AN ANALYSIS OF INLAND FISHERIES RESOURCE USE IN THE EASTERN CAPE, SOUTH AFRICA

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Abstract

South Africa's Draft Inland Fisheries Policy identifies inland fisheries as an opportunity for socio-economic benefits such as jobs, food security and economic development, based on small-scale fishing and recreational value chains. Using roving creel surveys, this study examined various fishing groups in publicly accessible dams in both an urban and a rural settlement in the Makana Municipal area, Eastern Cape, South Africa. While inland fisheries are particularly relevant for rural communities, there is very little information on the current use of these resources, irrespective of inland fisheries' importance. This thesis presents a conceptual framework for a study that: (1) reviews available information of inland fisheries and development attempts in South Africa; (2) provides an assessment of the use of inland fisheries on publicly accessible dams in the Makana Municipal area and (3) evaluates case studies of current and past utilization of selected inland fisheries initiatives in the Eastern Cape. The results of this project provide insights into the current conditions and development potentials of inland fisheries in the Eastern Cape. There was a difference in species composition between the dams, but no difference in the CPUE between dams. For example, in Grey dam many species were present, but as the dam size is only one hectare, this would result in an estimated yield harvest of only 207 kg/ha/year. Anglers were encountered at all dams, although fish were only retrieved by anglers in the rural dams of Committees Drift. Dam usage in the rural area was mostly subsistence angling, and this was significantly greater than in the urban area. Subsistence fishers utilised the fish to sustain themselves and their families and for better livelihoods. Anglers from outside the area tended to utilise the dam for recreational angling. Dams found in the urban area were also mostly used by subsistence anglers, though there were a few uses for aesthetic purposes. The urban dams were also utilised recreationally (picnics, year-end functions, swimming), as opposed to the rural dams which were only used for angling. A total of 10 interviews were administered to key respondents in the form of a questionnaires to determine the importance of the fisheries to them. Catch documented from the questionnaires, interviews and logbooks constituted 1238 species and 978 020 kg. Of all the anglers encountered from the interviews, the gill net catch species varied by dam. The fate of fish caught by anglers was dependent on employment status, with most unemployed anglers selling their fish for income and most employed anglers consuming their catch. The findings show that dams were used mostly by small-scale fishers and recreational anglers. Ichthyological surveys revealed that popular fish harvested were moggel, common carp, largemouth bass and Mozambique tilapia. The results are discussed in the context of appropriate development of fisheries in small dams in the province, with recommendations to continue monitored surveys to better inform the inland fisheries policy. The findings from this thesis show that having small scale fisheries in place and providing good access to the dams is essential for rural populations, in turn, providing better livelihoods through hunger alleviation and generating household income.

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List of abbreviations

CFE – Cape Fold Ecoregion

CPUE – Catch per Unit Effort

DEFF – Department of Environment, Forestry and Fisheries

DWA – Department of Water Affairs

FAO – Food and Agriculture Organization

GDP – Gross Domestic Product

IFFS – Integrated Food Security Strategy

IUCN – International Union for Conservation of Nature

MDB – Municipal Demarcation Board

MDG – Millennium Development Goals

MEDC – Medium economic developed countries

MEI – Morpho -edaphic index

NDP – National Development Plan

NEMBA: BA – National Environmental Management: Biodiversity Act

NT – Near threatened

RDP – Reconstruction and Development Plan

SAIAB – South African Institute for Aquatic Biodiversity

SANBI – South African National Biodiversity Institute

SANParks – South African National Parks

SAWS – South African Weather Services

Appendices

This thesis is dedicated to Prof OLAF WEYL

(1972–2020)

CHAPTER 1: General Introduction

1.1 INTRODUCTION

South Africa is considered to be a medium development country (MEDC) (World Bank, 2007), meaning that while its gross domestic product (GDP) is above the 90% threshold of its debt, it still suffers from poverty, unemployment, and food insecurity (Irons and Bivens, 2010; Pescatori, Sandri and Simon, 2014). National poverty lines are at 57% for the population, with the Eastern Cape Province having the second highest level in the country (71%) (Stats SA, 2011). Therefore, poverty alleviation is a key challenge to be addressed by the government (Lehohla, 2017). The Reconstruction and Development Plan (RDP) is a crucial element of the National Development Plan (NDP), with the NDP's goal to eliminate poverty and reduce inequality by 2030 (NDP 2011) being first on the agenda of the global Millennium Development Goals (MDGs) (Nelson, 2007).

A core strategy for conquering poverty is to increase employment opportunities (Armstrong, Lekezwa and Siebrits, 2008). Increasing avenues into the labour market can assist in reducing the current unemployment rate, which was 28.48% according to a labour force survey in 2020 (Stats SA, 2020). The unemployment rate in South Africa has increased since the early 1990s (Kingdon and Knight, 2004; Kingdon and Knight, 2007), causing a negative effect upon economic welfare, crime, social instability, destruction of human capital and the gross production of the country (Kingdon and Knight, 2004). Unfortunately, without a strong development plan, or abundant and well managed natural and financial resources, many people are left bereft of income to supply them with basic needs. While the Integrated Food Security Strategy (IFSS), adopted by the Department of Environmental, Forestry and Fisheries (DEFF), sets South Africa as a food-secure country at national level, local-level analysis shows that there is significant lack of food security within the country (Arndt *et al*., 2020). Accordingly, developing inland fisheries could be a tangible solution to reduce the threat of low food security within South Africa (Weyl *et al*., 2020).

Fisheries are one of the most prevalent resources designed specifically for the alleviation of hunger problems, either directly or indirectly (Weyl *et al*., 2020). There are 38 million fishers in the world, roughly 90% of which are small-scale fishers who fish for personal consumption (Weyl *et al*., 2020). Inland fisheries contribute globally to poverty reduction, food security, as well as social benefits from recreational and cultural use (Béné *et al*., 2015; Lynch *et al*., 2016). The estimated capture for Africa is currently 3 million tonnes in live weight per year, which forms 25% of the global inland captures (FAO, 2020). Globally, inland fisheries harvest a wide variety of fish species from water bodies including rivers, lakes, reservoirs, streams, canals, wetlands, dams and other land-locked waters (Welcomme *et al*., 2010; McCafferty *et al*., 2012; Lynch *et al*., 2015). One major constraint to developing South Africa's inland fisheries, however, is the current lack of a formalised inland fisheries policy (Weyl *et al*., 2007).

As the value of inland fishery resources has become more widely acknowledged, the literature base has expanded accordingly in order to address and synthesise knowledge of the sector. Research on fresh water fisheries has thus been considered from multiple perspectives, including history (Britz, 2015), small-scale, commercial and recreational use (Cooke and Cowx, 2006) and ecological uses (Arlinghaus and Mehner, 2003; Smith *et al*., 2005). From a policy perspective freshwater fisheries research has focussed on the development of conceptual and implementation frameworks and unpacking the political and ecological implications of fresh water resource (fisheries) use (van Wilgen *et al*., 2020). Central to research on freshwater fisheries are aspects relating to emerging conflicts between livelihood needs, economic development, and ecological sustainability (Funge-Smith and Bennett, 2019). Evidence suggests these conflicts are likely to deepen with increasing population numbers and the corresponding growing need for food security in the face of dwindling resources (Scherr, 2000). Consequently, awareness of sustainable fisheries use and the subsequent design of fresh water fisheries use have become central in debates for promoting sustainable fisheries, from both a theoretical and practical perspective (Bennett, 2005; Grafton *et al*., 2006). Although freshwaters are still largely overlooked, or conflated with other biogeographical realms, they are not incorporated in major inland policy frameworks (Lynch *et al*., 2020; van Rees *et al*., 2020). A potential reason why these resources are overlooked could be due to their poor management strategies (Lynch *et al*., 2017).

Any natural resource under exploitation needs some level of management to ensure sustainability for the future, and management must be context-specific to be successful. The social justice perspective argues that local people have the right to use resources within their localities (Drew *et al*., 2011). This is a potent argument, especially within contexts where local communities were historically denied access to these resources due to discriminatory conservation and water management policies, such as under the apartheid regime in South Africa. Fisheries resources, however, appear to be insufficient to support the livelihood requirements of a growing human population (as opposed to subsistence and food provisioning requirements) (Glazewski, 2019). With growing social calls to make access to fisheries a human right, this should result in more stringent management strategies. In order to overcome the challenge of reconciling competing demands for fisheries, there must be a more comprehensive understanding of ecological dynamics (distribution, abundance and diversity), livelihood aspects and governance complexities of inland fisheries (Hauck, 2008). Research on freshwater fisheries has increased, with a focus on critical social issues including extractive use, livelihoods, ownership and governance aspects; however, impetus has been on large-scale commercial fisheries rather than on small-scale inland fisheries (Johnston *et al*., 2012; Kolding and Zwieten, 2014).

Inland fisheries at a global scale

Globally, inland fisheries' yields are estimated to be 12 million tonnes (FAO 2020), while Lymer *et al*. (2016) estimate the global theoretical annual inland yield and harvest from inland waters to be around 72 million tonnes, presenting visible uncertainties on the actual yields of the fisheries. These yields are important, in Africa especially, as they present an untapped and largely unmanaged resource, and thus a possible pathway towards alleviating poverty and ensuring food security (Brockington *et al.*, 2006; Béné *et al*. 2015; Lynch *et al*. 2015). Small-scale inland fisheries, especially among rural communities, can provide both food and generate cash income as people are able to sell the fish that they do not consume (Sowman *et al*., 2014). The potential contribution of fisheries to livelihoods for small-scale needs and cash income generation can contribute to the local gross domestic product, which in turn can ensure higher levels of food security, which could minimise the burden on local government to ensure livelihood security. However, for this livelihood strategy to be effective, people need to have access to water bodies such as dams and have suitable equipment to harvest fish resources in an ecologically sustainable manner (Ellender *et al*., 2009, 2010a; McCafferty *et al*., 2012). In South Africa, the history of inland fisheries has not been systematically documented (Britz, 2015) and there is limited recent information available to fill the gap on the lack of recent and comprehensive data on inland fisheries, despite multiple studies highlighting the gap in literature (Weyl *et al*., 2007; Ellender *et al*., 2010b). Current knowledge is based on work done between 1990 and 2011 (McCafferty *et al*., 2012) but with fast-growing changes in economic, social and ecological contexts, these data need to be updated to better inform inland-fisheries management policies.

Another key aspect that is necessary in informing better management policies is the location of the fisheries and the user-conflicts that arise from the said communities. User conflicts often arise when there are no set rules or guidelines on how the fisheries should function (Brownscombe *et al.*, 2019). Communal rights versus open access are critical issue faced by many rural communities that are run by the Chief. These conflicts between land tenure are often bought about by lack of information within the community (Britz *et al.,* 2015). This is because the community members are not sure about communal rights or who owns the fisheries. Other user conflicts often arise between recreational anglers, small-scale anglers and/or commercial fishers for specific species or the time the anglers have access to the same fishing area.

A critical opportunity thus exists to articulate research progress and gaps and to strengthen scholarship in the field. The aim of this introductory chapter is therefore to: (1) provide a summary of the knowledge available on inland fisheries in South Africa, (2) offer insights into future research and management prospects, taking into account the socio-political contexts of inland fisheries use and governance in the Eastern Cape Province, and (3) introduce the contents of the thesis.

1.1.1 History of inland fisheries in South Africa

Much of the literature regarding South African inland fisheries was reviewed by McCafferty *et al*. (2012) and Britz (2015). I have compiled a short synopsis of their reviews; these are the only reviews on the subject conducted in the last decade, a testimony to the lack of inland fisheries research and documentation in South Africa.

The management of South Africa's inland fisheries dates back to the 19th century (Britz, 2015). The government attempted its first legislation in the 1980s, aimed at developing marine and inland fisheries by redirecting the focus from stocking of alien species for angling to conservation of indigenous fish species (Britz, 2015). At this time there were very few publications on the translocations of fish species or the legislation that governed them. The only information that was available was evidence of steady adverse impacts as a result of alien species in the environment (Skelton, 1987; Cambray, 2003).

In the early part of the 18th century the government wanted to introduce and establish non-native freshwater angling species for the recreational sport fishing economy (Harrison, 1959). The focus of these legislations was the introduction of non-native species into local waters. The introduction of non-native fishes started with Law 21 of 1884 provided for the introduction of trout, which was later revised as the Fish Protection Act (Act 15 of 1893) (Alletson, 1997). This was specifically not intended to be a development of the fishery for the improvement of human livelihoods (Thompson, 1913), rather, the focus of this Act was to develop recreational fisheries, and the two pieces of legislation neglected recommendations for sustainable resource use.

The Fish Protection Act (Act 15 of 1893) included fishing rights and areas, prescribed fishing licence fees, and provided for research and other ways to promote inland fishery development (Anon, 1944). In the Cape (now Western and Eastern Cape provinces) and Natal (now KwaZulu Natal Province) colonies, trout was introduced for recreational angling (Anon, 1944; Alleston, 1997). After a period of 50 years, the public sector established the Natal Fisheries Board in 1932 (Alleston, 1997) and a little later, the Cape Provinces Inland Fisheries Division in 1942 (Anon, 1944). In 1942 South Africa became a union, and the Joint Provincial Inland Fisheries Advisory Board was formed (Anon, 1944). Then in 1947, Natal established the Natal Parks Game and Fish Preservation Board, which promoted angling access to the general public, with trout and bass being the main species (Alleston, 1997). South Africa formed the Inland Fisheries Division in 1950, which was later renamed the Department of Nature Conservation in 1952 (Hey, 1977). In the mid-1980s, South Africa's priorities shifted from the stocking of alien fish species for angling to the conservation of South Africa's indigenous fish (Hamman, 1986). The Department of Nature Conservation became the Department of Environmental Affairs in the 1990s and its focus moved from conservation to the management of invasive species under the guidance of the National Environmental Management Biodiversity Act (Act 10 of 2004), which included several legislative instruments established to deal with managing non-native invasive species (Britz, 2015).

