from Pongola or Richards Bay favour the recreational fishers at their expense.

The different stakeholders were not happy with the perceived unequal benefits and value being derived from fish resources from the dam. On the one hand the local communities on the eastern shores who do not have infrastructure from which to access the dam see their benefits as much lower than those by the private land owners on the western shores who have developed lodges and game farms on the dam frontage. These inequities were also perceived in terms of historical racial inequities (Britz et al., 2015).

A Sustainable Use Plan (SUP) for the Phongola Dam was commissioned in 2004 by the Department of Water Affairs and Forestry (DWAF, 2004). The purpose of the SUP was the fulfilment of NWA objectives, in particular section 2 regarding: equitable access to water; redress of past gender and racial discrimination; efficient and sustainable utilisation of water; facilitation of social and economic development; ensuring adequate provision for the growing demand for water particularly for recreational purposes; protection of aquatic and associated ecosystems including their biodiversity; reduction and prevention of pollution and degradation of the water resource; meeting of international obligations; promotion of dam safety; and adequate representation of communities in terms of both race and gender on the management institutions. At the time of our study, the SUP had still not been effected. Thus, despite the intention to address equity issues, increased integration of communities into use and economic activities on the dam has been lacking highlighting the need for policy and governance reform (Britz et al., 2015).

4.3.4.2 Flag Boshielo

The dam infrastructure and water resources for Flag Boshielo are managed by DWS. Environmental resources and biodiversity are generally managed by the Limpopo Department of Economic Development, Environment and Tourism (LEDET), which in turn delegates management responsibility to Schuinsdraai Nature Reserve for fishing conducted from reserve land and restricted public land under DWS management. It is worth noting that an informal co-management arrangement was emerging organically, which involves stakeholders such as DWS, LEDET, the nature reserve, private land owners and rural local communities. This arrangement was emerging in the context of dealing with a major problem regarding poaching by commercially-orientated net fishers from outside the area (Britz et al., 2015).

The Limpopo Environmental Management Act (Act 7) of 2003 provides the legal framework for techniques and practices regarding utilization of fish within the Dam. Chapter 6 of this Act deals with aquatic biota and aquatic ecosystems. Sections 56 to 60 give regulations on the catching of fish, use of fish nets, traps and other devices, closure of the angling season, protection of aquatic ecosystems and pollution of aquatic ecosystems and other regulations. The Act prohibits the conduct of fishing activities without a permit and within a protected area. Among other things, the Act also prohibits the use of more than 2 fishing lines or 2 hooks on a line, the use of fish poisons, fish feed in fishing spots and electrical or explosive methods of stunning and/or killing fish. Effectively, the Act allows the use of specified angling techniques but prohibits the use of fish traps, nets and other obstructions.

Although the Limpopo Environmental Management Act provides overarching guidelines on acceptable fishing techniques and practices, there are currently no dam-specific guidelines governing bag limits for various fish species in Flag Boshielo. These institutional gaps raise critical questions about the governance and management of the fishery, particularly in light of reported the rampant increase in poaching by informal commercial fishers, who use various types of nets, boats and rafts.

Land tenure around Flag Boshielo includes communal lands, premises belonging to the DWS, Schuinsdraai Nature Reserve, Tompi Seleka College of Agriculture, one community-based fishing camp and privately-owned commercial farms. Schuinsdraai Nature Reserve, private farms and DWS premises provide formal access to recreational anglers, angling clubs and local fishers. However, there are reports of irregular entry and use of illegal nets through these areas. By contrast, communal lands provide both formal and informal access to various categories of anglers and fishers, as well as angling clubs. Within communal lands, formal access for recreational, subsistence and commercially orientated anglers and fishers is via the Matlala Aloe Park eco-tourism resort, which is also described as a "fishing camp". Gill net (and other net) fishers and poachers also reportedly access the fishery via Matlala Aloe Park. Informal access for anglers and fishers, who use fishing rods and hand lines, is mainly through communal land immediately below the Flag Boshielo Dam wall. However, this fishing area is currently not favoured due to possible risks of crime, since a number of fishers and anglers have been accosted while fishing and/or camping (Britz et al., 2015).

In the case of Flag Boshielo and various other dams in Limpopo Province, the environmental agencies operating under auspices of the Limpopo Economic Development, Environment, and Tourism's (LEDET) Community Outreach Programme had elicited the cooperation of various local communities in different districts and municipalities in the apprehension of net fishers from outside the rural communities. It was not clear to what extent local people also reported illegal net fishing by members of their own communities, nor the degree to which local people continued to collaborate with larger commercial fishers from further afield. Consequently it was also not clear whether or not the current endemic activities by small-scale commercially orientated artisanal fishers, indicated an increase in prevalence or simply an increase in the visibility of this practice (Britz et al., 2015).

4.3.4.3 Voëlvlei

Biodiversity within the Voëlvlei Dam and its catchment is managed by Cape Nature under the Western Cape Nature Conservation Laws Amendment Act No 3 of 2000, which is stated as, "An ordinance to consolidate and amend the laws relating to nature (and environmental) conservation and to provide for matters incidental thereto". Regarding fisheries, the Act makes various provisions such as those in relation to the gear types and fishing methods that are prohibited, how to use specific types of fishing gears, pollution, bag limits, introduction of live fish into aquatic resources, etc. The Act states that 'the Director or Board may grant exemption in writing from any of these provisions to any person doing research on fish or fish food. The Act further states that all these provisions do not apply to any privately owned inland waters.

Voëlvlei Dam is predominantly used for recreation. The following recreational activities commonly take place at the Voëlvlei Dam: Bird-watching; Shoreline and Boat Fishing; Boardsailing/windsurfing; Swimming; Yachting; and Picnicking and sunbathing. Other events that are held at the Dam include various angling competitions (for Bass and Carp) as well as a number of Regattas. The dam is a popular recreational angling site being located within 100 km from Cape Town metropolitan area. The Stanford Bird Club have also visited the Dam for their bird fairs in the past. There are well organised local recreational club structures managing access and activity on the dam under authorisation from the Department of Water and Sanitation. The main recreational clubs that make use of the Dam are the Vogelvlei Yacht Club, the Western Province Artificial Lure Angling Society, the Western Province Freshwater

Angler's Association, the Tulbagh Angling Club, the Witzenberg Angling Club and the Cape Piscatorial Society. The lack of a dam resource management plan and policy on inland fishing has retarded a proposal to initiate a commercial fishery for carp and catfish. The restricted public access to the dam raises issues of equity.

There are various protected areas around the Voëlvlei Dam. These include the Voëlvlei Nature Conservancy and Waterval Nature Reserve. These reserves are home to the Geometric Tortoise which is critically endangered as well as a number of sensitive plant species including King Protea. The Dam also occurs in close proximity to Du Toits Kloof Mountain Range.

The nearest town to the Dam is Gouda, which is predominantly a residential rural town established in support of the agricultural activities in the surrounding areas. The town is also marketed for tourism, with the nearby Voëlvlei Dam and Bergriver being taunted as excellent venues for swimming, fishing, canoeing and yacht sailing, while the mountains are perfect for hiking, bird watching and finding wild flowers like proteas and other rare and endangered species, including snakes, baboons, and cheetahs.

Smallmouth Bass are the main attraction. Other fish species found in the Dam include carp, rainbow trout, catfish and Cape witvis (*Barbus andrewi*). Fishing can be done legally through a license that can be bought from the Receiver of Revenue or from the Post Office. Anglers are allowed two bass/day and are not allowed to sell the catch. Most anglers practise catch-and-release. There is no control on fishing of alien species, especially carp and catfish, as these are viewed as being not good for the Dam because they are bottom feeders and thus discolour the water whereas the bass do not.

The Western Cape Department of Agriculture commissioned a project to evaluate the potential for a semi-commercial/commercial fishing on public dams with a view to targeting the West African expatriate market for fresh water fish. This followed a realisation that there are a growing number of 'African' shops in cities such as Cape Town that specialise in stocking food for foreigners from other African countries including frozen or dried/smoked fish (mostly tilapia and cat fish species) imported from other countries (Ndofor Epo, 2018). Clearly there is a growing niche market for freshwater fish in South African cities. In addition product development could be undertaken to develop markets for inland fish among South Africans through awareness raising, marketing campaigns and the introduction of new fish product forms based on inland fish species from South African Dams and other inland fish resources. This is particularly pertinent in inland impoverished areas where the need for a cheap source of protein supply exists. For recreational fishers, the concern is that the dam is being taken over by large alien invasive species, namely catfish and carp, which are causing the recreational fishery for bass to decline. The experimental gill net fishery for these invasive species was seen as one of the solutions. But the allocation of a commercial fishing access right is problematic for the relevant authorities (Cape Nature and Western Cape Province Department of Agriculture) due to the lack of a guiding policy.

4.4 Governance and co-management of Inland Fisheries – South Africa

In this section, the case studies are used to analyse the appropriateness of existing and proposed governance arrangements and requisite institutional mechanisms for pro-poor market chains for inland fisheries in South Africa.

4.4.1 Influence of resource characteristics

The results of the stock assessment further confirm previous findings (Fouche et al., 2012; McCafferty, 2012; Britz et al., 2015; Weyl et al., 2015) that the productivity in most dams is dependent of ecological characteristics of the area in which a specific dam occurs. Generally, productivity on most dams is low, such that these cannot support commercial fishing. Apart from low production, there is likely to be season variability (where the water is depleted through water extraction for domestic, industrial and irrigation purposes, given that the public dams were built primarily for these purposes) and periodic variation of volumes, either due to drought or heavy rains. The findings of the stock assessment show such low productivity for Flag Boshielo and Pongola (to the extent that the stock assessment team failed to catch fish for sampling for the two week period they were there). Although the productivity in Loskop Dam was found to be higher than in Flag Boshielo, the concern was the high levels of metal pollution that are absorbed by the fish, to the detriment of consumers. The pollutants are largely as a result of industrial, agricultural and domestic activities upstream of the impoundment. The main conclusion is that while properly managed fisheries could support small scale fisheries, most dams cannot support commercial fisheries. Given that each dam will have its own ecological characteristics, a precautionary approach will require to be used in the management fisheries on public dams. Such a cautionary approach should also ensure that we do not raise community expectations that the sector is the solution and panacea for rural unemployment, poverty and food insecurity. In this context, the potential for contribution of inland fisheries towards rural economic development will need to be balanced with a science-based sustainable productivity and socio-economic analysis of the specific water bodies. The development of the sector will need be aligned with productivity of particular geographic areas and specific water bodies based on scientific estimates and analysis.

The collection of various types of ecological, biological, social and economic data and information, which could be used for monitoring and management purposes will be vital. Therefore part of the management framework that needs to be developed and put in place are protocols for routine and *ad hoc* data collection.

4.4.2 Regulatory framework

The primary legislation for management of all South Africa's freshwater resources is the National Water Act of 1988 (NWA). While the Act does not specifically mention fishing as a beneficial use of public dams, this is covered under the Department of Water and Sanitation (DWS)'s policy for promoting secondary socio-economic benefits for disadvantaged local communities from public dams. In this context, access to public dams for fishing activities is implicitly covered under the definitions of water use in Chapter Four of the NWA. Chapter Four is founded upon the principle that national government has overall responsibility and authority over water resource management, including the equitable allocation and beneficial use of water in the public and societal interest. The Act states that "a person can only be entitled to use water if permissible under the Act" (NWA, 1998: chapter 4 preamble, p17). This includes the various types of both licensed and unlicensed entitlements to water use. Part 1 of the Chapter sets out the general principles for regulating water use, and broadly defines what water use is. The preamble to the chapter further stipulates that, "In general a water use must be licensed unless it is listed in Schedule I, is an existing lawful use, is permissible under a general authorisation, or if a responsible authority waives the need for a license" (NWA, 1998: chapter 4 preamble, p17). The preamble further states that "In making regulations the Minister may differentiate between different water resources, classes of water resources and geographical areas" (NWA, 1998: chapter 4 preamble, p17).

The management of biodiversity though has historically been decentralised to provincial level, either through provincial government departments such as LEDET in Limpopo or parastatal such as Cape Nature in the Western Cape and EKZN Wildlife in KwaZulu-Natal. The provincial bodies use provincial legislation as management tools. As can be seen from the existing provincial legislation, there is lack of congruence and alignment is the different provincial legislation (Britz et al., 2015), and also most important, these are based on protection of biodiversity rather than the consumptive use of natural resources of the benefit of communities. In order to systematise policy and legislation and allow for the developmental approach to inland fisheries resource governance, an Inland Fisheries Policy (DAFF, 2016) is being developed. This is in terms of the Constitution (Republic of South Africa 1996) which stipulates that the governance of fisheries is a national competency.

The National Environmental Management Act (NEMA) number 107 of 1998 is primary Constitutional legislation that gives legal effect to the environmental rights defined in the Constitution (section 24)**.** The environment is defined in terms of human wellbeing, and thus the main objectives of the NEMA are: 'to promote sustainable development through the utilisation and protection of South Africa's natural and cultural resources; to foster equitable access to the benefits that can be derived from South Africa's natural and cultural resources; to empower the South African public, community organisations through participation, environmental education, capacity building, and research and information services'. Additionally, NEMA establishes principles to guide the decisions and actions of all organs of state in environmental management; provides for establishment of institutions that can co-ordinate and harmonise environmental functions of the state and the promotion of participation of stakeholders in environmental governance; establishes procedures for cooperative governance; establishes procedures for conflict management; promotes integrated environmental management by establishing minimum procedures for environmental impact assessment, and also enables national or provincial authority agencies to prescribe environmental impact assessment regulations; establishes procedures for ratification of, and giving effect to international environmental instruments; and promotes compliance and enforcement of provisions of the Act. In addition, NEMA promotes co-governance by enabling the establishment of environmental management cooperation agreements that can promote the principles of integrated environmental management. In this context, the NEMA should be viewed as a very progressive and powerful instrument for guiding the reform of inland fishing rights and governance in alignment with the Constitution.

In order to achieve the Department of Water Affairs and Forestry's (DWAF) policy objectives for recreational use of water resources, the Department developed guidelines for the development of Resource Management Plans (RMPs) for the integrated recreational water use (DWAF, 2006). The guidelines emphasize that to achieve the objectives of the NWA, it is imperative that DWAF involve all stakeholders in planning procedures to ensure that management objectives and actions for a water body reflect the needs and expectations of the stakeholders affected by the water resource, in particular communities living next to such water bodies. In addition, the guidelines stress that RMPs; have to compliment local Integrated Development Plans (IDPs); reflect the conservation value of the resource; and redress the past racial, gender and socio-economic imbalances suffered by communities. RMPs could enable informed decisions about the utilization of water resources for recreational purposes and also facilitate public-private partnerships that could unlock the potential that such resources provide in an equitable and sustainable manner without perpetuating old negative norms.

In principal the policy requirements for RMPs procedures are to legitimise and support recreational fishing rights, in effect leaving small-scale fishing for livelihoods (and aquaculture) in a void. In addition, the technocratic approach for the compilation of RMPs favour existing empowered interests and institutions that already dominate governance bodies like the Participatory Management Committees – as evidenced by the Phongola example for developing the Sustainable Management Plan (SUP) for that water body. Interventions are thus needed in the processes and procedures for the development of RMPs in order to address past inequities and imbalances so that disadvantaged poor communities are empowered in the development of RMPs. If DWS policy prescriptions that communities which host water resources should share in the benefits emanating from the utilisation of these resources for recreational purposes is to be met, then it is important that communities have both physical access as well as access to the water-based recreation economy through active and genuine participation in the development and implementation of RMPs. For example, entrepreneurs from communities should be provided the opportunity to undertake economic and developmental initiatives through the establishment of partnerships and concessions, which would help develop local skills and also increase economic benefits for communities (Britz et al., 2015).

4.4.3 Actors – composition and activities, and fishing rights

The dams are used by multiple actors and multiple purposes. For example, public dams were constructed as storage dams for domestic, industrial and irrigation water. The stocking of dams with fish (some exotic) was mainly to create recreational fisheries on public dams. Apart from angling, other recreational activities such as yachting, camping, swimming, etc. have been developed or found use on public dams on frontage land. Another main activity is tourism and activities associated with this. The value chain concept means that all actors in the various value chains (small scale fishing, recreational fishing, tourism, etc.) are stakeholders for the ecosystem values that dams provide. They have therefore to have a stake in the governance of the dams where they derive benefits.

Given the multiple uses and users, it is important to understand use right practices on public dams and other inland water when re-structuring rights (access, consumptive and management) particularly for the inclusion of hitherto marginalised communities, whose rights have been poorly defined as a result of lack of supporting policy and legal foundation. Properly defined rights, which are accepted as legitimate by all stakeholders will be required in order to derive increased benefits for communities and avoid user and use conflicts.

Authorisations for access and fishing rights for recreational anglers and tourism operators are well defined under existing national (NWA) and provincial environmental legislation. Thus for such historical reasons, recreational angling and other water sports codes and tourism have currently a dominant presence on most public dams. Although legally they only have access just like most other stakeholders, building of infrastructure on the dam frontage for their members by sports and recreational clubs, creates *de facto* exclusion rights through fencing off such areas, thereby restricting access for other stakeholders. This is the type of situation on the West side of Pongola and Voëlvlei and also many other dams. Equally, the lease of land on the dam frontage to build lodges, guesthouses and fencing off the areas also creates exclusionary rights.

This historical legal context and the economic argument that such activities are beneficial to the local economies (job creation and tourist spend) gives these historical users *ad hoc* and *de facto* rights compared to formally marginalised communities. In some instances, for example, on Pongola in this study, recreational anglers and lodge owners have gone as far as confiscating and destroying small scale fishers' boats and nets. Until the new inland fishing policy comes into effect and is implemented effectively, the concern is that the creation of exclusionary rights by entrenched historical users has the potential for continued inequity in the allocation of fishing rights and rights to other value chains for communities. This will need to be addressed through reforms of property and access rights for inland fisheries and other ecological resources linked to public dams.

Under the current NWA, communities have general access rights to dams and in principle, they should also be able to fish using recreational permits just like recreational anglers. Most provincial legislation bans the use of gillnets though, which is the preferred fishing gear for most small-scale fishers. Thus the main conflict arises where fishers from communities use nets (for example, in Pongola, Flag Boshielo and Loskop). On Pongola Dam, the ongoing ambiguity of the legitimacy of fishing activities by communities (the WUA passed a decision allowing their use while under existing provincial legislation they are banned, so much so that EKZN Wildlife had not issued permits for use of nets on the dam since 1998) has resulted in a serious conflict between fishers from the communities on the east side of the dam, commercial fishing charter operators, and the EKZN Wildlife authorities resulting in confiscation of fishing equipment belonging to small scale fishers by SAPS. The underlying view among most anglers and most environmental authorities is that gillnets are destructive, especially to the target species for angling and sports fishing and should therefore be banned.

The position of recreational angling on dams had been underwritten by the enabling supportive provincial nature conservation legislation that largely catered for recreational angling and biodiversity conservation. This legislation does not facilitate or cater for subsistence and/or small scale commercial fishing, *de facto* restricting or denying fishing rights for communities. As a result, the legal basis for inland subsistence and commercial fishing remains poorly defined. The draft Inland Fisheries Policy will require the revision and harmonisation of existing provincial legislation to provide for equitable and sustainable access to fish resources on dams for all stakeholders including communities. In addition, the new policy proposes putting in place appropriate institutional arrangements for inland small scale fisheries.

4.4.4 Adaptive ecosystems (Co-) Management

Co-management of fish resources is seen as the most appropriate governance arrangement for fisheries especially involving multiple stakeholders at different tiers (Hara, 2003; McCay, 1993; Bromley, 1991; Ostrom, 1990; Jentoft, 1989; McCay and Acheson, 1987). The NWA provides for co-management structures for management and utilization of public dams for the various uses by the various users. Thus the establishment of Catchment Management Agencies (CMAs) in the country's nine designated water management areas is provided for under the NWA. CMAs are supposed to be vehicles for devolution of management authority and responsibility. The Act requires that each CMA draws up a management strategy for their catchment and for the CMA to perform core functions required to implement the Act including the active promotion of user participation including communities (section 80 (e) of the NWA). This had been given further substance by the implementation guidelines (DWAF, 2001) which emphasized that representivity and inclusivity of all stakeholders' interests, needs and values, especially those of hitherto marginalised communities and the rural poor need to be considered as part of the catchment management processes. A second body proposed by the NWA are Water User Associations (WUAs), which are statutory bodies defined as cooperative institutions of individual water users that wish to undertake water-related activities for their mutual benefit. The involvement of users in management through CMAs and/or WUAs offers to create and extend management rights to users. WUA's (for example that created for Pongola) have to date not been effectively used to manage fishing rights. It remains to be seen whether such bodies can be used for strengthening and protecting fishing property and access rights for communities without other interventions such as a new dedicated Inland Fisheries Policy. One of the main problems is that such bodies (CMAs and WUAs) usually involve power dynamics, resulting in capture of power and authority by the most economically powerful for their own interests. On most dams, most WUAs and CMAs are dominated by organised interests such as commercial farmers through their Irrigation Boards (Sithole, 2011). In instances such as on the Pongola, organised interests such as recreational fishers and tourist operators have chosen to stay away from the WUA, seemingly because it has a strong presence of communities stakeholder interests. As a result of the lack of this lack of inclusivity, the Pongola Dam WUA has been ineffective in addressing the fishery and other water use conflicts on the dam.