Comprehensive knowledge of both native and non-native species' ecology and uses is required for effective fisheries management (Weyl and Cowley, 2015). This type of management is necessary to control access and biological sustainability, and to ensure continued economic benefits for both local communities and the national economy (McCafferty *et al*., 2012). In addition, robust fisheries' dependent and independent data pertaining to the demography of participants, fishing effort and catch are fundamental requirements if fisheries are to be managed in a biologically and socially sustainable manner (Weyl *et al*., 2020). Thus, the need for an Inland policy was established by Weyl *et al*. (2007) to assist with the management of all the uncertainties surrounding the sector. To date, DEFF has started the process of formulating the National Freshwater (Inland) Wild Capture Fisheries Policy, and such information would help to better inform policy objectives such as the 'Ecosystem Approach to Fisheries', which supports the ecological and sustainable use of natural resources to obtain economic and social development (Weyl *et al*., 2020).

Inland fisheries development in South Africa

In South Africa inland fisheries are under ongoing development, but there are major data gaps which are needed to further develop the sector (McCafferty *et al*., 2012). This includes the evaluation of current use, studying the history of the sector, reviewing governance of the sector and documenting catch and effort data (Weyl *et al*., 2020). Within South Africa many inland fish monitoring initiatives have failed, as have the formalisation of inland fisheries; this, combined with unmonitored harvesting of fisheries resources, has resulted in many undocumented fisheries data or incomplete catch and effort databases (McCafferty *et al*., 2012). Certain initiatives, such as catch restrictions, have been implemented, including permits and subsistence licences, however, enforcement is both lacking and impractical due to the lack of human management capacity (Barkhuizen *et al*., 2016). For example, licences have been issued to both subsistence and commercial fisheries, but enforcement and monitoring are focused on commercial ventures due to limited human resources and feasibility (Barkhuizen *et al*., 2016).

Fishing is assumed to increase the economic value of the country (DEFF, 2020), for example, the introduction of farmed Tilapia production in Uganda (Asche *et al*., 2021), although this value is not always realised, and indeed, the trends can be obscured by incomplete datasets. Total harvesting of freshwater fish is perceived to be very limited in South Africa (Ellender *et al*., 2010a). The general notion is accepted that inland fisheries are used mainly on a leisure and societal basis rather than on a professional level (Weyl *et al*., 2020 b). One of the challenges faced is that information on small scale fisheries (catch, employment etc) is often not recorded, cannot be retrieved or seen and therefore are omitted from national and global datasets, and thus often side-lined in policy making processes; this is also known as a *hidden harvest* (Lynch *et al*., 2020). The World Bank, FAO and the WorldFish centre's Hidden Harvests study (World Bank *et al*., 2012) use a variety of alternative fish-yield assessment approaches to evaluate fish harvest accompanying national (or FAO) statistics. Comparative estimates of fish abundance are often poorly derived, not only due to limited availability of human and financial resources, but also due to a lack of standardisation in the assessment approaches (Cooke *et al*., 2016). This leads to the prevailing perception that current resource use is low and dominated by recreational users, which may not account for the actual and realised total use of fishery resources. Inland fisheries development represents a potential vehicle for bolstering socio-economic benefits, including job creation, rural livelihoods, food security and poverty alleviation (DEFF, 2019). To do this successfully, however, requires comprehensive information on the current utilisation of fisheries across all stakeholders and user bases, lest an inland fishery policy is created which does not provide for historically overlooked users.

The demographic characteristics for fishers found in a study done in the Free State revealed that anglers were comprised of White South African anglers ≥ 60%, Coloured South African anglers ≥ 25% and Black South African anglers ≤ 16% for recreational anglers, while Coloured South African anglers ≥ 84% and Black South Africans 16% made up subsistence fisheries users (Ellender *et al*., 2009), despite the demographic of the province being overwhelmingly Black South African. Another study within the same province found that both recreational and subsistence fisheries used the same fisheries (Ellender *et al*., 2010). The anglers encountered in all studies were comprised of ≥ 90% males across the race spectrum. However, this study did not reveal what the primary uses of the fishery are, as results pertained only to the two dominant user groups and the dominant gender. The fact that subsistence anglers were using the resources regularly suggests that inland fisheries may well be effective in achieving the objectives set out by DEFF to ensure rural livelihoods, with no current studies done to suggest otherwise. Extrapolating whether the fisheries are being used mainly for recreational purposes or directly for sustenance or indirectly for economic enhancement is essential to be able to create effective policy which manages the resource sustainability. A viable method of achieving this information is through deriving catch and effort data for inland fisheries by way of fishery-dependent surveys (Latzka *et al*., 2013).

Studies on Inland fisheries done in South Africa

Catch and effort counts, and trends therein, of freshwater fish harvests are needed for accurate fisheries management, as this provides data on resource availability to a certain community, the species being harvested and the rate of harvesting for sustainability purposes (Young *et al*., 2006). Most traditional fisheries assessment models tend to focus on patterns of growth, and/or survival of fish as well as behavioural models to help understand stock dynamics on a broader scale (Alonzo and Mangel, 2004). For a quantitative assessment to occur, robust catch and effort estimates are integral, as they describe the amount caught over a particular period of time. This can then be used to determine total productivity and yield of a water body and to calculate from this a recommendation for total allowable catch (Sutherland, 1998). Fisheries total catches have been declining since the early 1990s (King, 2013). Not only are the catches decreasing but the size of the individual fish in catches are becoming smaller (Cowx and Walters, 2002), which negatively impacts the species' spawning biomass (Alonzo and Mangel, 2004). Therefore, long term data and monitoring plans should be implemented to track ecologically significant changes in fish populations, as this can be affected by both harvest rates and environmental changes (Ayllón *et al*., 2020).

In South Africa, few studies have captured inland fisheries harvest, resulting in low estimates of capture quantity nationally (Figure 1.1). Lake Gariep, the largest impoundment in South Africa, has been the subject of most South African estimates captured at a national level. In one of the few long-term studies quantifying harvests, Lake Gariep was found to provide a total harvest of 282 t·year^{1} over a 35-year period, with the dam providing between 2–207 t·year^{1} for commercial fisheries (Ellender *et al*., 2010; Barkhuizen *et al*., 2016). Another study at Lake Gariep focused on the user group dynamics, utilising questionnaires and interviews. The social surveys revealed a range of between 3–15 anglers per day^{-1} in one sampling survey and 17–44 anglers per day^{-1} in another, but no catch or effort data was recorded (Ellender *et al*. 2009). A cheap and reliable method to assess productivity is to use tournament angler data to calculate catch rates and effort count (Hargrove *et al*., 2015). Van der Waal (2000) assessed fishery use in the Mutshindudi River catchment in the Limpopo province to show the contribution of the river to food security and the possibility of rural development. However, once again, no harvest data was recorded. These methodological and data oversights have resulted in a lack of comprehensive and inclusive fish harvest data within the country.

Fishing has proven to be one of the most cost-efficient ways in which to obtain protein, which is required for human growth and development, especially among the young (Allan *et al*., 2005). Inland water bodies provide ecosystem services by way of tangible benefits such as water for human consumption, irrigation, livestock and fisheries which contribute to food security, as well as other indirect benefits which help to alleviate poverty and increase quality of life (Welcomme, 2008; Sterner *et al.*, 2020). For example, commercial harvesting of the fish for drug manufacture may be derived from certain fish species, and ecosystem dynamics as a result of ecosystem engineer species may alter water quality parameters (Allison and Ellis, 2001; Béné *et al*., 2015). Inland fisheries within rural and urban communities are often utilised by several groups, ranging from recreational anglers, small-scale fishers and commercial fisheries. In South Africa, the first two use groups are the most dominant of the three. Community-based management is often used in the management of these fisheries, which in many cases results in user conflicts arising within the communities (Bishop, 1980; Napier *et al*., 2005). These conflicts are based mostly on the notion of ownership, availability of suitable species and lack of management (i.e., sustainability of the resource), all of which must be resolved for any formal fishery initiatives to succeed. Ownership of land and water has been a long-standing problem in South Africa, due to the history of the country where the majority of land was owned by white South Africans (Hamilton, 1982).

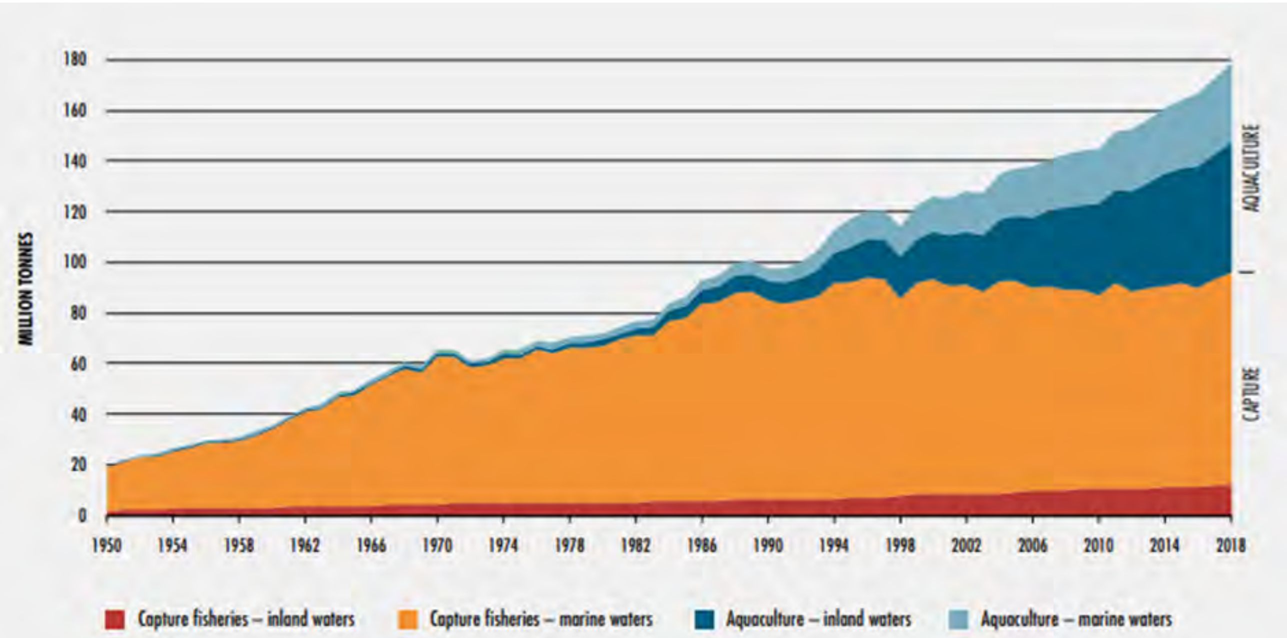


Figure 1.1 The low inland fisheries capture globally to other sectors from 1950–2020 (adapted from FAO, 2020: The State of World Fisheries and Aquaculture: Sustainability).

To be able to incorporate inland fisheries development objectives, the inland fisheries mandate was included within the Department of Agriculture, Forestry and Fisheries in 2009 (now the Department of Environmental, Forestry and Fisheries, DEFF). This renewed interest in developing inland fisheries is demonstrated by the Draft National Freshwater (Inland) Wild Capture Fisheries Policy (DEFF, 2019). The policy includes a section on the profile of inland fisheries in South Africa, which includes small-scale fisheries, recreational fisheries, culture-based fisheries and fishing permits, among other factors. It also includes a much broader section which details the national inland fishery policy framework as well as the policy implementation section. Both are of utmost importance toward developing appropriate management strategies which promote the capacity of inland fisheries to contribute to achieving the sustainable development goals (SDGs) of poverty reduction and achieving zero hunger (Lynch *et al*., 2020; Weyl *et al*., 2020). While in South Africa attainment of the SDGs has been slowly deteriorating, practices are in place in an attempt to restore them little by little, including land reform. This is a crucial step in developing equal distribution and access of natural resources, especially in the South African context, as this economic benefit can help uplift and transform historically deprived communities.

The legacy of the South African apartheid era has persisted post-apartheid, causing much uncertainty regarding land ownership and human rights (du Plessis, 2011). During the apartheid era various land reform and redistribution programmes were formed through the land tenure system. Communal land was located in rural areas, which covered 13% (about 18 million ha) of South African land (Thompson, 2001). Most of this land is found in Mpumalanga, KwaZulu-Natal and the Eastern Cape, with all citizens having rights to the communal land (du Plessis, 2011). This communal land was divided into bantustans, based on language and culture, namely, Bophuthatswana for the Tswanas, Venda for the Vendas, and Transkei and Ciskei for the Xhosas (now part of the Eastern Cape) (Khunou, 2009). The bantustans had pseudo-rights based to a governance system of chiefdoms who answered to the government as political pawns, however, they were crippled in terms of autonomy and finances, which only entrenched the inequalities within black communities (Pires and Moreto, 2011). Most land was and is owned by the government, although statutory recognition of rural communities as collective owners of the land they reside in is slowly emerging through land reform (du Plessis, 2001).