Given that the dams are socially, economically and ecologically dynamic, there will be need for adaptive ecosystems co-management. Adaptive co-management has basis in the understanding that ecosystems are complex adaptive systems that require flexible governance with the ability to respond to environmental feedback. Given the complex and dynamic nature of social ecological systems of public dams, this will require (adaptive) co-management systems whereby stakeholders need to self-organize, learn by doing, and actively adapt to and shape change with social networks that connect institutions and organizations across levels the different scales, and which facilitate information flows. Adaptive co-management rests on the understanding that the institutional and organizational landscapes should be approached as carefully as the ecological landscape in order to clarify features that contribute to the resilience of the social-ecological system. These include the vision, leadership, and trust; enabling legislation that creates social space for ecosystem management; funds for responding to environmental change and for remedial action; capacity for monitoring and responding to environmental feedback; information flow through social networks; the combination of various sources of information and knowledge; and sense-making and arenas of collaborative learning for ecosystem management (Pers et al., 2004). Such an approach that could ensure the derivation of human wellbeing, ecological wellbeing and inclusive governance will need to be built into the draft Inland Fisheries Policy.

4.5. Management and governance arrangements for inland fisheries

4.5.1 Structural and Organisational arrangements for co-management

The three dams, just like most of the water bodies that will fall under inland fisheries, are public belonging to DWS. The aims and objective of the draft Inland Fisheries Policy is to formalise and enhance benefits for rural communities living near these water bodies. This will need to be done without jeopardising the benefits for other stakeholders such as recreation anglers, tourist operators, etc. Effective management will need to be based on adaptive co-management between the relevant government departments (for example, Department of Environment, Forestry and Fisheries (DEFF), DWS, the provincial agencies of the environment and Department of Transport (DoT)), small scale fishers, recreational fishers, other water users such as irrigation farmers (most likely through their associations) (see figure 4.1). Currently, inland fisheries is placed under the Aquaculture Technical Services sub-Directorate in the Aquaculture and Economic Development Chief Directorate of DEFF: Branch Fisheries. In order to facilitate the development of inland fisheries, DWS and DEFF have each nominated a person to be the liaison official with regard to inland fisheries in their Departments. The DoT will also need to be brought on board with regard to the policy for requirement of management plans for all inland water bodies. Lessons on organisation for co-management in marine fisheries in South Africa and in fisheries in general from elsewhere could provide guidance for the formation of viable co-management arrangements for inland fisheries. Revised legislation will need to legalise and empower co-management as the basis for governance of inland fisheries. In recognition of the fact that the inland fishery stakeholdership involves multiple stakeholders at different scale or layers, a formal cooperative governance working group structure will need be established for inland fishery sector coordination (Figure 4.1) (DAFF, 2016; Britz et al., 2015).

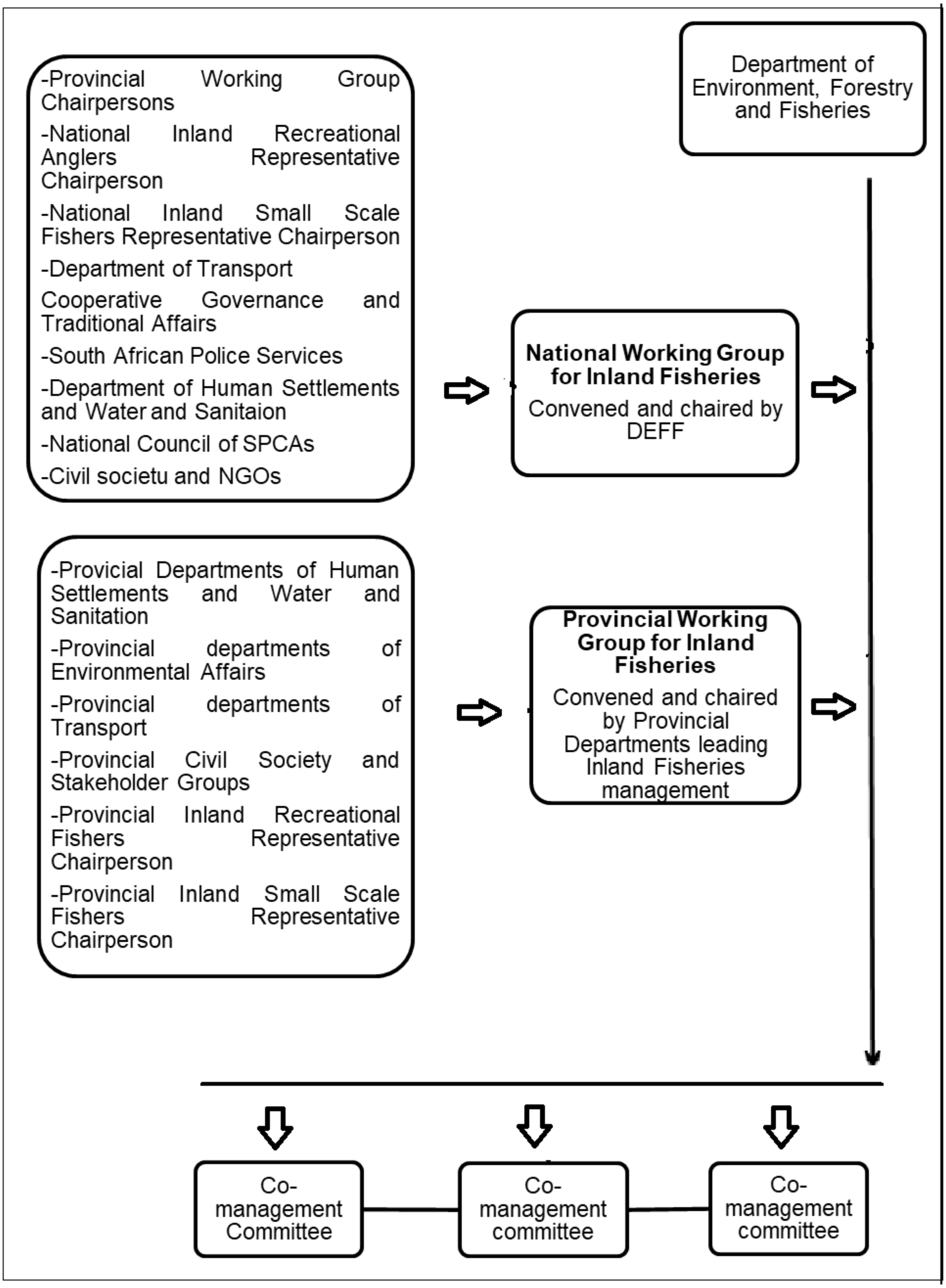

Figure 4.1. Proposed organizational structure for inland fishery cooperative governance (source; DEFF, 2020).

The Branch Fisheries within the old DAFF has now been incorporated into the Department of Environment, Forestry and Fisheries (DEFF) which will henceforth be responsible for Inland Fishery governance.

In terms of multi-level organisation for the governance of inland fisheries, it is proposed that a National Working Group for inland fisheries composed of the key departments (DEFF; branch Fisheries, DWS, DEA, Department of Cooperative Governance and Traditional Affairs (COGTA) and DoT and also the provincial heads of departments for the environment and/or boards) and civil society stakeholder groups such as the National Recreational Angling Association, National Small-scale and Subsistence Fishers Association (should this be created in future), University Based Researchers, etc. will need to be established under the leadership of DEFF: Branch Fisheries. The National Working Group will be convened by the DEFF: Branch Fisheries. The Working Group's task will be to monitor and review inland fisheries policy implementation and provide policy guidance and strategy to the Provincial Working Groups. The size of the working group will need to be limited to only those stakeholders that can and need to contribute towards national policy and strategy for inland fisheries.

At Provincial level, a Provincial Inland Fishery Working Group will be convened by the Provincial Department of the Environment and Fisheries. Representatives of the government departments with mandates relevant to inland fishery matters, fishing interest groups and other stakeholders shall be members of the provincial working group (DAFF, 2016). The Provincial Working Group will deal with all matters relevant to inland fishing policy implementation in the Provinces. The draft Inland Fisheries Policy (DAFF, 2016) proposes that even at provincial level, the provincial environmental departments should have the ultimate authority for inland fisheries although at operational level the existing historical arrangement whereby provincial departments or boards for the environment have been responsible for fisheries management at provincial level is likely to continue for some time given that DEFF: branch Fisheries does not currently have the capacity to manage fisheries both at provincial level and local level on the ground. The problem though is that even under the current arrangement, little is happening because the departments and boards for the environment do not have adequate capacity either. In fact most do not have aquatic scientists. It is proposed that DEFF: Branch Fisheries should thus urgently take steps to build capacity at provincial/regional and local levels so that it can urgently take over the development and management of inland fisheries. It is further proposed that task groups for inland fisheries should be formed at provincial level. These should be composed of all the key stakeholders at provincial level (Figure 4.1). The task groups should also include departments of economic affairs so that fisheries is included in economic planning in each province. The responsibility of the provincial task groups will be strategic and operational decisions at provincial level and also resolution of disputes and issues emanating from the local level. It is important to emphasize though that the role of DEFF provincial departments as the key government partner in co-management arrangements will be crucial. Eventually, the department of fisheries will need to develop its own capacity in rural areas for the sustainable management of inland fisheries in the mode of Department of Agriculture's agriculture extension officers.

The lowest tier management body would be the co-management committees responsible for the management of particular water bodies (figure 4.1). According to the draft Inland Fisheries Policy (DAFF, 2016), these will need to be convened by the provincial departments of the Environment and Fisheries. The co-management committees on the ground shall be responsible for the day to day operational management decisions (e.g. formulation of *operational rules*) and *process issues* about fisheries in their areas of jurisdiction. The formation of co-management committees should be context specific based on the existing situation in an area, who the key primary stakeholders are, relationships among the various stakeholders and the capacity for cooperative governance among the stakeholders. These could be built afresh and be beach based or village based (territorial) or could be built around existing functional organisations such as WUAs, CMAs or traditional authorities. Alternatively, fishery sub-sector associations (for example Small scale fishing associations, Recreational fisher associations, etc.) could form the basis for cooperative governance of inland fisheries. The DEFF: Branch Fisheries in association with relevant provincial departments could facilitate and recognise the establishment of such representative associations. In this context, recreational fisheries on many water bodies are already effectively run on co-management principles with well organised angling clubs and associations managing their activities under agreement with various statutory authorities. What model to follow will depend on analysis of the existing situation and dynamics on the ground. Co-management committees will need to be composed of all key stakeholders at the local level of an area, and could also include chiefs or/and ward councillors where this is necessary and appropriate if they are to be seen as being legitimate (Figures 4.1 and 4.2).

4.5.2 Stakeholdership for co-management

One of the main conundrums and challenges for the governance of inland fisheries in South Africa is that there are multiple categories of stakeholders for the ecosystem services that are derived from the dams and therefore the way these benefits can be sustainably utilised by all stakeholders. Given the social and ecological dynamism of the people (stakeholders) and the natural resources, the governance will need to be based on an adaptive and ecosystems approach (benefits based on achieving human wellbeing, ecological wellbeing, and good governance). Figure 4.2 summarises some of the key categorises of stakeholders for public dam ecosystem services and their value chains on the four public dams used in this study (and in effect in South Africa).

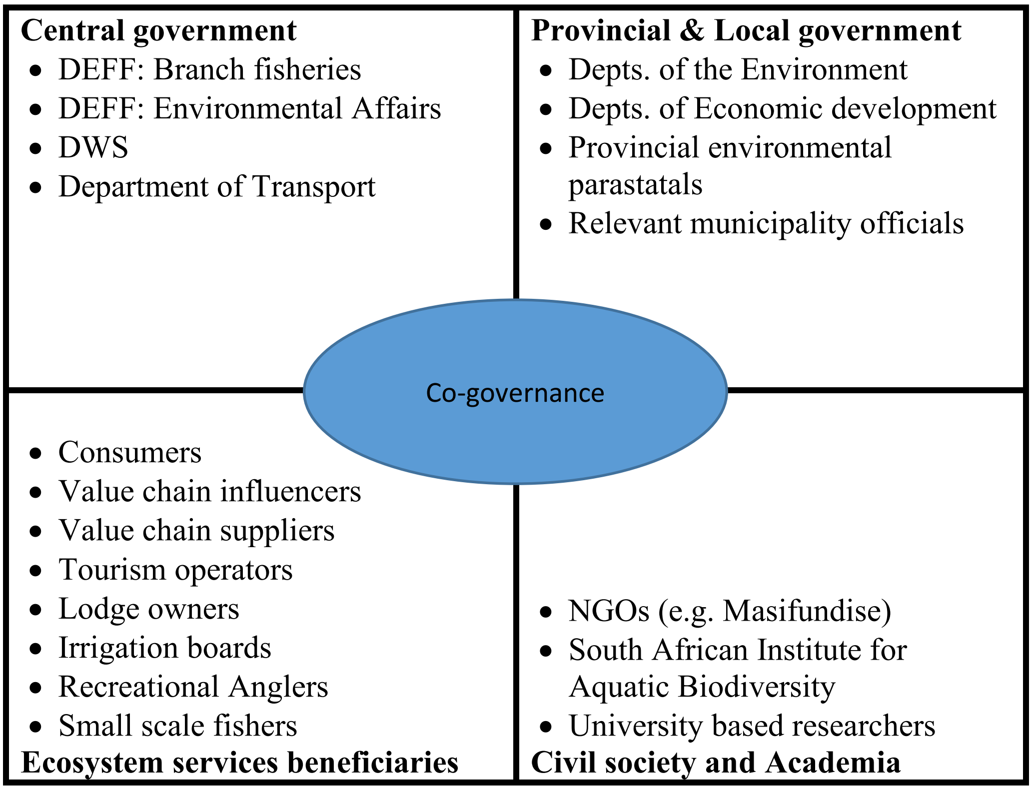

Figure 4.2. Key stakeholders for the co-governance of ecosystem services on Public Dams in South Africa

Central government departments hold the mandates and responsibilities for ensuring the sustainable utilization of natural resources and maintenance of biodiversity in public dams and their dam catchment areas on behalf of society (Figure 4.2). These mandates are provided for through appropriate legislation and policies. For example, the NWA, NEMA, NEMBA, SAMSA, future Inland Fisheries Policy, Tourism Act, Food and Nutrition policies, etc.

In most instances, the central government mandates are implemented by their provincial departments and local governments (Figure 4.2). This usually involves decentralisation of authority. Historically, the management of biodiversity on public dams had been done through provincial legislation through provincial departments of the environment or parastatals such as EKZN Wildlife (KwaZulu-Natal) and Cape Nature (Western Cape). The proposed Inland fisheries policy is based on centralising legislative mandate for inland fisheries into the hands of the Department of Environmental Affairs and Fisheries: branch Fisheries. This would ensure one overarching policy and legislation from which provinces can derive decentralised authority and responsibility and co-management bodies devolutionary authority and responsibility.

There are many people that benefit from the ecosystem services that are provided by dams (Figure 4.2). For example, small scale fishers benefit through food and nutrition security through fish taken home to eat or sale of extra catch. Recreational anglers benefit from the leisure of sport fishing and the value chain suppliers from sale of equipment and bed nights for those anglers staying more a day. Irrigation farmers benefit from the water and also the commercial farmers provide direct employment, and also employment through the post-produce supply value chains. Lodge owners and tourist operators provide services that enable people to come for recreational angling or for holidays based on nature and other ecological services around public dams. All these activities involve other value chain actors (suppliers of equipment or provisions), thereby extending benefits along the value chains (vertical) and value networks (horizontal). Consumers of the various ecological products at the top tier of the value chains creating demand for the products and services.

Civil society and Academia working with fishers and doing research form a key fourth category of stakeholders. The former have the role of helping communities derive maximum benefits from public dams through advocacy and policy implementation activities, while the later conduct independent natural and social science research in support of evidence-based findings in support of advisory, monitoring and policy and legislation review.

For inclusive and legitimate co-governance, most of these keys stakeholders will need to be involved. This can vary based on scale and/or level and also on who the stakeholders on a specific dams are. In most instances, the primary stakeholders (those that have a direct involvement and therefore stake in a dam) will need to be included in the ground level co-management arrangements that impact on their activities and benefits. Some level of vestedness is essential for legitimacy and effectiveness of co-management arrangements since ultimately, primary users control whether a management system will work or not. Hence, if direct users cannot live with a regulatory system and its framework, it hardly matters what other interests think or find appropriate. Without such active involvement by primary stakeholders and vested interests, the legitimacy and strength of co-management arrangements is diluted.

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CHAPTER 5. TOWARDS DEVELOPMENT OF AN INCLUSIVE SUSTAINABLE SMALL-SCALE INLAND FISHERIES SECTOR

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5.1 Introduction

This project set out to test the recommendations made by the preceding WRC Inland Fisheries Baseline and Scoping Study (Britz et al., 2015) with regard to the formalisation of an inland fisheries sector in South Africa. The baseline and scoping study recommended that such formalisation should be based on a developmental approach (that is, a move away from an overly conservation approach), inclusivity to deal with historical marginalisation of (small-scale) fishing communities and a defensible scientific approach that could ensure biological and socio-economic sustainability of the sector so that future generations could also continue to enjoy the benefits from the sector. In order to contribute towards the development and formalisation of such a sector, this study took an approach that looked at the key areas of knowledge and information that could be necessary and important for such a task. These are; i) assessment of fish stocks and their potential; ii) market value chains associated with inland fisheries and economic value of the sector; iii) institutional arrangements for the governance and co-management of inland fisheries; and iv) strategies for optimising the inland fisheries-based rural livelihoods and rural economies. Chapters 2, 3 and 4 of this report synthesize the work done through several deliverables under the three components listed above respectively. We also use and make reference to the findings of the baseline and scoping study (Britz et al., 2015) and other work previously done by members of the team and others on inland fisheries in South Africa. See together, the findings from this project (and other previous projects) provide a good overview of the key issues requiring decisions in the future development and formalisation of the sector. This chapter discusses and makes suggestions and recommendations on how South Africa can move towards the development of an inclusive sustainable small-scale inland fisheries sector, using the findings of this project, other studies, and the experiences of developing and managing small-scale fisheries in other African countries and beyond.

The project was based on four case study dams, namely Pongola in KwaZulu-Natal, Flag Boshielo in Limpopo and Voëlvlei in the Western Cape Province and Loskop in Mpumalanga (the stock assessment and fisheries potential component surveyed Flag Boshielo and Loskop dams instead of Voëlvlei). The project team was multi-disciplinary, comprised of fisheries natural scientists and social scientists, based on the study areas listed above (stock assessment – natural science; market value chains – economics/social science; and institutional arrangements – natural/social science). There were also a number of students undertaking their post-graduate degrees as part of the project. A note on mutlidisciplinarity and interdisciplinarity: it is increasingly realised that there is a need for a new approach to fisheries management, one which transcends disciplinary boundaries in order to interpret and solve the complex problems that we face in fisheries, which a single discipline cannot resolve alone (Ommer, 2007; Degnbol et al., 2003; Neiss and Felt, 2000). Integrative multidisciplinary and interdisciplinary approaches are required to develop new attitudes, methods and solutions. Multidisciplinarity is a non-integrative mixture of disciplines in the sense that a subject is studied simultaneously by different disciplines. Thus the natural scientists in our team studied the fish biology and ecology (and also tested the conventional methods for investigating these issues on dams), while social scientists studied the market value chains in inland fisheries and also the economic value of the sector; as well as appropriate institutional arrangements for the sustainable governance and co-management of the sector given the biological, ecological, social, economic and stakeholder characteristics. The strength of the multidisciplinary research approach is that it aims to deepen the understanding of a topic within each discipline through the results obtained in another discipline (Lenhard, 2006; Thompson Klein, 2004). Thus, the project team interacted and infused knowledge from the other components to deepen understanding of the findings in their component. The research question was formulated to be interdisciplinary, based on the broad nature of the historical problem of non-recognition of inland fisheries in South Africa, and what measures could be required to develop and formalise the sector while ensuring sustainable utilization. Thus, although the approach to dealing with the research question was multi-disciplinary in nature, this chapter interprets the findings using the findings from all three components, other previous findings and from literature on small-scale fisheries, thereby infusing interdisciplinarity.

5.2 Fisheries management regime for inland fisheries

The science of fisheries management strives to replace chance and uncertainty about the future with a reasonable degree of predictability (Charles, 2001; Cochrane, 2000). Fisheries managers are usually faced with the following main questions (Tweddle et al., 2015; Fogarty and Collie, 2009; Gulland, 1974):

a) How big is the resource and how much fish can be caught each year while maintaining the stock for the future?
b) Given the potential catch, how should this be used for the greatest benefit of (national) society?
c) What action needs to be taken to achieve these objectives?

The ideal type of fisheries management (i.e. state centric, which assumes that there are no informal systems among fishers and fishing communities) is to a large degree based on the assumption of free access and hence the need to regulate fishing effort in order to obtain biological conservation. This necessitates the establishment of a Fisheries Management Regime (FMR). Hersoug and Paulsen (1996) proposed that a FMR comprises of three interdependent components namely, a Fisheries Management System (FMS), a Monitoring Control and Surveillance (MCS) system, and a Fisheries Judicial System (FJS). The FMS specifies the regulatory framework for the fishing activities and encompasses the general rules and the different management measures (e.g. the technical/input regulations such as the gear to be used, e.g. mesh sizes, net dimensions, etc.) restrictions, vessel restrictions, and output regulations such as quotas). The MCS component is based on the need to monitor and control the fishing activities, and enforce the regulations. The MCS unit provides data such as catch for the management unit as well as other information for the judicial system (e.g. who is permitted to fish, to what extent, where and with what kind of gear). The FJS is part of the general judicial system, sanctioning the violators, indicating both the type and level of possible punishment. The important thing to note is that all the three are strongly interdependent; the FMS relies on an efficient MCS and the MCS, in turn, on a working FJS (ibid.). The influence also works in the other direction in that to attain the full benefits from a fishery, a co-ordinated and fully functional FMR is required. From a management point of view, the important questions are whether control and enforcement actually work, to what extent control and enforcement contribute to the goals set – be they biological, economic or social – and finally what are the costs that will ensure effective monitoring, control and enforcement activities?