Categorisation of the land rights in South Africa

At present, land is categorised into what is called land tenures, which can be defined as the relationship (legally or customary) among people, as individuals or groups, with respect to land (FAO, 2002; Adams *et al*., 2007). These are divided into four categories, namely, private, communal, open access and state-owned properties (du Plessis, 2001). Private land tenure is the consignment of rights to a private party (FAO, 2002). This can be to an individual, a group of people, a community, government, and so on. Consent is needed from those that hold the rights to be able to use the land. Communal land is a right of commons that may exist within a community, and each member of the community has the right to independently use the land (Clark and Luwaya, 2017). An example is an individual who is a member of said community using a communal field to graze their cattle, but a member of a different community would not have access. In contrast, in open access land tenure there are no rights assigned to anyone and no-one can be excluded from using the common areas (FAO, 2002).

State owned rights in rural communities are left in the custodianship of the leaders of those communities such as Chief Zwelizihlangene Maxinana of kwaPikoli homestead in Committeess Drift, who help to manage the land on behalf of the state or government. Access to communal land is therefore semi open, unless the community specifically creates an organised system to control it, based on the Communal Land Rights Act of 2004, which allows the ownership to be transferred from the state to groups, individuals or communities (Cousins, 2007). This might be through the chief, headsman, a community leader or Tribal Authority (Cousins and Classens, 2004). In South Africa, dams fall under state and communal tenure systems, which means that all members of the community have the right to utilise the ecosystem services such as fisheries, irrigation water, grazing pasture and so on (Clark and Luwaya, 2017). This means that the local community has what is called user rights (they can utilise the land), but does not have the right to transfer, sell or lease out the land (FAO, 2002).

Historical inequalities only serve to increase current inequalities and levels of need or reliance on the ecosystem services, especially when they are entrenched in policy regarding physical location, and thus it is an insidious and multiplicative problem (Ellender *et al*., 2009). The segregation of the resources was a deliberate endeavour by the apartheid government to control all ecosystem services within the country and to repress people (King, 2007). Thus, the local traditional communities did not have control rights and only limited user rights, whilst the Afrikaner minority had total user and control rights to the majority of the natural resources (Thornton *et al*., 1989). For many years, some historically disadvantaged communities were unable to utilize local resources despite their direct dependence on them for food, sanitation or income generation. Local communities residing in former homelands are mostly disadvantaged citizens who are directly dependent on the natural resources found on these lands for food, grazing, water consumption and fishing, yet under the Bantustan system they were prohibited access to the areas which contained their means to live (Costello-Nichitas, 1987). There have been some legislative changes post the apartheid era. One of the changes was the demolishing of homelands, however, for the communities that live in these areas many of the economic conditions under which they lived still remain, such as the use of natural resources for food and the dependency on livestock (Kemerink *et al*., 2011). In the current context of inland fisheries, access to the fishery in Lake Gariep was controlled through a minimal entry fee and permits

(Ellender *et al.*, 2009), which is currently no longer the case (DEFF, 2019). The legal aspect of local control rights may no longer be in place, but the historical problems are still present due to the lack of management of fisheries resources (Cooke *et al.*, 2021b). Historical patterns in land ownership and segregation-based policies have left South African inland fisheries subject to complex user dynamics. The most dominant users of inland fisheries in South Africa are recreational anglers and small-scale fisheries (Weyl and Cowley, 2015; Barkhuizen *et al.*, 2017). Both these user groups contributed 41% and 51% respectively in total fishing effort in the Free State Province in 2010 (Ellender *et al.*, 2010a), a trend which is likely reflected across the entire country's fishing effort. In South Africa, ten years ago most recreational anglers were White South Africans, and small-scale subsistence level anglers were predominantly black African South Africans and Coloured South Africans (Ellender *et al.,* 2009), and today the situation is still the same (Hara *et al.*, 2021) Thus, understanding who is using which fishery and why, is necessary to develop the sector in an unbiased and effective manner. A particular emphasis on user rights and access to well managed resources is integral in order to start to ameliorate historic damage and promote economic enhancement. Factors (such as catch data, effort data, angler demographics and so on) which are paramount in understanding these inland water bodies, have been highlighted by Weyl *et al*. (2020), and will help to support the National Freshwater (Inland) Wild Capture Policy currently being formulated.

1.1.2 Small-scale fisheries

Small-scale fisheries can contribute towards the 'sustainable livelihood approach' in developing countries (Allison and Ellis, 2001; FAO, 2003). South Africa has specifically adopted the economic contribution of small-scale fisheries as a tool for poverty alleviation (Sowman, 2006; Sowman *et al*., 2014). Consequently, South African small-scale fisheries have now been formalised and recognised by the government through the Marine small scale fisheries policy and the current draft Inland policy (Sowman, 2006; Weyl *et al*., 2020). This is timely as increasing poverty rates mean that people are more reliant upon small-scale fisheries, which provide concomitant socioeconomic subsidies to local and informal economies in a largely currently undocumented manner (Weyl and Cowley, 2015).

Small-scale anglers are individuals who live close to the water body, use basic forms of transportation and use artisanal type fishing gear. Generally, these fishers are dependent on fisheries for food and for a primary or supplementary source of income (Britz *et al*., 2015).

Consequently, the number of people using inland water resources are growing at an increasing rate, including impoundments (Weyl *et al*., 2007; Ellender *et al*., 2009; McCafferty *et al*., 2012; Barkhuizen, 2016). Small-scale fisheries are more informal, and users are often not formally recognised by the government (Sowman, 2006), and this could account for the lack of catch data availability. The increased usage by small-scale fishers is important (Weyl and Cowley, 2015), and is positive for the local economy. However, this industry cannot reach its full potential due to a lack of visible clear roads to reach the dams by potential fishers and the cost of fishing gear, and these are thus impediments to the 'sustainable livelihood approach'.

Widespread lack of access to fishing gear is a possible factor in the failure of South African attempts to use inland fisheries for poverty alleviation (McCafferty *et al*., 2012). This opens the possibility for exploration of readily available fishing gear. Gill net fishing has been used in countries such as Greece and the Philippines (Stergiou and Politou, 1996), however, gill nets are associated with high by-catch rates (Ortiz *et al*., 2016). There are increasing reports of the initiation of small-scale fisheries using gill nets in several provinces of South Africa, such as the North-West, Western Cape and the Free State (Weyl *et al*., 2007; Weyl and Barkhuizen, 2020). Gill net angling is largely used in small-scale fisheries, rather than recreational angling (Britz *et al*., 2015). In order to be able to develop fisheries, a look into recreational angling needs to be considered, as it constitutes about 60% of catch data (Mannheim *et al*., 2018).

1.1.3 Recreational angling

Recreational anglers are individuals who fish in bodies of water for leisure, generally access the water body by car, have permanent employment and may release, consume or sell a portion of their catch (Ellender *et al*., 2009; Weyl *et al*., 2017). Recreational angling is a widespread activity globally, in both freshwater inland water bodies and marine environments (Cowx, 2002; Arlinghaus and Cooke, 2009). It is associated with mostly natural and cultural values which add to human well-being, capacity building and knowledge transfer (Lynch *et al*., 2015). Recreational anglers could be considered to constitute a form of formalised fishery because individual anglers are usually affiliated to a formal organisation or management structure (Granek *et al*., 2008). This involves the payment of membership fees to their respective clubs and or payment of licences, which generate income. Growth in this sector has added positively to the GDP of most countries. There is a growing belief that not all recreational anglers fish solely for recreation. While most of the fish caught are released shortly thereafter, some keep the fish for consumption (Cooke and Suski, 2005).

These activities can provide catch data information for most inland water bodies through recorded tournament data. Recreational fishers are often highly engaged in citizen science efforts and follow given appropriate protocols for data capture. There is the potential to leverage this accumulated body of knowledge to generate high powered yet cheap data regarding water quality, fish health, and productivity, despite recreational fishing generally being considered a leisure sport (van der Waal., 2000; Taylor *et al*., 2015).

1.1.4 Fisheries development

Quantifying and understanding the sociological and ecological interacting factors which drive fishery persistence will enable policy to be developed in a rational and sustainable manner (Mc Cafferty *et al*., 2012). A guideline for attaining this follows. First, effort estimation should occur through creel surveys and angler counts (Barkhuizen *et al*., 2017), second, participation estimates and user information should be derived through semi-structured interviews, and third, species composition and abundance should be assessed via field surveys (Ellender *et al*., 2010). Possible fisheries recommendations for South Africa are grouped into four different categories, namely, community-managed subsistence fishery, commercial fishery, recreational fishery and open-access fishery (Weyl *et al*., 2007).

Various initiatives have been attempted by the South African government with regards to inland fisheries management and sector development (DEFF, 2019). For example, the government attempted to establish formalised fisheries in Xonxa dam, Lubisi dam, Lake Gariep, Lake Van der Kloof, Darlington dam and Ntenetyana dam. All these initiatives failed to establish a formalised fisheries unit, leaving many people without employment and without any usable catch and effort data recorded, making the initial objectives obsolete (Rouhani, 2003; Mc Cafferty *et al*., 2012; Britz, 2015). Reasons for the failure of these initiatives are not documented, but only assumed, with the blame attributed to a lack of fishing equipment, low value of the resource and a cultural resistance to fishing (Charles, 2001; McCafferty *et al*., 2012). There are also rising management concerns that these commercial and small-scale fisheries might threaten endangered fish populations (Charles *et al*., 2000). All of these conflicting factors have prompted the government to start a formalised Inland Fisheries Policy to try and better manage the resource.

1.1.5 Fisheries Policy

The current policy frameworks available for fisheries in South Africa only give an overview of the inland fisheries sector. The aim of this policy development is to be able to align inland fishery governance with the constitutional requirements for a sustainable development approach to natural resource utilization for the benefit of all citizens (DEFF, 2019). Another objective of the policy, aligned to the constitution, aims to secure ecologically sustainable development and use of natural resources, while promoting justifiable economic and social development (Constitution, Section 24 b (iii)). The primary objectives of the policy are to develop fisheries governance in the country, as none currently exists, to promote equity among fishery resources that will enable them to be utilised in a sustainable manner, and to grow the inland fisheries value chain. This is all in line with the FAO 2030 SDG goals (Lynch *et al*., 2020) and South Africa's National Development plan in fighting poverty and hunger. Combining the history of the fishing sector and the current use of fisheries resources and aligning these data with the estimated harvests and governance currently available, could assist in creating a more concise fisheries development (Weyl *et al*., 2020).

There is, however, very little information available with which to guide the development of inland fisheries (McCafferty *et al*., 2012). Information on specific management objectives tailored for the entire range of stakeholder groups is currently non-existent, and therefore must be addressed as an imperative to encourage equitable development. The information that is available indicates that developing the inland fisheries sector will not be easy. An analysis of the history of formal fisheries in the Free State Province demonstrated that most of these initiatives were unsuccessful (Barkhuizen *et al*., 2017). Most formal interventions have failed in South Africa due to lack of equipment, no clear useable road leading to the fisheries and a lack of suitable species to exploit (Mc Cafferty *et al*., 2012). In addition, a lack of skills to manage and operate a fishery successfully was indicated to be a major constraint to small-scale fisheries development (Isaacs, 2006). As a result, most utilisation of inland fisheries in South Africa remains informal, in the form of angling for recreation, food and personal livelihoods (Ellender *et al*., 2010).

The knowledge gaps holding back inland fisheries development in South Africa can be thus summarised as (i) catch rates, fishing effort and yields, (ii) the failure of formalised small-scale fisheries to develop, iii) user-conflicts between fisheries user groups and (iv) community-based management dynamics of ownership and self-governance (Weyl *et al*., 2020).

1.1.6 Thesis aims, objectives and structure

The primary aim of this thesis is to better understand how people use small dams in urban and rural settings in the Eastern Cape Province of South Africa. To do this, I selected 7 dams in Makhanda and Committees Drift in the Makana municipal area. To represent dams in a rural (Committees Drift) and an urban (Makhanda) area, fisher surveys were conducted to describe fish species composition, human activity and fish utilisation from these dams.

In CHAPTER 2 I used data from fisheries surveys to describe the fish communities in these dams, to test the hypothesis that species composition was similar between the various dams within an area.

In CHAPTER 3, the results from effort surveys and roving creel surveys were used to present a comparison of the demographics of dam users between the rural and urban areas, and for what purposes people used these resources. Interview data were used to describe the demography of fishers using the dams, and catches were quantified to estimate harvests by anglers.

During the creel surveys the existence of a small gill net fishery in the Committees Drift dams was discovered. This fishery is described in CHAPTER 4, with details on the management practices and harvests from the fishery.

The final Chapter (CHAPTER 5) is a discussion chapter on the utility and future prospects of small fisheries in rural areas. I make suggestions for how such fisheries should be integrated into small-scale capture fisheries policy.