In order to develop and formalise an inland fisheries sector in South Africa, a Fisheries Management Regime for the sector needs to be established comprised of FMSs, functional MCS systems and FJSs. Some (please note that this list is not exhaustive. consultation with stakeholders could generate more or result in revision of this list) of the key questions that we will need to deal with are;

1. How should inland fisheries be organised in terms of FMSs in practice and reality, and what criteria should be used for the establishment of these management systems?;
2. What types of input and technical regulations are necessary for each FMS (or each impoundment?) for sustainable utilization?;
3. Will output regulations be used in the sector, and if so what procedures would be used for determining the annual upper limits?;
4. What management procedures and processes would be required for the sustainable utilization of inland fisheries in each FMS?;
5. What type of rights would be appropriate for equitable sustainable utilization of inland fisheries, and how will these be distributed?;
6. What institutional and organisational arrangements would be appropriate for inclusive and equitable management of inland fisheries?;
7. How should management of inland fisheries be funded?;
8. What legislative changes would be necessary for recognition of the sector; and
9. How could communities organise themselves better for improved access to inland fisheries value chains?

The next sections expands on these issues. The issues are not discussed precisely as listed. They are discussed within the key headings below, which have been formulated based on what would could be the key aspects of an inland fisheries 'Fisheries Management Regime' for South Africa.

5.3 Geographic demarcations of Management Areas (FMSs)

There are more than 700 public dams in South Africa spread out in all the nine provinces (Hara and Backeberg, 2014). In addition, there are also natural lakes, rivers and floodplains. All these will form the basis for an inland fisheries sector in South Africa. The impoundments (dams) and natural systems are unique as they are in most instance separate entities (in particular, the dams) and allocated in geographic areas with different ecological and physiological characteristics. As reported in chapter 2 of this report the natural productivity and therefore the abundance of fish stocks in impoundments vary, with productivity of dams and natural systems in the warmer province such as Limpopo, Mpumalanga, KwaZulu-Natal and the Northwest being higher. It would certainly be impractical to view, let alone legislate, each impoundment or natural system as a separate individual FMSs. Therefore, one of the key issues under the new management regime under the Inland Fisheries Policy (DAFF, 2016) would be resolving whether a general FMS with a slate of general management rules, regulations, procedures and processes would be applicable to all impoundments in South Africa, or whether the impoundments will be grouped and demarcated as geographic management areas whereby specific FMSs are then developed and implemented to manage these areas based on their unique characteristics. The question therefore becomes; 'what characterisations (environmental, geographic, systemic, etc.) should be used to demarcate the impoundments and natural systems into management areas where specific FMSs would be developed apply?

A pervasive problem of small-scale fisheries in Africa and worldwide is the lack of centralised landing and launching sites where daily catch data can be recorded. As a result, fishers operate from their villages, which makes it difficult to regulate their activities or collect systematic catch data like is done in rights-based and quote based fisheries. The data collection systems that are generally used in small-scale fisheries are 'catch assessment surveys' and annual frame surveys. With the small-scale fishing sector to be based on hundreds of impoundments, and natural systems, South Africa faces a similar challenge, probably on a bigger scale, given the number of impoundments. Careful thought will need to be applied in terms of how fisher activities are going to be organised and regulated, particularly if this is going to be a rights-based, limited access and limited output fishing sector.

5.4 Inland fisheries rights and institutional arrangements for governing rights

Rights to a fishery have to be based on type of resource and what the appropriate methods for sustainable harvesting should be, the size of the resource and what the sustainable levels of harvesting should be and who should be given such rights. Such decisions, presumably, have to be based on recommendations from scientists on the appropriate levels of sustainable utilization, as is the practice in the marine sector. In the marine sector in South Africa, the scientists make recommendations through 'Scientific Working Groups' for each sub-sector (e.g. Hake, Small Pelagics, etc.), which are comprised of scientists and industry stakeholders. Another group type that makes inputs are 'Resource Management Working Groups', which discuss management issues for governing fishing activities and also the apportioning of rights. The baseline and scoping study (Britz et al., 2015) and also this project made recommendations for the organisational and institutional arrangements for inland fisheries (see chapter 4 of this report), which proposes 'National and Provincial Working Groups' convened and chairmanship of the national department (Department of the Environment, Forestry and Fisheries (DEFF): branch Fisheries) and provincial departments for fisheries. What is different from the marine sector is that there is currently no systematic collection of biological, ecological, social, economic data and information that could form the basis for advice to the Minister for evidence-based decision-making on the type of rights and appropriate levels of harvesting for sustainable management. Since the development and formalization of the sector cannot be postponed until one had such systems in place, this alludes to the 'Precautionary Principle Approach' (DAFF, 2016; Britz et al., 2015; FAO, 1995), whereby exploitation should be formalised and allowed at precautionary levels, and that collection data from such activities should also be put in place so that a database can be developed that would provide scientific information on which future decisions could be increasingly based.

While the allocation of fishing rights is ultimately a political decision, in the case of inland fisheries, the premise of the inland fishing policy is that customary fishing activities will be formally recognised as use rights.

5.5 Lessons from Other African countries – Open access and 'Path dependency'

In most African countries, the colonial governments did not have formal many regulations to govern the largely artisanal fisheries. The reluctance of colonial governments (for example, the British) to regulate fishing activities in the colonies seems to have been general and not specific to any country. According to Hickling (1952) this general attitude against regulation of the fishing industries in the colonial territories was largely based on the arguments of the 1866 Royal Commission which had reviewed the fisheries laws of the United Kingdom. The commission had recommended the repeal of all laws for regulating fishing in the open sea and the inshore waters since the commissioners believed that there was no satisfactory evidence that fishing had made any negative impact on the fish stocks[23]. The lack of trustworthy time series statistics was put as the main reason for the failure to reach trustworthy conclusions. This argument was extended to the colonial territories, saying that "the state of most fisheries of the colonial and dependent territories was as primitive as that of the United Kingdom fisheries of 1866 and that in great majority of the cases, fisheries statistics did not exist or where they existed, they were incomplete and inadequate" (ibid.).

At independence, most African countries continued with the approach used under colonialism. In most instances, the open access approach was also preferable from a political and developmentalist approach (Hara and Njaya, 2016). Most states saw fisheries as a sector that offered livelihoods and economic opportunities for the rural poor and therefore as an economic development sector. Therefore, all potential participants had to have the freedom to enter and participate in a fishery both as a subsistence and economic activity, and secondly, that they were not be limited in terms of how much that could catch. As a result, most small-scale fisheries in Africa have historically been managed as 'open access' sectors and without limiting output. Licensing has mainly been used as a revenue collection tool, rather than a management tool. This open access and limitless output approach has set most African small-scale fisheries on treacherous 'path dependency' towards over capitalisation and over exploitation (ibid), in the end working against the very objectives that they had set out to achieve namely poverty reduction and food security.

The dangers of open access are all too clear from the experience of other African countries. South Africa should certainly try and avoid going that route. Besides, good precedence has been set in the marine small-scale sector (DAFF, 2012) where a permit holder has to have a right/permit to fish thereby limiting access, and also, the rights are based on limited output. Could this be where 'Community Based Fisheries Management (CBFM)[24], 'Territorial Use Rights in Fisheries' (TURF) and/or Customary Tenure (CT)[25] be the most potent and practical approaches to inland fisheries management in South Africa? Given that the management responsible agency (whether national and provincial) cannot have adequate enforcement capacity on and around all impoundments, Community Based Co-management could probably provide the most workable solution. Of course there will be the problems of defining

[23] One must also remember that this was a time when "Freedom of the Seas" was still a strongly held principal. The Dutchman, Hugo Grotius wrote "The freedom of the seas" in 1608 to justify free movement of merchant ships in their conduct of Dutch trade in the East Indies. The sea, he argued, was limitless and could not become the possession of anyone, but was, by nature, suitable to the use of all. Grotius's proclamation is said to be the basis for the fundamental assumption of the "freedom of the seas." In the western developed countries, the belief had been that fish in the seas was nobody's property and access to them had to be free and open to all. The resource was only capable of being reduced to possession by capture (McCrae and Munro, 1989). It was only with the of the United Nations Convention on Law of the Sea (United Nations Organisation, 1982) that states stated legally declaring Exclusive Economic Zones that sea enclosures began.

[24] CBM has gained currency in the last three decades in debates about ways of decentralising resource management responsibilities through seeking the active involvement of local user communities. CBM has been used to refer to initiatives by the state to accomplish resource management objectives through encouraging and facilitating the participation of user communities in the management of 'their resource(s)'. (Hviding and Jul-Larsen, 1995).

[25] CT refers to historical institutions that derive their tenancy from customary law and practice. They are based on forms of territorial divisions of coastal space and have been prevalent in the Pacific area. A notable feature of these systems is that they are multi-purpose in nature and not usually tied solely to fisheries. Intentionally or unintentionally, CT tends to have a bearing on management of aquatic resources. Hviding (1989) had used CT as a more inclusive term in preference to the narrow definitions connotated by concepts such as 'traditional fishing rights' and 'Territorial Use Rights in Fisheries' (TURF).

"community" (in South Africa's case fishers on dams include small-scale and recreational anglers), like everywhere else such systems are proposed for use. Tapela et al. (2015) and Britz et al. (2015) reported traditional and customary fishing practices on some dams and natural systems such as Lake Fundudzi in Limpopo and the Pongola floodplain, which could form basis for such CT management approaches.

In developing and formalising the inland small-scale fisheries sector therefore, South Africa needs to take note of and be warned against the mistakes that other Africa countries had made, which are proving extremely difficult to reverse or extricate themselves from. The involvement of local communities, both those that have historical rights and those attempting to get new rights, and other stakeholders in formulation of the appropriate rights and enforcement of such rights could hold the key for legitimisation of fishing rights (Battista et al., 2018; Pomeroy et al., 2015; Berkes et al., 2009; Jentoft and Mikalsen, 1994; Jentoft, 1989) and thus reduction of management transaction costs.

5.6 Funding for inland fisheries management

An underlying problem of managing small-scale fisheries, especially if they are managed from a safety net and/or welfare function (Bene et al., 2010; Jul Larsen et al., 2003) is the question of how the sustainable management of the sector will be funded. In an ideal conventional fisheries management approach, participants in a fishery are required pay a fee for the rights to fish. The size of fees is ideally supposed to be based on paying for management costs of the fishery (administration, Monitoring, Control and Surveillance (MCS) and research to support the management) – that is, cost recovery. In most African countries, the developmentalist and welfare approach has meant that in most instances, gear licenses are not set and reviewed annually on the basis of cost recovery. Over the years therefore, the fees have fallen behind the ideal level for cost recovery or value of the fishery to society. In most instances, the collection of gear licence fees is in itself usually poor. For example, in Malawi, only about 20% of the annual potential fishing gear licence is collected by the Department of Fisheries (Njaya et al., 2018). Also important to note is that gear licencing is not used as a management tool, but revenue collection towards the fiscus. The amount of funding from Treasury for a sector usually depends on how much a specific sector contributes towards revenue collection or to a country's Gross Domestic Product (GDP) (ibid.). Generally also, the economic value of small-scale fisheries in developing countries are often unknown, and the other benefits are intangible (Garcia et al., 2009). Because small-scale fisheries sectors do not contribute as much as other sectors to the fiscus, they do generate a significant welfare gains as a food security, health and as income security net, particularly during times of economic downturn. This in turn reduces government expenditure on various aspects associated with the effects of poverty. Thus, logically the inland fisheries sector should be funded from the fiscus due to the non-GDP welfare gains generated.

5.7 Need for proper recognition of the fishing sector on public dams

The primary function of public dams is as storage dams for domestic, industrial and irrigation water (see chapter 4). As the main source of annual replenish/refill of water is annual rain, fisheries productivity varies with the dam level. For example, during the water crisis in 2017/18 in Cape Town, the dam levels had declined to as low as 15% (Voëlvlei – 37%; Theewaterskloof – 31%). https://www.greenagri.org.za/assets/documents-/Dam-Levels/Monday-Dashboard-13022017.pdf). The Department of Water and Sanitation only recognises recreation fishing as a legitimate activity on public dams (Department of Water and Sanitation (DWS), 2015) and there is thus a need for legislative recognition of extractive fisheries as an ecosystem service. The Inland Fisheries Policy provides direction for such recognition and legitimisation of small-scale fisheries on public dams.

5.8 Inland fisheries co-management

Co-management (between government and other stakeholders) is the proposed management approach for inland fisheries in South Africa (chapter 4). Some of the key dimensions of the co-management paradigm are as a mechanism for power sharing, institution building, enhanced trust and social capital, problem solving, knowledge-sharing and social learning (Evans et al., 2011; Berkes, 2009; Chuenpagdee & Jentoft, 2007). In addition, co-management is seen by many as a normative process to improve the legitimacy and effectiveness of fisheries management (Battista et al., 2018; Pomeroy et al., 2015; Evans et al., 2011; Berkes et al., 2009; Jentoft, 1989).

Success of co-management is usually evaluated both in terms of process indicators (for example, participation, influence, rule compliance, resource control and conflict) and outcome indicators (for example household income, household well-being, resource well-being, fishery yield, and resource access) (d'Armengola, et al., 2018; Whitehouse and Fowler, 2018; Brooks et al*.*, 2012; Cinner et al*.*, 2012; Gutierrez et al., 2011; Evans et al., 2011). The co-management evaluation studies undertaken so far demonstrate the importance of considering both process and outcome indicators in order to meaningfully evaluate and improve the impact of co-management as an approach for small-scale fisheries management in developing countries. While the process indicators do not directly address issues of power-sharing or trust-building, they do suggest as whole that improved inclusion of stakeholders in governance processes, improved capacity to control or influence decision-making, and improved compliance to management rules over time as benefits of co-management. Positive trends in process indicators are expected to lead to improved management outcomes, although literature shows that this is not guaranteed (Béné and Neiland, 2004, 2006).

In South African inland small-scale fisheries, decisions are required on the evaluation criteria of successful co-management. Such indicators will need to be both process and outcome. Evans and others (Evans et al., 2011) suggested that improved yield and household income are key desirable outcomes for small-scale fisheries co-management in developing country contexts and thus advocated for the continued emphasis on these two outcome indicators. For South Africa, a survey of these indicators at the outset of the co-management arrangement could act as the control or baseline against which to evaluate success and progress thereafter, given that there might not be a control group (non-co-management arrangement) for comparison or on which the observed changes can be judge as being attributable to co-management.

5.9 Organisation for participation in lucrative fisheries MVCs and improved benefits

On most public dams, fishing grounds and fishing rights for rural inland fishers are highly contested. A key success factor for inland fisheries going forward would be the diffusion of challenges associated with access rights. Jordaan and Grové (2012) similarly suggested that the security of tenure was a key success factor in respect of emerging farmers' access to commercial agri-food value chains (see chapter 3). Securing access to fishing grounds and the protection of fishing rights could provide incentives for inland fishers to invest their time, build social networks for sustainable fishing practices and economic investment in fishing enterprises. Tenure security could also have some spin-offs that could contribute towards overcoming factors affecting entry by rural women and men into higher earning inland fisheries MVCs (chapter 3). For example, fisheries tenure security could open opportunities for access to credit to invest in fishing enterprises, which could enable fishers to intensify fish production and therefore income from fishing. This could be the case on dams where fishers are not able to upgrade their fishing activities because of lack of clear and protected fishing rights such on all the three dams (Pongola, Flag Boshielo and Voëlvlei) used as cases for this study.

Fishers and venders (processors and traders) could also greatly benefit from improved organisation as groups such as cooperatives. For example, the women fish vendors on Pongola have benefitted from being organised as a cooperative (Sizabantu), which in turn has been able to negotiate a fish purchase monopoly from the fishers that had been given fishing permits (chapter 3). Government's role has been to help organise the women into a cooperative, and also make the issuing of the fishing permits to the fishers conditional that they will prioritise the sale of their catch to the women's cooperative, thereby creating a win-win situation. Currently the recreational fishers operating on Flag Boshielo are said to be taking away and selling their catch for income and profit (some argue that this is to offset their costs – but then it is not expected that one should be offsetting their costs if they are fishing for leisure). It is said that the fish is sold in the inland towns for very good margins (see chapters 3 and 4). The Inland Fisheries Policy categorically proposes forbidding recreational fisheries from catching fish for sell, other than catch and release by defining a recreational fisher as "A person who engages in fishing for pleasure or competition and is not dependent on the activity to meet primary income or basic nutritional needs. The catch is not generally sold or otherwise traded" (DAFF, 2016:5). Thus on dams such as Flag Boshielo, a rule could be introduced to stop this practice, but then issue permits for organised small-scale fishers to occupy the niche to be left by the recreational fishers.

Going forward, institutions are required to clear the path for rural fishers' entry into lucrative MVCs such as the SMME envisaged in the Business Plan for Sizabantu Cooperative on Pongola Dam (chapter 3). Such enterprises will need to be capitalized through the appropriate government departments, whether provincial of national. The fishers and vendors would get shares in the enterprise and employment as well. On dams such as Pongola, some of the women could need to be trained to fish. All members of such an enterprise would have to be paid benefits based on performance in how much fish they bring in or how much they sell (if they are vendors). As an enterprise set to generate better revenues through better linkages with lucrative MVCs, members will periodically get dividends to demonstrate the premium for following the SMME model. The enterprise could be supported to carry out value-addition activities and move products to distant high-value locations. To ensure sustainable stocks and catches, the authorities would need to keep the number of enterprises and the number of fishers and vendors in these within manageable levels.

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CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

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In order to develop and formalize the inland fisheries sector once the Inland Fishery Policy is in place, a Fisheries Management Regime is required. The findings of this project, and others, lead to a number of conclusions and recommendations for the realization of an inclusive and sustainable inland fisheries sector that could benefit both the present and future generations.

6.1 Geographic Management Areas

Given that it would be impractical to manage on each impoundment and natural system as individual Fisheries Management Systems, one of the critical issues that is demarcating the impoundments and natural systems into management areas where specific management systems and processes will apply. The main question is 'what criteria will be used to come up with these demarcations?'. The scoping study conducted by Britz et al. (2015) identified regions in South Africa comprising impoundments with high fish productivity. However, the stock potential of these impoundments within these regions is largely unknown and as a consequence require that a stock assessment be conducted. As the work on stock assessment and fisheries potential (chapter 2) demonstrates, some of the criteria for selection would have to be based on the biological and physiological characteristics of the impoundment, knowledge of species that could form the main basis for small-scale fisheries by both recreational angling and local communities, and ease of accessibility. Waterbodies known to contain vulnerable aquatic species might be avoided or managed differently. Such areas are likely to cut across provinces, thereby requiring management strategies that will involve the relevant provincial authorities where applicable.

6.2 Need for a programme of routine data and information collection for decision-making

A programme of routine data and information collection will be required, which would form basis for future management decision-making. The type of information should include biological, ecological, socio-economic aspects as this will assist in establishing how an evolving multi-sectorial environment will be governed. At the moment, the information available, albeit sparse, is mainly based on *ad hoc* research and studies, such as the present project (Britz et al., 2015; McCafferty et al., 2012). Some of the information is based on studies funded by interest groups such as the recreational angling organisations. Other techniques such as the use of GIS should be part of collecting information on productivity of the impoundments, as initial suitability analysis (Britz et al., 2015). Hence to determine whether species with proven commercial value can be sustainably harvested present in the waterbody of interest, an assessment of the fish diversity and composition is required following the procedures outlined in Weyl et al. (2007). In most countries, information on small-scale fisheries is collected using catch assessment surveys and frame surveys, given that fishers are not required to land their catches at specific points and rights are not based in limits on output. In most instances, such surveys do not include the collection of socio-economic information (for example, beach prices). It is, therefore, important that any future programmes of routine data and information collection pertaining to biological and catch data that social and economic information be included. Moreover, waterbodies to be identified should preferably be in areas where environmental and anthropogenic impacts are low (e.g. catchment areas not exposed to prolonged drought or where the catchment area has high land use activity).

6.3 Fishing rights

One of the key issues for the development and formalization of a small-scale fisheries sector is the formulation of legal fishing rights for small-scale fishers. Most of the permit systems that currently allow communities to fish on dams are based on recreational fishing permits. In a few instances, provincial governments have permitted gillnet fishing (for example on the Pongola Dam and Van der Kloof Dam) (see chapter 3 and Britz et al., 2015), to the displeasure of the recreational fishers on Dams where such permits have been given and also against the current provincial regulations (for example, the gillnet fishing permits on Pongola had been instituted by the DWA against the advice of Ezemvelo KwaZulu-Natal Wildlife as the provincial regulations ban the use of gillnet on Dams). On some dams such a Bloemhof some commercial fishing has been permitted (Britz et al., 2015). On other dams, illegal gillnet fishing has been reported, resulting in conflicts with recreational fishers and other stakeholders such as lodge owners (Britz et al., 2015). Therefore one of the keys issues under the Inland Fisheries Policy will be determining and legalizing the type of fishing rights and the regulations and fishing techniques that should govern such rights. This will have to take into consideration the current harvesting rates of both the 'informal' small-scale fishers and recreational anglers (particularly those that take the fish away for own consumption or for sale). The current information and models indicate limited room for growth on most waterbodies (Britz et al., 2015; McCafferty et al., 2012). As a consequence, such decisions will have to carefully weigh the volume and type of rights and how these are to be distributed. It is also important that open access should not be allowed and also, the rights should be based on limiting fishing effort and output volume. Experience from other African countries point to the fact that open access and unlimited output results in over capitalization of and the eventual over-exploitation of small-scale fisheries.