CHAPTER 2: Fish species composition and relative abundance in three urban and four rural dams in the Eastern Cape

2.1 INTRODUCTION

Small-scale fisheries in South Africa are touted as avenues for food security, and contribute to improving rural livelihoods (Charles *et al*., 2000; DEFF Capture (Inland) Policy, 2020). The value of inland fisheries within the Eastern Cape is largely neglected, despite the varied fish species composition found within the province (Whitfield and Paterson, 2003). As detailed in Chapter 1, the development of these fisheries would need to be carefully planned to ensure that such fisheries are biologically, socially and economically sustainable. The use of fisheries has slowly increased over the past two decades with an increase in small-scale fisheries and the development of alternative management approaches for these resources, as opposed to conventional approaches which have clearly failed to address the complex needs and dynamics of South African inland fisheries (Table 2.1). Colonial and western approaches have proven to be untenable for the sustainability of small-scale fisheries in South Africa, and it is possible that the use of traditional management and indigenous knowledge bases could lead to prosperous and sustainable fisheries worldwide (Charles *et al*., 2000; Reid *et al*., 2020).

Table 2.1. Conventional approaches and new approaches of inland fisheries on a global scale (reproduced from Sowman et al., 2011).

Conventional approach	New approach
Single-species approach	Ecosystem approach
Biophysical focus	Holistic (socio-ecological) approach
Centralised	Decentralised and devolved
Command and control	Enabling and empowering
Reactive	Proactive
Regulatory	Incentive-based
Sectoral	Integrated and coordinated
Technocratic	Participatory
Blueprint	Adaptative learning process
Technical solutions	Context specific solutions
Scientific knowledge systems	Recognition of other knowledge systems
Reliance on quantitative data	Incorporation of qualitative interpretation

Failure of the new approaches (Table 2.1) is mostly attributed to a lack of implementation of policies, and mismanagement of the sector (Sowman, 2011). For fisheries to provide benefits to communities, feasibility studies need to be completed on the fisheries and subsequent predictions made prior to management recommendations, in order to validate the sector. The validation of small-scale fisheries is slowly evolving into a complex socio-ecological system which now sees fisheries as a web of inter-related, ecological, biophysical, economic, social and cultural components (Anthony, 2001). Each component within the sector needs to be addressed to provide for a better understanding and study of the fisheries as a water resource in its entirety. Due to the drought cycle throughout South Africa, fisheries resources are endangered in most parts of the Eastern Cape, as water becomes prioritised for human consumption in such cases (Rouault and Richard, 2003; Baudoin *et al*., 2017). Rather than considering only the social or ecological aspects of inland fisheries, we must start considering them as interlinked components which will ultimately control and drive the need, use and system productivity; these cannot be managed separately but as one system, and thus the data must be representative of all users and factors (Reid *et al*., 2020).

To guide this process Weyl *et al*. (2007) recommended the use of a decision-support matrix to help managers decide what scale and which management regime would be appropriate in the South African context. This decision-making framework requires information on biological (productivity, species composition and abundance) and social (current users, access rights, willingness for development) considerations to make recommendations on whether fisheries would be best suited for subsistence, recreational or small-scale commercial use. On assessment, future management can be directed towards developing either small-scale or recreational fisheries.

Small-scale fisheries could either be of a subsistence or commercial nature. Commercial fisheries use artisanal gear such as gill nets and long lines and this approach is recommended for waterbodies where predicted fish yields are likely to exceed 50 Mg/yr, and where fish communities include species that have a proven ability to support fisheries elsewhere (e.g., Mozambique tilapia *Oreochromis mossambicus*, common carp *Cyprinus carpio*) and where there is limited potential for fisheries to impact on conservation priority species (Weyl *et al*., 2007). Appropriate fisheries can be present where there are formalised agreements about the use of the fisheries (Arlinghaus, 2002; McCafferty *et al*., 2012), sufficient suitable species upon which to base a fishery, appropriate access rights to fisheries resources by the community (Weyl *et al*., 2007; McCafferty *et al*., 2012) and an abundance of skills to execute the fishery successfully (Isaacs, 2006).

Small scale subsistence fisheries are recommended in areas where there is limited capacity for formal enterprise, either because fish yields are likely to be low, or because the area lacks potential for recreational fisheries development. The conditions of this fishery would be the same as for that of recreational anglers, the difference being that a recreational angler either releases their catch back to the water body or keeps them for consumption. A recreational fishery would be advisable to start where 1) the required yield would be < 50 t/ty or < 100 t/ year based on any MEI (Morpho-edaphic index used as a first estimate of potential fish yield) model applied, 2) the location has pre-existing recreational usage and a local interest towards developing further tourism, or 3) is situated close to a nature reserve with an associated local community (Weyl *et al*., 2007). Recreational fisheries are recommended for dams which contain popular angling species. The chief native fish species of angling interest include the moggel *Labeo umbratus* (Smith, 1841), the yellowfish *Labeobarbus* (Burchell, 1822), the long fin eel *Anguilla mossambica* and the Mozambique Tilapia *Oreochromis mossambicus.* However, the predominant recreational target species are all non-native species in South Africa, having been introduced primarily for sport fishery enhancement (Weyl and Cowley, 2015). While the introduction of non-native fish species in South Africa was intended to confer socio-economic benefits, these species have negative implications for native biodiversity (Ellender and Weyl, 2014; Weyl *et al*., 2020). Many non-native species were introduced into South Africa in the early 19th century for recreational purposes, including Common carp *Cyprinus carpio* (Linnaus. 1758), largemouth bass *Micropterus salmoides* (Lacepède 1802) and small mouth bass *M. dolomieu*, spotted bass *Micropterus punctulatus* (Rafinesque 1819), *Oncorhynchus mykiss* and *Salmo trutta* (Ellender *et al*., 2014; Ellender and Weyl, 2014; Weyl and Cowley, 2015). A total of 55 non-native fish species were recorded between 1926–2013 in South Africa (Ellender and Weyl, 2014). Globally, and within South Africa, more studies assessing ecological and socioeconomic impact, both positive and negative, need to be performed to inform further management options (Simberloff, 2005, 2006b; Weyl *et al*., 2020).

2.1.1 Eastern Cape

There are a large number of fish species present in the Eastern Cape, both native and non-native (van der Waal and Skelton, 1984). This is due to the large geographical range and number of ecoregions encompassed within the province. There is an overarching freshwater ecoregion in the Eastern Cape, the Southern Temperate Highveld, which is further divided into the Amatole–Winterberg Highlands and the Zambezian Lowveld ecoregion.

The Southern Temperate ecoregion comprises most of the Eastern Cape, with the Northern border being the Drakensberg Mountains (Shelton *et al.*, 2018). The Southern temperate region is a grassland biome, with generally cold and dry winters (Carbutt *et al*., 2011). Topographically, the landscape of the region varies from flat to hills and valleys with a mountainous escarpment with elevation ranges of 300–3482 mm. Seasonal summer rainfall of the region varies from 400–2500 mm per annum (SAWS, 2020), running into a variety of streams, river and dams. The largest river found in the ecoregion is the Orange River system, including its two tributaries the Caledon and the Vaal rivers (Cambray *et al*., 1986). The ecoregion extends to the south of the Eastern Cape, where the coastal rivers are further divided into types, with the largest systems extending from inland water sources (Gamtoos, Sundays, Great Fish and the Kei River systems (Skelton, 1980). The Amatole-Winterberg Highlands lies in a low-altitude coastal plain area and includes headwaters from the Buffalo River, the lower Great Fish, the Keiskamma and the Swart Kei (Hughs and Hughs, 1992). The Zambezian lowveld runs from the south of the Zambezi Delta in Mozambique towards the Tugela River system in South Africa (Timberlake, 1998). There is also a small portion of the Cape Fold Ecoregion (CFE) found in the Eastern Cape province, although most of it is situated in the Western Cape of South Africa (Abell *et al*., 2008). Rivers that are supported by the erratic rainfalls in this region include the Great Fish, Sundays, Kowie and Bushman's rivers (Van Nieuwenhuizen and Day, 2000).

2.1.2 Eastern Cape fish fauna

Both native and invasive fish species are found broadly distributed throughout the catchments in these ecoregions. About thirty indigenous species are found in this ecoregion, eleven of which are endemic, with a further eleven being critically endangered, three endangered and one near threatened (Skelton, 1987). Several threatened species are found within the Great Fish River system. The majority of these inhabit protected areas (Skelton *et al*., 1995) such as the Eastern Cape rocky *Sandelia bainsi* (found in four river systems in the Eastern Cape), the border barb (*Barbus trevlyyani*), the rock catfish (*Austroglanis sclateri*) and the Treur River barb (*Barbus treurensis*). Other native fish species found in the Great Fish River system include the African longfin eel *Anguilla mossambica*, Mozambique Tilapia *O. mossambicus* and Cyprinids such as the moggel *Labeo umbratus*, and *G. callidus* (Skelton, 1993).

Non-native fish species are abundant and common throughout all of the key river systems (Leprieur *et al*., 2008). Notable introduced species in the Eastern Cape are *Oreochromines*, *Tilapiines* (Cichlidae), and common carp (*Cyprinus carpio*, Cyprinidae), which were introduced for aquaculture purposes and have since spread across the country (Casal, 2006; Vitule *et al*., 2009). Species such as the largemouth bass *Micropterus salmoides* and bluegill sunfish *Lepomis macrochirus* were introduced during the 1900s (Harrison, 1959) for recreational fishery purposes, the majority of which were illegal introductions (Woodford *et al*., 2017). The Inter-Basin Water Transfer Tunnel linking the Orange River and the Sundays and Great Fish Rivers facilitated the invasion of extralimital species such as the African sharptooth catfish, *Clarias gariepinus*, and the orange river mudfish *Labeo capensis* into the Eastern Cape. Also present in the Sunday's River system are the estuarine round herring, *G. aestuaria* and the *Cyprus carpio* (DWA, 2010).

The persistence of both native and alien freshwater fish species is attributed to predation, competition, biotic and abiotic factors (Jackson *et al.*, 2001). In most South African impoundments abiotic factors such as temperature, pH and salinity affect fish abundance in freshwater bodies (Ellender and Weyl, 2014). This makes the variety of species inconsistent across locations within the Makhanda region where the study took place. The dominant species in the Eastern Cape catchments are *M. salmoides*, *G. callidus* and *Tilapia sparmanii* (DWA 2008). The most abundant species recorded in the Kariega catchment in a study were *Glossoggobius callidus*, *Gilchristella aestuaria*, *Myxus capensis* and *Rhaddosargus holubi*, which constituted 78% of the fish fauna (Whitfield and Paterson, 2003). These broadly represent the most commonly found species in the Eastern Cape River systems. The Great Fish River system contains the common fish species, and the Labeo species such as *Labeobarbus aenus*, present near Tsomo, and the moggel *Labeo umbratus* (DWA, 2010). *Sandelia bainsii* and *Barbus trevelyani*, found in the Western Cape, are listed as endangered in the International Union for Conservation of Nature red list (Rodrigues *et al.,* 2006). Both species are threatened due to the presence of alien fish species and degradation or loss of habitat due to water loss, and as such represent a conservation concern.

2.1.3 Aims and objectives

Assessing the biological potential of dams is necessary to create a baseline for interpreting any results from research on fisheries utilisation (Chapter 3), and also for making realistic recommendations regarding their development. For this reason, the aims of this chapter were primarily to provide descriptive biological information on the seven dams to (1) provide a first estimate of potential yield based on the application of empirical yield models,

(2) determine fish species composition to assess for the presence of fish species suitable for fisheries development and the potential presence of conservation priority species, and (3) provide a comparative assessment of fish abundance between the dams. In terms of dam differences, I hypothesised that (1) species composition would be independent of dam and (2) that fish abundance (measured by catch rates in experimental gear) would correlate with the potential yield estimated from morpho-edaphic index (MEI) models.

2.1.4. Study area

The Eastern Cape is the second largest province in the country, but it is the most poverty stricken, with a population of 7 million people all occupying a land coverage of 169 000 km^2 (Stats SA, 2016), about 13.9% of South Africa's land area. The province was formed in 1994, incorporating the Xhosa homelands. The province is the fourth richest in terms of total income, and the eighth in terms of per capita income, yet it remains one of the poorest provinces in South Africa (Pauw, 2005). The current high poverty and unemployment rates can be linked to the history of the province and its neglect. The Eastern Cape is divided into two metros and seven district municipalities. This study took place within the Makana municipality.

Makana Municipality is situated on the south-eastern seaboard in the western part of the Eastern Cape, and is one of seven municipalities in the Sarah Baartman District, with a population of roughly 86 600 (Stats SA: MDB, 2017). A range of public and private nature reserves span the area. The study sites were split between urban areas, i.e., within Makhanda, and rural areas, using Committees Drift.

Grahamstown (now known as Makhanda) is the hub of the Makana Municipality and was founded in 1812 (Makana Local Municipality Socio-economic Review and Outlook, 2017). The town is best known for its historical events and history of lack of water. Water usage is very restricted and a scarce natural resource in the municipal area, and has been periodically decreasing over the course of years (Rouault and Richard, 2003). The majority of land and water usage within the province is primarily for fisheries, grazing and agriculture, with specific emphasis on cattle, maize and sorghum (Kakembo and Rowntree, 2003). The urgent need to provide more water services for human consumption has often conflicted with the need to maintain the good ecological condition of the rivers, which has had a negative effect on the fish species (van Niekerk *et al.,* 2008). The necessity to have reliable access to clean and abundant water has driven innovation to develop alternative water supplies and improve access to water resources through building infrastructure such as impoundments and water transfer systems. An example of such impoundments and transfer systems created due to water scarcity in the town of Makhanda is the Settlers dam which receives all of its water supply from the Kowie river system (Snowball *et al*., 2008). The dam was constructed in the 1960s due to a water shortage the town was experiencing (Mullins, 2011).The supply from this system was a subsidiary to already existing alternative water transfer schemes developed in the 1800s such as the Fort England Spring, the Grey Dam, Douglas Dam, Hamilton Dam, Cradock Dam, the Slaaikraal Dams, Milner Dam and Jameson Dam, some of which have since dried up, and the ongoing shortages have forced the use of rainwater within the community for survival (Mullins, 2011 and Tandlich *et al*., 2014). Makhanda has experienced intermittent droughts since the 1800s, with the longest drought period being that which was experienced in 1984 which lasted 33 years (Mullins, 2011). The current projected average rainfall precipitation in Makhanda is 460.6 mm, with an average temperature of 23ºC in the hottest month (February) and 15ºC in the coldest month (July) (SAWS, 2020). The entire province experiences severe water shortages, with the spring season providing most of the rainfall (Mahlalela *et al*., 2020). These locations hold several fish species from the Kowie river system, which include a variety of native and non-native fishes as described earlier in this chapter. The three dams in Makhanda included in this study are Grey Dam (33°19'29.83" S, 26° 31'39.57" E), Douglas dam (33°19'14.55" S, 26° 31'15.72" E) and Gowie Dam (33°17'39.01" S, 26° 30'56.19" E) (Figures 2.1 and 2.2). All have open access and are found within the city limits and easily accessible by walking or by automobile.

Committees Drift (Figures 2.1 and 2.3) is a rural area community based in the Ngqushwa Local municipality, Eastern Cape. Committees Drift was a military outpost established by the British during the frontier war of 1819 (Robson and Oranje, 2012). It is 60 km from Makhanda, with an estimated terrain that varies between 60–1000 metres above sea level (Taylor, 2012). Committees Drift dams span the Great Fish and Kowie Thickets and have a mean annual rainfall ranging between 350–550 mm respectively (Palmer, 2004). Dams were built during the 80s and 90s for the purpose of hydroelectricity, agricultural water supply, and to mitigate water shortages, resulting in about 3 150 impoundments (Mc Cafferty *et al*., 2012). All four dams selected for the survey in this community are tributaries to the Great Fish River system (Figure 2.1). Sinqumeni Dam is a medium-sized class dam with a size of 98 ha (DWA, 2014). It is a tributary (Sinqumeni River) of the Great Fish River 20 km upstream of the river mouth and located in the village of KwaPikoli, where the residents utilise the land primarily for livestock farming and human food growing purposes. All four dams found in Committees Drift have open access and the water is mainly used for human consumption, irrigation and fishing by subsistence fishers and recreational anglers. The four dams in Committees Drift included in this study are Sinqumeni Dam (33°11'23.68" S, 26° 57'37.14" E), Mankazana Dam, Ndlambe Dam and Nqwelo (Figure 2.3).

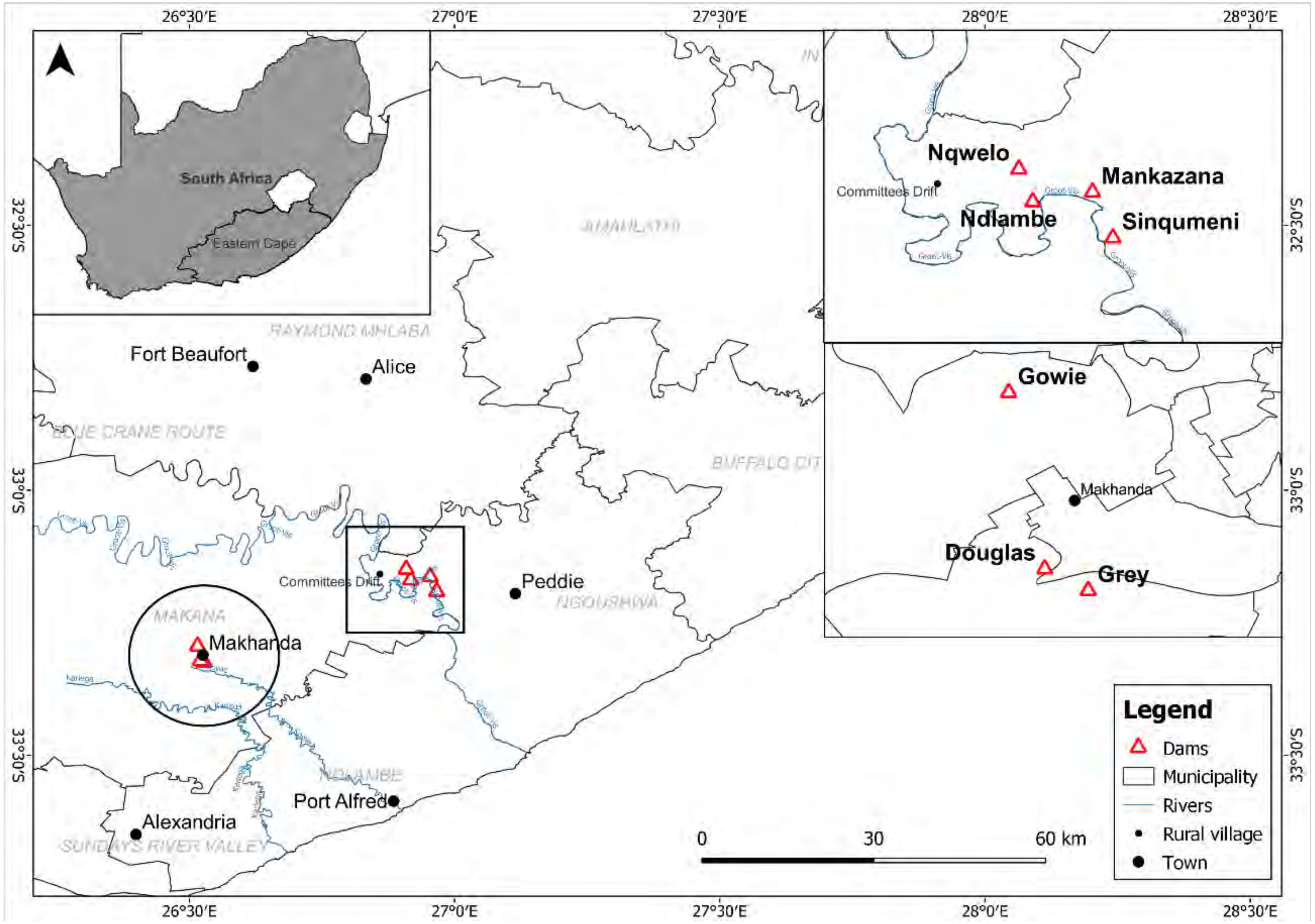


Figure 2.1. A map of part of the Eastern Cape with seven impoundments found in the urban settlement of Makhanda, Grey dam, Douglas dam and Gowie dam and those found in Committees Drift, Sinqumeni dam, Mankazana dam, Ndlambe dam and Nqwelo dam where the study was conducted.

Figure 2.2. The study site of the three dams situated in Makhanda, a) Douglas dam, b) Grey dam and c) Gowie dam. Photo cred: G. Padare and N. Matam.

Figure 2.3. The study site of four dams situated in Committees Drift, a) Sinqumeni dam, b) Mankazana dam, c) Ndlambe dam and d) Nqwelo dam. Photo cred: G.Padare and N.Matam

2.2 METHODS

Data were obtained from surveys on seven impoundments (Figure 2.1) that are part of the regular monitoring program of NRF-SAIAB (NRF-SAIAB AEC 2018/02; 2017/02; 2012/05; 2011/01 and DEDEAT permit No. 20/18CR, 22/18CR). Each dam was sampled twice, first between November and December 2018 and the second time in February 2019. During each survey, temperature, pH, electric conductivity (EC), turbidity, salinity, total dissolved solids (TDS), dissolved oxygen and dissolved oxygen % were measured using a multimeter AQUAREAD® AP-800 obtained at the South African Institute for Aquatic Biodiversity.

2.2.1 Estimating potential yield

A first estimate of potential fish yield was obtained using the morpho-edaphic index (MEI) approach developed by Ryder (1965) to take into account lake fertility, indicated by TDS or conductivity, as well as the mean depth of the lake, in the prediction of fish yields. It is recognized that the estimates of fish yield obtained from MEI models are closely related (Ryder *et al*., 1974), and that these models have some predictive utility on the total annual yield attainable from a dam, based on recommendations made by Weyl *et al*. (2007). To obtain a first estimate of the potential fish yield in each dam, the Marshall and Maes (1994) model developed for African reservoirs was applied. In this model

$$Yield\left(\frac{kg}{ha}yr\right) = 23.281 * \frac{CON}{MD}^{0.447} \qquad \text{(Equation 2.1)}$$

Where MD is mean depth and CON is the mean conductivity measured in $\mu S/\cdot m^{-2}$.

2.2.2 Fish species composition and relative abundance

Fish populations were sampled using gill nets and fyke nets (NRF-SAIAB AEC 2018/02; 2017/02; 2012/05; 2011/01 and DEDEAT permit No. 20/18CR, 22/18CR). A set of three multifilament nylon gill nets, each consisting of five panels of 70 m in length and 2.75 m depth with stretched mesh sizes of 35, 45, 57, 73, 93, 118 and 150 mm, were set in the dams (Figure 2.4). The nets were deployed overnight and retrieved in the early hours of the morning. Total gill net sampling effort was therefore 6 net nights on each dam.

Figure 2.4. Gill net deployment. Photo credit: D.Khosa.

Four double-ended fyke nets (8 m guiding net, first-ring diameter of 55 cm with a 10 mm mesh size at the cod end) were set in each of the dams overnight (Figure 2.5). Fyke nets were set in waters approximately 1–1.5 m deep, parallel to the shoreline. All the fyke nets deployed were fitted with otter guards (plastic mesh with openings smaller than 10 cm x 10 cm) to prevent Cape clawless otters, *Aonyx capensis* (Ellender, 2016), from entering the nets. The use of otter guards can influence the size of fish caught, but their use is deemed necessary to avoid by catch. Four fyke nets and three gill nets were set overnight (between 5–6 PM and retrieved between 7–8 AM). Total fyke net sampling effort was therefore 8 net nights on each dam.

Figure 2.5. Double ended fyke net being deployed in a dam. Photo cred: D. Khosa

All fish sampled during the survey were retrieved alive from the water using a boat, identified to species level using Skelton (1993), measured to the nearest mm total length (TL), weighed to the nearest gram and released back into the water to avoid any mortality. Any that did not survive were given to the local fishing community.

2.2.3 Analyses

Species composition was expressed as the number of individuals of each species recorded in each dam. To test the first hypothesis that species composition was independent of dam, I used a 7 (dam) × 7 (species) Chi Square contingency table analysis, using the total number of fish sampled from each species during the survey period. The fish from the fyke net and gill net surveys were combined because sampling effort (6 gill net nights and 8 fyke net nights) was identical for all dams surveyed. To compare total CPUE between dams a Kruskal-Wallis test was used, and then a Dunn's post hoc test to show pairwise differences.

Relative abundance was inferred from the mean catch per unit effort (CPUE), which was calculated as

$$\overline{CPUE} = \frac{\sum_{i=1}^{n}\left(C_i / E_i \right)}{n},\qquad \text{(Equation 2.2)}$$

Where, *Ci* is the catch (in weight) by each gear *i*, *Ei* is the effort expended by each type of gear *i* and *n* is the number of gears used. Effort units were standardized to net.set^{-1} for gillnets and fyke^{-1} nets.

A linear regression was used to correlate predicted MEI with fish biomass CPUE to determine whether CPUE alone could be used as a proxy for rapid assessment of inland fisheries potential.

2.3 RESULTS

Water quality and species assemblage varied across all dams (Tables 2.2, 2.3). A total of 621 fish were sampled during the survey (Table 2.3) and seven species were identified overall, including Moggel, Banded Tilapia, Mozambique Tilapia*,* Common carp, Largemouth bass, Bluegill sunfish and long fin eel.

2.3.1 Sinqumeni Dam

Water quality parameters for Sinqumeni Dam are summarized in Table 2.2. Sinqumeni Dam (Figure 2.3) covers a surface area of 14 ha and has a volume when full of 1151 m^3 and a mean depth of 5.78 m. Estimated fish yield was 128 kg/ha and up calculated to a potential 1.8 t/year. A total of 49 fish weighing 28.3 kg were sampled. For the fyke nets total CPUE was 1.8 ± 0.9 fish net-set^{-1} in terms of numbers and 0.08 ± 0.06 kg net set in terms of biomass (Figure 2.6). For the gill nets CPUE was 6.0 ± 3.0 fish net-set and 8.5 ± 2.9 kg net set in terms of biomass (Figure 2.6). A total of five species were sampled during the surveys (Table 2.2) (n = 30, biomass = 24.17 kg, TL range = 420–550 mm). Moggel dominated in terms of numbers and biomass followed by bluegill sunfish (n = 10, biomass = 1.218 kg, TL range 90–230 mm) then common carp (n = 3, biomass = 2.4 kg and TL range = 90–230mm), largemouth bass (Lacepède, 1802) (n = 3, biomass = 0.472 g, TL range 100–220 mm) and Mozambique tilapia (Peters, 1852) (n = 3, biomass = 0.3 kg and TL range 80–220 mm) all had the same number of fish with different biomass (Figure 2.7).