6.4 Organisation of fishers and vendors for improved benefits

Chapter 3 argues that fishers and communities could improve their positioning and capability to get enhanced benefits by organising themselves into groups that can apply for fishing rights as a group for critical mass in terms of amount of product for sale. For example, the women's cooperative (Sizabanthu) in Pongola have marketed all the catch from the permitted small-scale fishers (albeit through the assistance of government a decree, which made one of the conditions for granting the fishing rights as the prioritisation of selling and trading daily catch to and with the women's cooperative). There is also an example of a fisher in Pongola who had been offered a delivery contract for tiger fish by one of the local guesthouse restaurants, but the contract had to be cancelled because he could not fulfil the contract due to inability to assure quality standards, consistency of delivery and inadequate volumes. One can envisage that if the contract was offered to a group of fishers (as a cohesive entity), they could probably have been in a better position to fulfil the contract. Such groups could be in form of cooperatives or SMMEs (chapter 3). One can also envisage that fishing rights could be better organised as group right that are controlled through co-management committees. Therefore, groupings could enhance both economic benefits and act as an aid to co-management.

6.5 Upgrading position on MVCs

Small-scale fishers and fish vendors (or grouping of these) could upgrade their positions in the MVCs by adding value to their catch through processing their catch (e.g. by salting, sun drying or smoking) and selling their catch to urban communities. For example, on Flag Boshielo, some recreational fisheries take away their catch to sell in the adjacent towns. Fishers on Flag Boshielo could occupy this value chain through upward integration of their value chain activities. Another example is that of catfish from Voëlvlei. At the moment, catfish caught from Voëlvlei are sold locally to mostly foreign farm workers in the area at a very low price because the fishers themselves do not eat the fish for cultural reasons. Yet shops that specialise in selling food to foreigners in the Cape Town CBD (and in other cities such and Johannesburg) import catfish for selling in these shops. This provides an opportunity for fishers in Voëlvlei Dam to process and upgrade and integrate their activities on this value chain. Most small-scale fishers and vendors sell their fish using visual estimation of the size of the fish, which results in selling fish of different sizes for the same price (chapter 3). For example, on Pongola, we weighed fish specimens of 100, 110, 120, 150, 170, 180 and 190 gram that were each sold for the same price of R20. Therefore one way of adding value could be using weight-based pricing.

6.6 Social economic values

It should be recognised that the main value of the inland fisheries is not just in the commodity value of the tonnage landed by small-scale fishers. One of the main values lies in the food security, employment and sustainable livelihoods. With better integration some of the socio-economic benefits could be derived from the tourism and equipment supply associated with recreational fishing if fishing communities could be better integrated into these value chains. Chapter 3 argues that there are opportunities for benefit sharing schemes with local communities in respect of output or expenditures associated with recreational fishing. What the Inland Fisheries Policy needs to do is to facilitate the recognition of all values associated with inland fisheries and craft mechanisms for sustainable inclusion of small-scale fisheries and rural communities living in the vicinity of public dams. In this context, both small-scale and recreational fisheries could contribute to improved rural livelihoods in inland fishing communities if these communities were pro-actively integrated into all the value chains on public dams and other natural freshwater resources.

6.7 Niche markets

One of the ways for inland fishing communities (fishers and vendors) to reap more benefits from their fishing activities could be for them to create monopoly power over their product and sell it to niche markets. With good marketing to lodges, restaurants and shops in nearby towns, the fishers and vendors could enhance their benefits from fishing. For example, we found that currently, most local shops around the three dams did not sell local fish from the inland fisheries sector. The fish in shops was mostly marine such as the powerful brands such as Lucky Star (Oceana), Hake from I&J and Sea Harvest, imported Chinese tilapia, etc.). Local restaurants did not have local fish on their menu either. Inland fishing communities could become leaders in a supplier-driven value chain. However, there are several things that are needed for this to be realized. First, the fishers and vendors need to operate more collaboratively especially at the marketing stage. Such collaboration might also engender collaborations at the production stage since the benefits from improved earnings by vendors are likely to flow back to producers (fishers) also. The best form of collaboration could come through the establishment of producer and marketing cooperatives or some form of Small, Micro to Medium Enterprise (SMME). This way, the fishers and vendors could sell their produce together and create the desired critical mass in terms of product volumes and monopoly position. There is an example of such platform for doing this in Pongola where fishers and vendors have formed a cooperative named Sizabantu (i.e. helping people). In order to succeed in such a venture, the fishers and vendors will need more business management skills to operate at the higher value chain positions. They will also need infrastructure such as cold storage facilities, mechanical dryers, mechanical fish smoking machines, etc. This is where support in terms of training and investment capital could give the inland fishing communities the required initial push.

6.8 References

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APPENDICES

APPENDIX 1: List of Project deliverables

Deliverable No.	Title of deliverable
1	Review report on fish stocks and fisheries potential
2	Review report to characterize Market Value Chains
3	Review report on governance and co-management arrangements as well as progress report
4	Research report to characterize Market value chains
5	Interim Research report to assess fish stocks and the fisheries potential as well as progress report
6	Research report on institutional mechanisms for pro-poor Market Value Chains
7	Final Research report on fish stocks and fisheries potential as well as progress report
8	Report on co-management and governance
9	Report on economic value of inland fisheries as well as progress report
10	Report on stakeholder consultation and policy dialogue seminar
11	Final synthesis report

APPENDIX 2: Capacity Building – KS/2497//4

Project Title: Towards enhancing contributions of inland fisheries to rural livelihoods: An empirical assessment of freshwater fish stocks, fisheries potential market value chains, and governance and co-management arrangements.

Project Leader: Professor Mafaniso M. Hara

Organisation: Institute for poverty, Land and Agrarian Studies (PLAAS), University of the Western Cape (UWC)

List of student on the project

The following is the list of students that had been recruited for capacity building on the project. A total of six students had been recruited. One graduated in April 2020, three have made good progress and should finish in 2021. The covid-19 pandemic have had a disruptive effect on fieldwork and therefore progress in the studies of the students. Two have not made much progress. A short summary on each student and the status of the studies is provided in the table below.

										(SA Citizens/ Permanent residents only)				
Student name and Surname	**Student ID**	**Student registration No**	**Youth (0=No; 1=Yes) 35 and younger**	**Gender**	**Race**	**Qualification**	**Country of origin**	**Country where citizenship**	**South African permanent resident? (0 = No; 1 = Yes)**	**SA province of origin**	**Nearest town**	**Name of Communi-ty**	**Settlement (Is it Rural/Urban/Peri-Urban/Informal)**	**E-mail address**
1. Melvin Swarts	8611065060085	2542937		Male	Coloured	PhD	R.S.A	R.S.A		Eastern Cape	Humansdorp	Vaaldam	Rural	melvin.swarts@gmail.com
2. Hlulani A. Hlungwani	8902115400086	20072081	1	Male	African	PhD	R.S.A.	R.S.A		Limpopo	Polokwane	Mapapila Village	Rural	Archie.hlungs@gmail.com
3. Sikhanyisele Njingana	8706260471085	2870088	1	Female	African	Masters	R.S.A	R.S.A		Eastern Cape	King Williams	Keiskamma hoek	Peri-Urban	khanyenjingana@gmail.com
4. Zandi Naka	8707100339085	2555880	1	Female	African	Masters	R.S.A	R.S.A		Western Cape	Cape Town	Khayelitsha	Urban	zandinaka@gmail.com
5. Fortunate Mashego	8608080727086	3847564	1	Female	African	Masters	R.S.A	R.S.A		Limpopo	Hazyview	Bushbuck ridge	Rural	flmashego@gmail.com
6. Tawonga Mkandawire	ZN378098	SU 22800948	1	Female	African	Masters	Zambia	Zambia	0					tmkands89@gmail.com

Student Progress Report

1. Mr Melvin Swarts

Mr. Melvin Swarts made very little progress during the project period due to re-location to Queenstown in order to take employment there. He had planned to take a study leave in the first and second quarters of 2020 so that he could push on his studies. But this did not happen either due the Covid-19 pandemic, which threw all the plans into chaos. It is hoped that he will make better progress in 2021.

2. Mr Hlulani Archiebold Hlungwani

Mr HA Hlungwani had conducted all his field surveys and had finalised his data collection. The collection of data and stock assessment of Flag Boshielo, Loskop and Phongolapoort dams had been completed. By end of 2020, Mr. Hlungwani had been writing up his thesis. He will be submitting the thesis in early 2021. The publication of a paper remains essential in order for Mr HA Hlungwani to fulfil the requirements of a PhD. at the University of Limpopo.

3. Sikhanyisile Njingana

Ms Njingana finished her Masters and graduated in April 2019. She is currently looking for employment.

4. Ms Zandi Naka

Ms Naka had been undertaking her masters on the MVC component, using Pongola Dam as the case study. She had been working on the results of the fieldwork conducted as part of the MVC component on her case study dam. Unfortunately, she has not made much progress in the last year of the project (2020).

5. Ms Fortunate Mashego

Ms Mashego has been undertaking her masters on the MVC component, using Flag Boshielo as the case study. She is working on the results of the fieldwork conducted as part of the MVC component on her case study dam. There is every hope that she will finish her studies in 2021.

6. Ms Tawonga Mkandawire

Ms Mkandawire is registered with Stellenbosch University under the supervision of Dr Salie, and Professors Hara and Muchapondwa. She has completed her fieldwork despite disruption due to covid-19. She is currently busy writing up and should submit in the first half of 2021.

APPENDIX 3: Workshops, Conferences, Meetings and Policy Engagement

- Mafaniso Hara, Barbara Tapela and Edwin Muchapondwa. Attended a stakeholder workshop for the Inland Fisheries Project in Limpopo. Held at the Ephraim Mogale Municipal Council Chambers on 19th October 2015.
- Pete Britz, Mafaniso Hara and Qurban Rouhani – Consultants for the drafting and consultative development of Inland Fisheries Policy for South Africa for DAFF. The final draft had been agreed upon in 2016 and is currently undergoing a 'social impact assessment' by the PPME before it can go for the other stages of processing.
- Mr HA Hlungwani presented a talk titled, "Assessing the potential to establish an inland fishery in Flag Boshielo Dam, Limpopo Province, South Africa", at the Southern African Society of Aquatic Scientists Conference (SASAqS) that was held at OR Tambo Conference Centre in Johannesburg during 25-29 June 2017.
- Mr HA Hlungwani presented a talk titled, "Assessing the feasibility of developing a small scale gill net fishery in Flag Boshielo Dam", at the Southern African Society of Aquatic Scientists Conference (SASAqS) that was held from 24-28 June at the Cape St Francis Bay Resort, Eastern Cape.
- Dr JR Sara presented a talk titled, "The effect of drought on metal content in fish: Considerations for the establishment of a small-scale fishery at Flag Boshielo Dam", at the Southern African Society of Aquatic Scientists Conference (SASAqS) that was held from 24-28 June at the Cape St Francis Bay Resort, Eastern Cape.
- Hlungwani, H.A., Sara, J.R., Marr, S.M., Weyl, OLF. (2019) Establishing the fisheries potential of Flag Boshielo Dam based on the combined data collected from Flag Boshielo and Loskop dams. Presented at the South African Society of Aquatic Sciences (SASAqS 2019) conference, 30 June - 4 July 2019, Protea Hotel Marriott Zebula Lodge, Limpopo, South Africa.