2.3.2 Mankazana Dam

Water quality parameters for Mankazana Dam are summarized in Table 2.2. Mankazana Dam (Figure 2.3) covers a surface area of 35 ha and has a volume when full of 1850 m^3 and a mean depth of 5.28 m. Estimated fish yield was 151 kg/ha and was calculated to a potential 5.28 t/year. A total of 117 fish weighing 35.4 kg were sampled. For the fyke nets total CPUE was 3.6 ± 2.4 fish net-set^{-1} in terms of numbers and 1.0 ± 0.8 kg net set in terms of biomass. For the gill nets CPUE was 14.6 ± 6.1 fish net-set and 3.8 ± 2.6 kg net set in terms of biomass (Figure 2.6). Only three species were sampled during the surveys (Table 2.2). Mozambique tilapia (n = 64, biomass = 24. 5 kg, TL range 100–420 mm) dominated in terms of number and biomass followed by largemouth bass (n=50, biomass = 9.1 kg, TL range 70–320 mm). Banded tilapia (n = 3, biomass = 0.225g, TL range 90–120 mm) were rare (Figure 2.7).

2.3.3 Ndlambe Dam

Water quality parameters for Ndlambe Dam are summarized in Table 2.2. Ndlambe Dam (Figure 2.3) covers a surface area of 22 ha and has a volume when full of 915 m^3 and a mean depth of 4.21 m. Estimated fish yield was 188 kg/ha and up calculated to a potential 4.1 t/year. A total of 322 fish weighing 109.7 kg were sampled. For the fyke nets total CPUE was 4.8 ± 3.4 fish net-set^{-1} in terms of numbers and 0.9 ± 0.7 kg net set in terms of biomass (Figure 2.6). For the gill nets CPUE was 13.1 ± 24.6 fish net-set and 17.0 ± 9.9 kg net set in terms of biomass. Only three species were sampled during the surveys (Table 2.2; Figure 2.7). Moggel (n= 127, biomass = 69.7 kg, TL range 135–450 mm) dominated in number and biomass, followed by Mozambique tilapia (n = 191, biomass = 42. 9 kg, TL range 78–415 mm) and banded tilapia *i* (n = 4, biomass = 5.1 kg, 150–220 mm TL).

2.3.4 Nqwelo Dam

Water quality parameters for Nqwelo Dam are summarized in Table 2.2. Nqwelo Dam (Figure 2.3) covers a surface area of 14 ha and has a volume when full of 779 m^3 and a mean depth of 5.78 m. Estimated fish yield was 116 kg/ha and was calculated to a potential 1.6 t/year. A total of 12 fish weighing 0.235 kg were sampled. For the fyke nets total CPUE was 0.3 ± 0.2 fish net-set^{-1} terms of numbers and 0.7 ± 0.9 kg net set in terms of biomass (Figure 2.6). For the gill nets CPUE was 0.7 ± 0.5 fish net-set and 0.6 ± 0.6 kg net set in terms of biomass (Figure 2.6). Only two species were sampled during the surveys (Table 2.2; Figure 2.7), bluegill sunfish (n = 6, biomass = 0.7 kg, TL range 80–220 mm) and largemouth bass (n = 6, biomass = 4.3 kg, 140–510 mm TL).

2.3.5 Gowie Dam

Gowie Dam covers a surface area of 0.6 ha and has a volume when full of 26 m^3 and a mean depth of 3.8 m (Figure 2.2). Estimated fish yield was 159 kg/ha and was calculated to a potential 0.1 t/year. Only two species were sampled during the surveys (Figure 2.7), common carp (n = 8, biomass = 11.6 kg, TL range 220–710 mm) and a single largemouth bass (n = 1; biomass= 0.106 kg, length 180 mm TL). For the fyke nets total CPUE was 0.7 ± 0.3 fish net-set^{-1} terms of numbers and 0.6 ± 0.4 kg net set in terms of biomass (Figure 2.6). For the gill nets CPUE was 1.7 ± 0.6 fish net-set and 1.2 ± 0.6 kg net set in terms of biomass (Figure 2.6).

2.3.6 Grey Dam

Grey Dam (Figure 2.3) covers a surface area of 1 ha and has a volume when full of 68 m^3 and a mean depth of 3.8 m. Estimated fish yield was 207 kg/ha and was calculated to a potential 0.2 t/year. A total of 18 fish weighing 1.7 kg were sampled. For fyke nets total CPUE was 0.9 ± 0.5 fish net-set^{-1} terms of numbers and 0.05 ± 0.05 kg net set in terms of biomass (Figure 2.6). For gill nets there was no catch. Only two species were sampled during the surveys (Figure 2.7). African longfin eel *Anguilla mossambica (Peters, 1852)* (n = 1, biomass = 0.4 kg, 460 mm TL) and bluegill sunfish (n = 17, biomass = 2.2 kg, TL range 110–320 mm).

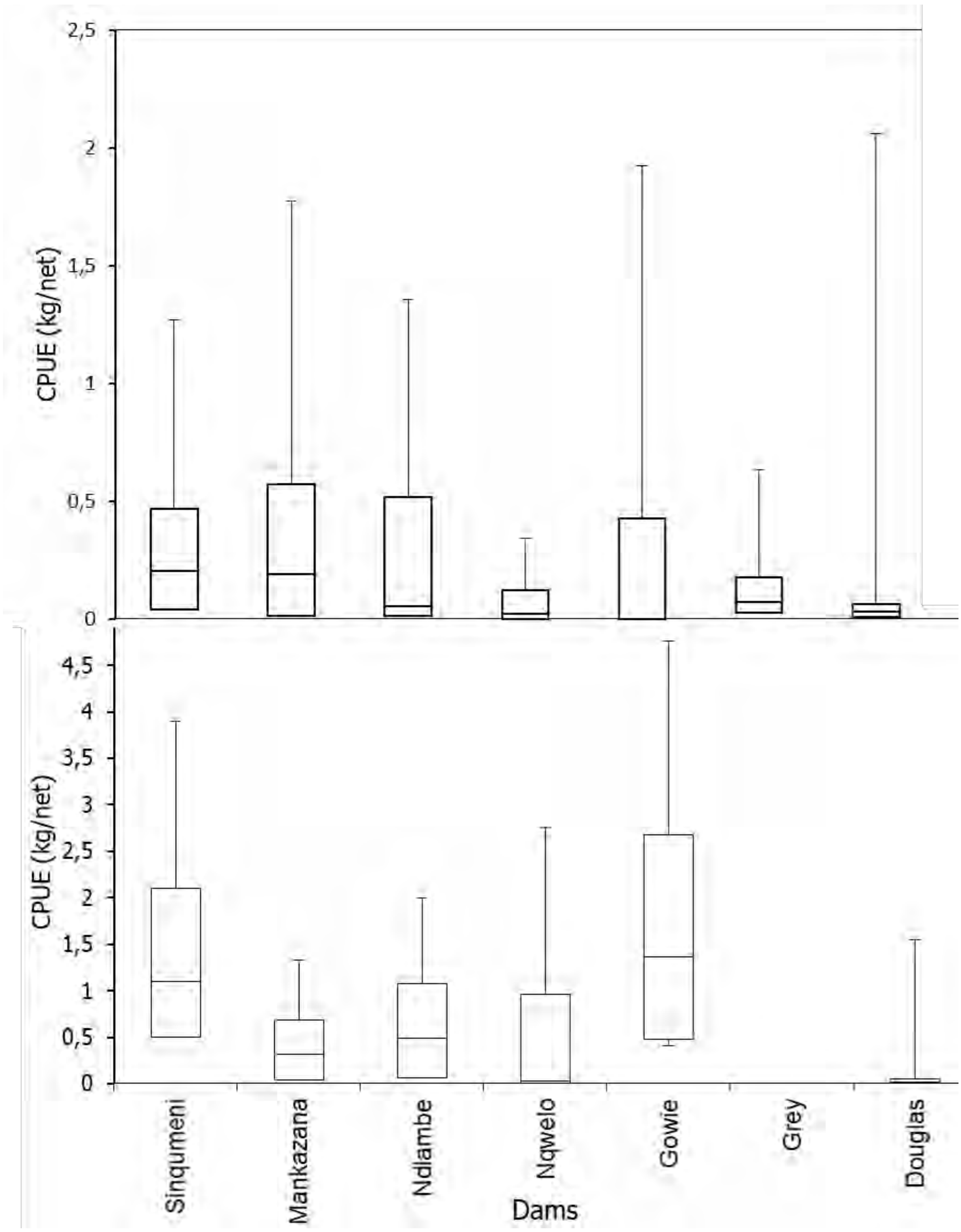
2.3.7 Douglas Dam

Water quality parameters for Douglas Dam are summarized in Table 2.2. Douglas Dam covers a surface area of 0.8 ha and has a volume when full of 35 m^3 and a mean depth of 3.8 m (Table 2.2). Estimated fish yield was 167 kg/ha and was calculated to a potential 0.1 t/year. Only three species were sampled during the surveys (Figure 2.7). African longfin eel (n =6, biomass = 6. 5 kg, TL range 450–1200 mm) dominated in terms of number and biomass followed by bluegill sunfish (n=87, biomass = 8.2 kg, length range 60–190 mm FL), and there was a single largemouth bass (n = 1, biomass = 0. 6 kg, length 360 mm TL) (Table 2.3). For the fyke nets total CPUE was 10.4 ± 2.4 fish net-set^{-1} terms of numbers and 0.5 ± 0.8 kg net set in terms of biomass (Figure 2.6). For the gill nets CPUE was 1.8 ± 1.1 fish net-set and 0.05 ± 0.03 kg net set in terms of biomass (Figure 2.6).

Table 2.2. Summary of the physical parameters of 7 dams in the Eastern Cape Province, and the potential production and annual yield (after Marshall and Maes, 1984), range and standard error (SE) for water quality readings taken during the survey in the summer months of 2018 (November and December) and 2019 (January and February) in all seven study sites found in Committees Drift and Makhanda, Eastern Cape. Electrical conductivity (μS^{-1}), pH, temperature °C and TDS. Dam data was retrieved from DWA Database (2019). Mean depth of Gowie Dam was estimated as there are no additional data.

Dam	Settlement	Size (Ha)	Volume	Mean depth (m)	Temp (°C)	Cond. $\mu S/m^2$	pH	Potential yield	
								kg/ha·yr	t/yr
Sinqumeni	Rural	14	1151	5.78	24.5	261	8.5	128	1.8
Mankazana	Rural	35	1850	5.28	23.6	346	8.9	151	5.28
Ndlambe	Rural	22	915	4.21	23.6	449	8.3	188	4.1
Nqwelo	Rural	14	779	5.78	23.0	208	8.3	116	1.6
Gowie	Urban	0.6		3.8	21.3	279	8.6	159	0.1
Douglas	Urban	0.8	35	3.8	23.1	311	8.6	167	0.1
Grey	Urban	1	68	6.8	22.0	902	8.3	207	0.2

a)



b)

Figure 2.6. Catch per unit effort (CPUE) for experimental gear a) fyke-net and b) gillnets set in 7 dams in the Eastern Cape Province between November 2018 and February 2019. Whiskers indicate interquartile range.

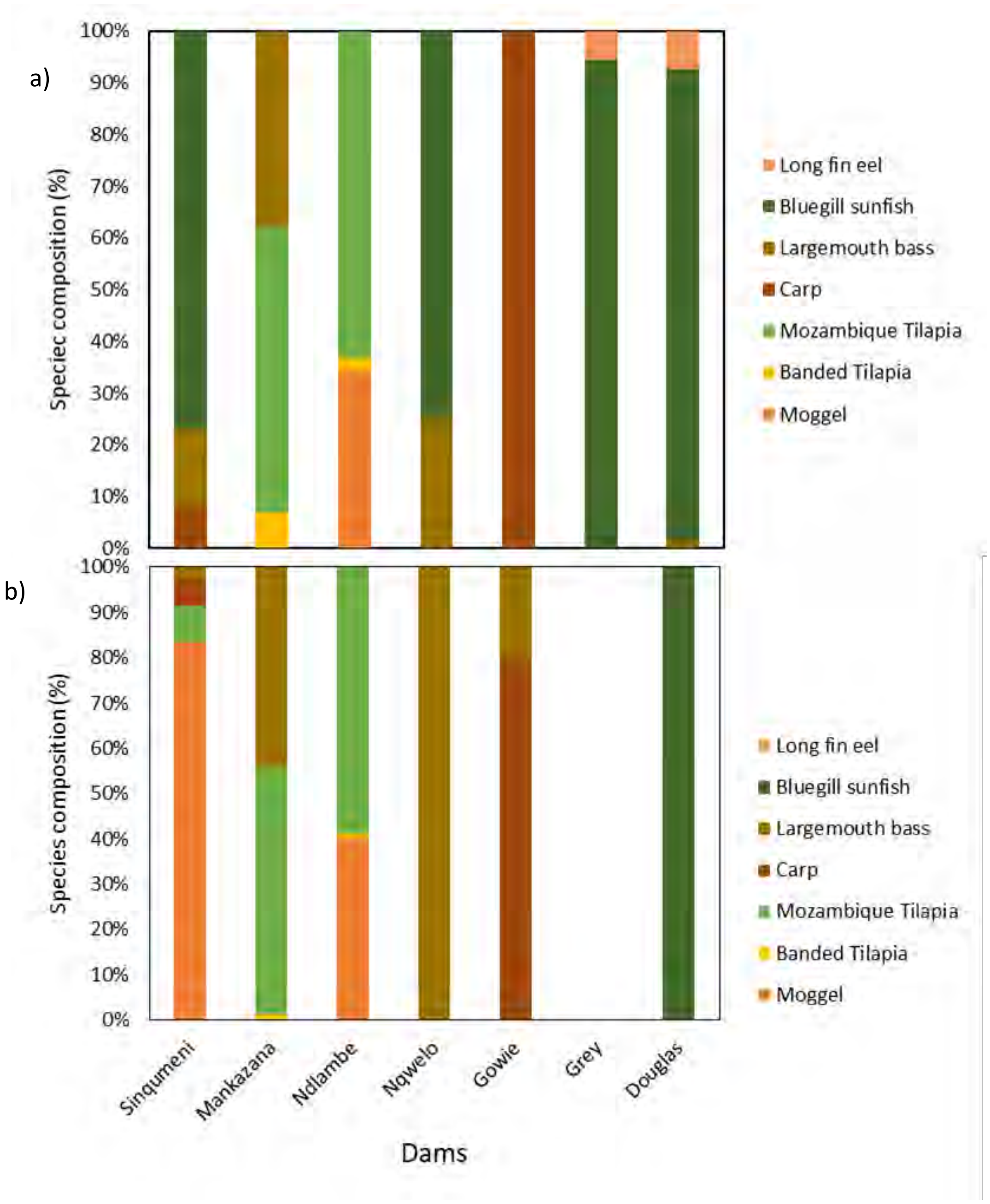


Figure 2.7. The catch composition of species sampled in a) fyke nets and b) gill nets deployed between November 2018 and February 2019.

Table 2.3. Catch composition from six dams sampled in the Makana municipal area in November 2018 to February 2019. Sampling effort was 6 multi-meshed gill net nights and 8 fyke net nights per dam. As sampling was identical, samples for both gears were combined.

	Species							
Dams	Carp	Moggel	Bluegill sunfish	Largemouth bass	Mozambique Tilapia	Banded Tilapia	Long fin eel	Total
Sinqumeni	3	30	10	3	3	0	0	49
Mankazana	0	0	10	50	64	3	0	127
Ndlambe	0	127	0	0	191	4	0	322
Nqwelo	0	6	0	6	0	0	0	12
Gowie	8	0	0	1	0	0	0	9
Grey	0	0	0	0	0	0	1	1
Douglas	0	0	87	1	0	0	6	94
Total	11	157	107	60	258	7	7	

2.3.8 Analysis

The Chi square contingency revealed that there was a significant difference between species composition between the dams (H^2: $\chi^2 = 1$, d. f. = 36, $P < 0.05$; Table 2.3), and therefore assemblage varied with dam identity. The urban dams i.e., Grey, Gowie and Douglas dams, had the least number of fish and fish variety, compared to Sinqumeni, Mankazana, Ndlambe and Nqwelo (rural dams). Mozambique Tilapia was more common in Mankazana and Sinqumeni. Both Sinqumeni and Ndlambe had an abundance of Moggel.

There was no significant relationship between MEI and CPUE biomass across the study sites as shown by the map ($R^2 = 0.31$; Fig 2.8). However, the relationship shown on the group is not sufficient to show a relationship between the two estimated measurements.

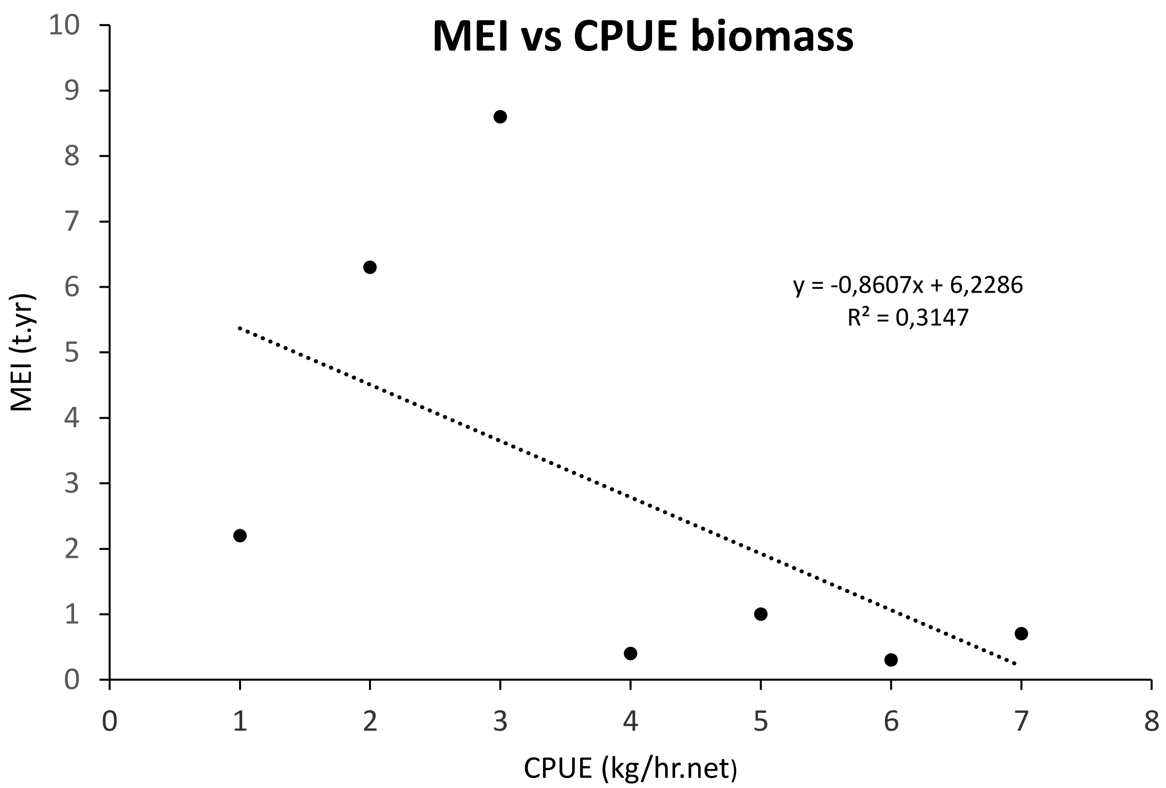


Figure 2.8. Linear regression of MEI and CPUE biomass across all dams.

Table 2.4. Catch composition, relative abundance and length structure of all species caught in seven dams situated in the Great Fish, Kariega and Settlers River systems using gill nets and fyke nets. Catch per unit effort (CPUE) is expressed as average ± SE (N and kg.net. night $^{-1}$).

Site	Gear	Species	IRI	CPUE (N/net)	CPUE (kg/net)	N (nets)	(fish)	Length Mean	Min	Max
Sinqumeni	Fyke	Bluegill sunfish	76.9	1.3±0.0	0.3± 0.0	8	10	141	90	230
		Carp	7.7	0.1±0.0	0.0±0.0	8	1	130		
		Largemouth bass	15.4	0.3±0.3	0.0±0.0	8	2	105	100	110
	Gill	Mozambique Tilapia	2.9	0.2±0.3	0.0±0.0	6	3	160	80	220
		Moggel	88.2	10±0.3	4.0±0.1	6	30	477	420	550
		Carp	5.9	0.0±0.1	0.0±0.6	6	2	463	460	465
		Largemouth bass	2.9	4.5±0.3	8.5±2.9	6	1	220	220	220
Mankazana	Fyke	Banded Tilapia	3.6	0.3±0.0	0.0±0.0	8	2	100	90	110
		Largemouth bass	39.3	1.4±0.2	0.4±0.0	8	11	146	70	270
		Mozambique Tilapia	57.1	2.0±0.1	0.9±0.0	8	16	272	190	420
	Gill	Banded Tilapia	1.14	0.2±0.0	1.9±0.1	6	1	120	120	120
		Largemouth bass	44.3	6.5±0.2	1.0±0.0	6	39	179	120	320
		Mozambique Tilapia	54.5	6.0±0.1	2.9±0.0	6	48	250	100	330
Ndlambe	Fyke	Banded Tilapia	2.6	0.1±0.0	0.0±0.0	8	1	150	150	150
		Mozambique Tilapia	63.2	3±0.0	0.1±0.0	8	24	134	85	405
		Moggel	34.2	1.6±0.1	0.8±0.0	8	13	363	160	400
	Gill	Banded Tilapia	1.1	0.5±0.0	0.1±0.0	6	3	213	210	220
		Mozambique Tilapia	58.8	27.8±0.3	6.7±0.0	6	167	221	78	145
		Moggel	40.1	19±0.2	10.4±0.0	6	144	376	135	450
Nqwelo	Fyke	Bluegill sunfish	85.7	0.75±0.4	0.2±0.2	8	6	163	80	220
		Largemouth bass	14.3	0.13±0.1	0.0±0.1	8	2	267	209	325
	Gill	Mozambique Tilapia	100	0.6±0.9	0.6±0.5	6	4	328	140	510
Gowie	Fyke	Carp	100	0.3±0.7	0.2±0.7	8	4	466	220	710
	Gill	Carp	83.3	0.8±0.2	1.6±0.1	6	4	516	470	600
		Mozambique Tilapia	16.7	0.2±0.0	0.0±0.0	6	1	180	180	180
Grey	Fyke	Bluegill sunfish	82.4	1.8±0.0	0.1±0.1	8	17	154	110	320
		Long fin eel	0.1	0.1±0.0	0.0±0.0	8	6	460	460	460

Douglas	Fyke	Bluegill sunfish	54.2	5.63±0.0	0.1±0.0	8	76	103	60	150
		Largemouth bass	39.0	4.0±0.4	0.2±0.0	8	1	360	360	360
		Long fin eel	7.2	0.6±0.7	0.8±0.3	8	6	803	450	1200
	Gill	Bluegill sunfish	100	1.9±0.0	0.0±0.0	6	11	117	100	190

2.3 DISCUSSION

The framework designed by Weyl *et al*. (2007) suggests that biological sustainability can be achieved when the physical and social factors of fisheries are monitored through various assessments. A precursor to this involves identifying focal fishery species and potential yields (as discussed in this chapter) and completing consultations with key user groups within the community (Chapter 3). Knowledge of these factors will create a better environment to make preliminary recommendations for fisheries development. Inland fisheries monitoring programmes must be established to ensure sustainable harvest levels, as well as ascertaining whether protected and threatened species are within the area. All of this is required to prevent over exploitation of these ecosystem services which pertain directly to human welfare. This state can be obtained by having pre-determined sustainable levels at which the fisheries can operate. Most subsistence fisheries do not have a set framework to determine low harvest and function at an informal level (Dlamini, 2021).

2.3.1 Species suitability

The majority of species sampled in this study, both native and invasive, can be used as fishery species to some degree, due to their life history traits and ubiquity across the sampled sites.

In terms of the native Mozambique Tilapia and the Moggel species, they were found to be abundant in the rural dams but less so in the urban dams. Gillnets are the most efficient way to harvest moggel at large quantities, particularly for fish larger than 150 mm (Potts, 2006). Potential fisheries for the species have been set up in the Eastern Cape, but currently they have had minimal success (Barkhuizen & Weyl, 2020).

Mozambique Tilapia, also found in relatively high numbers in some of the dams, is one of the most widely distributed species found in South Africa, and it is tolerant of a wide range of environmental conditions and capable of breeding in extreme temperatures (Dyer *et al*., 2013), which makes it a suitable species for fisheries. Aquaculture of Tilapia species is accelerating across the country due to perceived high yield, growth rate and low cost of culture, especially in the Eastern Cape and KwaZulu Natal (Pincinato, 2020). Fisheries could also be established for common carp, as it is another fast-growing species, and is able to proliferate in high abundance in a vast number of environments (Winker *et al*., 2011). Similar traits are found in largemouth bass (Wasserman *et al*., 2011). Both largemouth bass and common carp are a popular recreational angling species across South Africa and provide economic benefit as a result (Leibold and van Zyl, 2008).

Alien species represent the most suitable, and popular, species for recreational fisheries within the Eastern Cape (Bova *et al*., 2017). Subsistence fisheries, on the other hand, generally have no preference in species as all species are consumed, especially in poverty-stricken areas, as an affordable source of protein. For example, in the Mankazana, Ndlambe, Douglas and Grey dams, Largemouth bass and Bluegill sunfish dominated the assemblages. These are both invasive alien species which are considered suitable for commercial, recreational and subsistence fisheries due to their fast growth (Ellender *et al.,* 2014).

Both alien and native fish species were present and consumed within the study area (Chapter 3). This demonstrates the potential for a hidden socio-economic value for invasive alien species in terms of subsistence and recreational fisheries, which should be further incorporated into invasive species' assessments regarding resource management.

2.3.2 Biological synopsis

To ensure biological sustainability of fish populations, it is essential to ensure that harvesting and use of each species happens in a sustainable manner (Charles, 2001). This will mean that resources are available for both subsistence and recreational fisheries in the future. Therein, if a species is listed as endangered or threatened it must be protected, as these populations are not viable for sustained harvesting. No endangered species were encountered during the survey, although one was expected, *S. bainsii* (Rodrigues *et al.,* 2006), as it occurs in three of the Eastern Cape River systems.