- M. Hara, E. Muchapondwa, P. Britz, J. Sara and O. Weyl. Potential of Inland Fisheries for contributing socio-economic benefits to rural communities. Presented at the WRC organized "Re-imagining the role of inland small-scale fisheries post Covid-19, its contribution to food security and economic development" webinar/workshop on 23 June 2020. https://wrcorgza-my.sharepoint.com/:v:/g/personal/thobileg_wrc_org_za/ERwrKi0IsKBGqhh5sK2Pp8wBymw4-Le0A2hTB2hkqpV3Yg?e=OaJzrC
- M. Hara, E. Muchapondwa, P. Britz, J. Sara and A. Hlulani. Organised and presented the findings of the project at a virtual "Stakeholder Workshop" on 10th December 2020. Below is the summary table of the programme.

Topic	**Presenter**
Small-Scale Fisheries: Global and South African Perspectives: Inland fisheries Stock Assessment and Fish Potential Market Value Chains and Economic value of inland fisheries	Professor Mafaniso Hara Archiebald Hlulani Professor Edwin Muchapondwa
Effective governance and institutional arrangements	Professor Peter Britz
Towards development of an inclusive sustainable small-scale inland fisheries sector	Professor Mafaniso Hara

APPENDIX 4: Generic questionnaire use to collect information

Small-Scale Fishing Questionnaire (Project WRC K2497)

Background information
Case study Dam………………………..
Province ……………………………….
Location: ……………………………….

Introduction
My name……………, and I am from the University of …………….. We would like to ask you some questions. The objective of the study is to understand the contribution of fishing to livelihoods. The questionnaire will take approximately 20 minutes to complete. Your participation in this research is voluntary. You can choose to withdraw from the research at any time. You also do not need to answer a particular question if you do not wish to. There are no known risks or dangers to you associated with this study. The researchers will not attempt to identify you with the responses to your questionnaire, or to name you as a participant in the study, nor will they facilitate anyone else's doing so. All responses will be confidential and used for research only.

Section A: Identity

A1. Questionnaire number ______________ A4. Date ______________

A2. Enumerator ______________ A5. Suburb ______________

A3. (Optional) Codename of respondent______________ A6. GPS _____________

Section B: Household characteristics

B1. Household membership (*start with household head*)

Name (optional)	Age	Gender M/F	Education		Relationship to household head**
			Level*	Years	
1.					
2					
3					
4.					
5.					
6.					
7.					
8.					

*0 = None 1 = Primary 2 = Secondary 3 = Tertiary
**1 = Self 2 = Wife 3 = Husband 4 = Daughter 5 = Son 6 = Relative 7 = Other

B2. Religion of the household head ____________________ Denomination _______________

B3. How many people in your household earned income in 2019? Women __________

Men ____________

	Women	Men
Wage income (per year)		
Remittances (per year)		
Social grants (per year)		
Livestock (per year)		
Other income		

B4. Agricultural income (in 2019)

Name of crop	Number of bags/buckets	Unit Price	Total
1.			R
2.			R
3.			R
4.			R
5.			R
6.			R
Total			R

B5. Household livestock ownership (in 2019)

Livestock	**Number owned**	**Number sold**	**Income**
Cattle			
Sheep			
Goats			
Donkeys			
Pigs			
Chicken			
Ducks			
Rabbits			
Other			
Total			

B6. Type of dwelling and access to toilet facilities and clean water sources

Type	Tick	Number of rooms
Brick under tiles		
Brick under iron sheets		
Brick under thatch		
Mud under asbestos		
Mud under thatch		
Toilet		
Private tapped water		
Communal tapped water		
Borehole		

Section C: Consumption

C1. Who decides how income is used in this household?

1 = Mother 2 = Father 3 = Children 4 = Family

C2. On average, how much does your household spend per year?

Expenditure item	Value
1. Groceries	R
2. School fees	R
3. Health	R
4. Transport/fuel	R
5. Agricultural inputs	R
6. Society (Funeral, etc.)	R
7.	R
8.	R
Total	R

C3. Is your household a regular consumer of fish from Voëlvlei?

0 = No 1 = Yes

C4. How many Kgs of …….Dam fish did your household buy in 2019? Kgs_____

C5. How much did your household spend buying …… Dam fish in 2019? R_____

Section D: Production and Tourism Activities

D1. Is your household involved in fishing from Voëlvlei? 0 = No 1 = Yes

Number of years in this trade Number _________

D2. Who is involved in fishing?

1. Mother 2. Father 3. Daughter 4. Son 5. Other (specify _______________)

No. of females _______ No. of males _____ No. of girls ______ No of boys _____

D3. How many Kgs of Voëlvlei fish did your household catch in 2019? Kgs _______

Value _______

D4. What fish types did your household catch in 2019?

	Kgs caught by females	**Kgs caught by males**
Fish type 1 (specify):		
Fish type 2 (specify):		
Fish type 3 (specify):		
Fish type 4 (specify):		
Fish type 5 (specify):		
Fish type 6 (specify):		
Total		

D5. During which months of year ……were you involved in fishing? Months _________

Why only these months____

D6. How many days in total did you spend fishing at …….Dam in year …..Days ______

D7. Household gender aggregated processes matrix (no. of hours on a typical day)?

	Hours Spent by Females	**Hours Spent by Males**
Gathering fishing inputs (baits, etc.)		
Travelling to the fishing site the Dam		
Fishing activity at the Dam		
Primary/Basic Processing (Cleaning up fresh fish, etc.)		
Secondary/Advanced Processing (Filleting, salting, drying, canning, refrigerating or freezing fish, etc.)		
Retailing/Distribution of fish (packaging and readying fish for sale/delivery) to consumers		
Total		

D8. How many Kgs of fish did your household earmark for sale in past year? Kgs_____

Value _______

D9. Did your household incur any transport cost associated with delivering fish to buyers/consumers in 2019? Cost______

D10. Please provide the details of the material input requirements, sources and values.

Material	**Source**	**Labour Making Own (hours)**	**Value**
1. Fishing rods			
2. Fishing nets			
3. Bait			
4. Boat			
5.			
6.			
7.			
Total			

D11. What is the state of the household's fishing equipment?

0 = Don't know 1 = good enough 2 = need replacement

D12. Is fishing technology used environmentally friendly? 0 = No 1 = Yes

D13. What is the source of your fishing and fish processing knowledge?

1 = Scientific knowledge 2 = Indigenous knowledge 3 = Unknown

D14. Is this knowledge adequate for your needs? 0 = No 1 = Yes 2 = Not sure

D15. If not, what needs to be done to improve technology and production? _______________

____

D16. Was your household involved in angling (sport fishing) in 2019? 0 = No 1 = Yes

D17. The number of days your household was involved in angling (sport fishing) in the past year?

		Women	**Men**	**Total**
People involved				
Number of	Days			

	Hours per day			
Income earned from fish				
Income for paid work done				

Section E: Marketing

E1. How do you market your fish? ____

E2. Who is involved in marketing the fish?

1 = Mother 2 = Father 3. Daughter 4. Son 5. Other (________________)

E3. What were your total marketing costs for fish in the past year? Costs __________

E4. What were your marketing transport costs for fish in the past year? Costs__________

E5. How much does your household charge for a Kg of Voëlvlei fish?

	Price/Kg
Fish type 1 (specify):	
Fish type 2 (specify):	
Fish type 3 (specify):	
Fish type 4 (specify):	
Fish type 5 (specify):	
Fish type 6 (specify):	

E6. How is the price determined? ____

E7. How much fish did the household sell in the past year through the following channels?

Channel	Kgs	Value
1. Local buyers		
2. Small scale traders		
3. Other buyers		

Section F: Institutions: ownership and access

F1. Who owns the ……. ……Dam fish resources?

0 = Don't know 1 = Fishing Association 2 = Government 3 =Chief

4 = Community 5 = Private Individuals/Companies 6 = Other (specify __________)

F2. Does your household have access to fish resources? 0 = No 1 = Yes

F3. Who in this household has access rights to fish resources?

1 = Mother 2 = Father 3 = Daughter 4 = Son 5 = Female relative 6 = Male relative 7 = Family 8 = Other (specify _____________________________)

F4. Does the household have the right to catch fish? 0 = No 1 = Yes

F5. How are the fishing rights allocated? ____

____

____

F6. Can you decide how fish should be fished at the Dam? 0 = No 1 = Yes

F7. Can you exclude others from catching fish from the Dam? 0 = No 1 = Yes

F8. Can you sell, lease management and exclusion rights to the Dam? 0 = No 1 = Yes

F9. Are there clear and understood rules/practices regarding access and fishing in the Dam?

0 = No 1 = Yes

F10. If there are rules/practices, who sets them?

0 = Don't know 1 = Fishing Association 2 = Government 3 =Chief

4 = Community 5 = Private Individuals/Companies 6 = Other (specify __________)

F11. What type of rules/practices do you have to protect the dam fish resource and the environment?

____

____

F12. If there are rules/practices, how effective are they in regulating access to the dam and actual fishing?

0 = Not sure 1 = Very effective 2 = Effective 3 = Not effective

F13. Are the fish resources in the Dam over-exploited or underexploited?

0 = Don't Know 1 = Over-exploited 2 = Under-exploited 3 = Neither

F14. Is it possible to increase fish output without threatening the resource or damaging the environment?

____

____

F15. Are there any other stakeholders/NGOs/CBOs/Gov assisting households with fishing?

Name of stakeholder	Type of support
1.	
2.	
3.	
4.	

Section G: Knowledge of the resource

G1. Where does the fish in the dam come from? __________________________

G2. How many fish types are there in the dam? Number ________

G3. Is there more fish in the dam now than two years ago? 0 = No 1 = Yes

G4. Which benefits from the dam are you aware of?

	0=No 1=Yes
Sustain stream flows	
Flood reduction	
Recharge/discharge groundwater	
Biodiversity conservation and integrity	
Cycle chemicals	
Water supply	
Food supply (e.g. list)	
Socio-cultural significance	
Tourism and recreation	
Education and research	
Other	

Thank you