It is practically impossible to recommend management options for fishery development without biological assessments (McCafferty *et al*., 2012). While a suite of inland fisheries initiatives has been attempted in the province, they have not been successful. My results show that each dam varied in terms of species assemblage, as well as vast differences in CPUE. This indicates that a one-size fits all approach is not suitable within this context. The ultimate objective of developing fisheries is to promote and sustain economic and social well-being for the communities benefiting from the water resources (Charles, 2001). An integral aspect here is to determine and monitor harvesting levels to keep them within sustainable limits so as to not destroy the fishery. With regards to the dams in this survey, following the framework set out in Weyl *et al*. (2007) and Weyl *et al*. (2020), subsistence fisheries and/or recreational fisheries are the best options for achieving these objectives, primarily due to their small size and subsequent low yields. The yields obtained from the study are relatively low, i.e., < 50 t per year. This excludes the development of any formal small-scale fisheries from the study area as profits would not be possible, leading to yet another failed fisheries venture, likely enhanced by the lack of water security in the province. Fisheries, however, would be able to provide food security at a household level via subsistence fisheries and/ or recreational fisheries for the Makhanda and Committees Drift area.

There was a difference in species composition between the dams, but no difference in the CPUE between dams. This further shows that species-specific fisheries in the province might not succeed, especially in terms of subsistence fishing, but catch and release recreational fishing could. This is apparent especially in Grey dam, where many species were present, but as the dam size is only 1 ha this would result in an estimated yield harvest of only 207 kg/ha/year. A concern to note here is that due to the lack of an enforced inland fisheries policy, the use levels of dams with different potential productivity are currently similar, which if unregulated and unmonitored could cause them to become unsustainable. However, we cannot use CPUE biomass as a proxy for rapid assessment of inland fisheries potential, as the fish biomass was not related to MEI, and therefore a full assessment on a case-by-case basis is recommended until the drivers of productivity in this region can be further extricated. These drivers could be potentially related to both dam size and fluctuating water levels within the dams, as well as the human-mediated transport of invasive fishes between locations for recreational fishing purposes.

2.3.3 Fishery recommendations

The current use rates of most inland water bodies are dependent on their multiple user groups. Multiple stakeholders and recipients of ecosystem services can often lead to conflicts between users, community leaders and the government. The framework proposed by Weyl *et al*. (2007) aims to address these issues by conducting fisheries assessments in inland water bodies. Four recommendations were made based on the community, commercial fisheries, recreational fisheries and open access fisheries. The first type of recommendation is the community-managed subsistence fishery, which allows for the local community to run and manage it to obtain sustainable use while catering to better livelihoods. The second type is the commercial fishery, which focuses on the use of the resource by individuals who have obtained permission from provincial authority to harvest a pre-determined yield. The third is the recreational fishery, where the user group of the resource is solely recreational anglers, and the last recommendation is the open access equilibrium fisheries. By considering the fisheries assessments and the estimated yield between dams one is then able to ascertain which fisheries recommendation is suitable for the dams found in the study area. In Committees Drift a community-managed subsistence fishery would be most appropriate for this rural settlement, as most of the harvest is consumed locally, with only the excess being sold. The study area could potentially also follow the open access equilibrium fisheries management approach.

The Marshall and Maes (1984) model was used to estimate the potential fish yield. This model is used where there is no prior existing data available on the dam, such as those from the study area in Makhanda and Committees Drift. The MEI is used as a first estimate of potential yield in African reservoirs. The model was used to predict the estimated yield and potential total annual yield for each of the 7 dams found in the study area and calculations gave a representation of the likelihood of the greatest possible fishery production (Marshall and Maes, 1995). Typically, the smaller the dam, the less likely it will be to support a high density of fishers and fishery productivity (Welcomme, 1976). This was the case for the dams in this study. All of the study dams were limited in productivity potential by their size and none were big enough to produce the estimated fish yields determined by the MEI. Realistically speaking, a dam with a high productivity of about 250 kg/ha which is only 1 ha in size would have a yield of 250 kg total per year, which is low in terms of goods produced, regardless of the productivity of the dam.

Dam yield and productivity varies throughout the Eastern Cape. Darlington Dam (4000 ha) was assessed with a dam yield of 11.3 Mg/year with an estimated production of 23.45 ha per year for carp (Weyl *et al*., 2010). Tyefu dam is estimated to have a yield of 10.9 Mg/ year of moggel for a 10 ha sized dam (Britz *et al*., 2015). This is low compared to another study in Darlington Dam that showed a harvest rate of 1 Mg/day for all species retrieved (McCafferty *et al*., 2012). One of the most successful fisheries in the Free State was established in Bloemhof Dam from an average productivity rate of 201 Mg/year, sustainable for a period of 10 years. All other dams in the region, which had yields of less than 25 Mg/year, failed (Barkhuizen *et al*., 2016). The dams in the current study area all have low yields. In Mankazana Dam the potential yield per year would only result in 9 kg/ha, which is extremely low despite the high productivity estimated for it. This is due to the small size of the dams compared to Lake Gariep and Darlington Dam, proving that these small impoundments do not have the capacity to support such high numbers of fish productivity and harvest rates in the same manner. Fishery recommendations must reflect this viewpoint if sustainability of the resources is to be preserved for the community of users.

Considering our results, preliminary recommendations can be made for the type of fishery development suitable for the study area. All the dams found in the study area have the potential to support both a community-managed subsistence fishery and/or a recreational fishery. Sinqumeni Dam, Mankazana Dam, Ndlambe Dam and Nqwelo Dam are all situated within the Committees Drift community area. Use of the resources within the dams is primarily fish consumption by the local community (Chapter 3). When fish are sold it is on a very small-scale and done only to support the households, not on a commercial level. The predicted fish for all dams yield is > 50 Mg/year according to the MEI (Figure 2.8) and there is no IUCN red-listed species present. The surrounding local community manages the fishery resources, which makes future management easier to monitor to obtain usage estimates to ensure sustainability. Within the rurally located dams at Committees Drift there is some evidence of previous attempts at a fishery (Booth and Potts *et al*., 2006) as well as more recent ones (Chapter 4), but no tourism developments. Gowie Dam, Grey Dam and Douglas Dam are all situated within an urban community, Makhanda, and are also used predominantly by the local community. Fish obtained from the dams are used primarily for personal consumption, with excess being sold within the same community. There is also a history of recreational fisheries in both communities of the study area (Chapter 3). The dams in the area have no predicted tourism development. However, Makhanda is not far from a few nature reserves, including Thomas Baines, and a few game reserves approximately 16 km away, such as Kwandwe Game Reserve, Pumba Game Reserve, Temba Private Game Reserve. With so many nature reserves around the town, the tourism industry could be high, especially during peak times (holidays and school holidays). Therefore, all of the dams fall under the prescribed fishery recommendations for a mixture of either/or community-managed subsistence fisheries and recreational fisheries, per the framework established by Weyl *et al*. (2007).

The next step in building the framework is to establish information on the current patterns of usage of the dams with regards to demography, fishing type and intensity. In the long-term, development in fisheries management needs to ensure consistent monitoring of harvest levels to correlate with sustainable yields through the limitation of access to the fisheries resource, in order to ensure sustainable harvest and to restrict the use of illegal gear (Charles, 2001; Potts *et al*., 2007). This will be investigated in the next two chapters with the aid of questionnaires and a roving creel survey.

CHAPTER 3: Use of small dams by anglers in Makhanda and Committees Drift, Eastern Cape, South Africa

3.1 INTRODUCTION

Management authorities can use trends in fisheries catch and stock abundance, and link these with a suite of abiotic parameters to predict future fluctuations in fisheries resources and determine sustainable harvest levels. However, species-specific catch data and appropriate spatial information are prerequisites for creating robust management recommendations and stock assessments (Ellender *et al.,* 2010). A formalised fisheries assessment is required to ascertain what resources are available to which communities, what is being harvested (i.e., catch) and the rate of harvesting (i.e., effort) (Sutherland, 1998; Young *et al.,* 2006). In this manner, certain assumptions can be made regarding the long-term sustainability of the fisheries resource body. High catch and low effort indicate a healthy system (Vollmer *et al.,* 2018) but this should be monitored for over exploitation, and trends of catch reduction, i.e., catch management, needs to be set. In contrast, a high catch rate and effort indicates a system that is under severe pressure, or one that is currently being over exploited, and this would need management strategies to avoid overexploitation of the fishery (Halls *et al.,* 2006).

Globally, all fisheries catches have been decreasing since the early 1990s (King, 2013). It is not only the catch quantity that is decreasing, but the size of the individual fish is becoming smaller, which negatively affects the species' spawning biomass (Alonzo and Mangel, 2004; Winfield, 2012). The intensity of this trend varies with species due to differences in species-specific harvest rate and preference by each user group (Pal *et al.,* 2017). Most fisheries are currently being utilised for different reasons which include, but are not limited to, fishing, recreational activities and leisure (McCafferty *et al.,* 2012). Gathering high integrity monitoring data can contribute to conservation by enabling the incorporation of trends in populations of invasive, indigenous, and endangered species. Creating long term data sets of trends in catch and effort can benefit fisheries management in the future by securing sustainable practice and increasing economic contribution (Gaeta *et al.,* 2013).

Inland fisheries contribute to economic wellbeing (Nieman *et al*., 2021), livelihoods, food security and cultural values worldwide (Isaacs and Witbooi, 2019). In South Africa, inland fishery resources are widely available throughout the country however they currently lack proper management and thus are at risk of over exploitation (Chapter 1). The economic benefits of inland fisheries are of an informal capacity as most governments do not have the official measuring tools to assess, integrate and manage inland fisheries (Lynch *et al.,* 2020), especially in the form of a policy (Weyl *et al.,* 2007). Despite inland fisheries representing a growing area of policy interest, there is almost no information on harvest rates, or the values or indigenous knowledge associated with them (McCafferty *et al.,* 2012). As a result, most use of inland fisheries in South Africa is informal, and current data indicate that use is in the form of angling for recreation and/or for food and livelihoods (Ellender *et al.,* 2010). Based on the limited information that is available, formalised research on inland fisheries in South Africa needs to be developed to be able to better manage them (see Chapter 1). Inland fisheries offer a chance to increase and develop economic and social opportunities, but the specific user groups must be identified and characterised (McCafferty *et al.,* 2012). If fisheries are to be managed in a biologically and socially sustainable manner, robust data on fisher demography, fishing effort and catch composition are fundamental requirements.

Apartheid laws segregated and restricted access to natural resources (Ward & Shackleton, 2016), and these laws later influenced the usage of fisheries, as inland fisheries are still predominantly used by recreational anglers or subsistence anglers (Weyl *et al.,* 2007). Due to the wide geographical expanse, rich social history and diverse population of South Africa, the stakeholders of inland fisheries range from South African Black, South African Coloureds and South African White people (Ellender *et al.,* 2009). All groups use the fisheries during different seasons, at different times and in varying quantities (Mikalsen *et al.,* 2007). The user groups naturally vary with location and the needs of the community in question. In the North-West province, Weyl *et al.* (2007) found that most users of an impoundment were recreational anglers, as opposed to subsistence anglers which comprise the majority in other areas such as Lake Gariep. This aligns with the perception that small water body use is dominated by recreational anglers (Hampson *et al.,* 2017). However, this is a conclusion based on the results of relatively few studies that have been completed in South Africa, such as that done in the North-West. Observed differences are likely due to variability in resource availability, limited access to the fishery (i.e., through land rights or economic barriers), or the lack of a fishing culture within the community (Ellender *et al.,* 2012). It is important to understand which fisheries are supporting recreational fisheries or if the predominant use is for food provisioning. Nevertheless, inland fisheries development is hoped to be a vehicle for increasing socio-economic benefits including jobs, rural livelihoods, food security and poverty alleviation (DEFF, 2017). The feasibility of inland fisheries to sustain such a transformation relies on whether stakeholders are able and inclined to access water bodies for subsistence or recreational fishing and who exactly the stakeholders are. Therefore, a spatially discriminate understanding of stakeholder demography with regards to race and fishing type is essential for management recommendations. Only with this knowledge can objectives set out by DEFF be better projected and implemented for livelihood upliftment.

Throughout Africa small water bodies are considered to be important for fisheries (Marshall and Maes, 1994). Small water bodies are regarded as water bodies, including reservoirs, ponds and floodplains, with an area of less than 10 km^2 in size (Marshall and Maes, 1994). Small water bodies are estimated to number around 20 000 in continental Africa, but there is a distinct lack of information on the exact number each country has. Angola, Botswana, Lesotho, Malawi, Zimbabwe, Mozambique, Namibia, Swaziland, South Africa Tanzania provide some information regarding their inland water bodies, however, the rest of the continent has very limited data available (Anderson, 1989; Dos Santos *et al.,* 2017). Their size, chemical status and productivity is also largely undocumented, with Zimbabwe being the only country that has organized all available data and has gone as far as organising their reservoirs in a GIS system (Chimowa and Nugent, 1993; Marshall and Maes, 1994). There are approximately 3 150 constructed impoundments in South Africa with a surface area > 1.2 ha (DWAF, 1997), with further smaller impoundments being built up until the 1940's (McCafferty *et al.,* 2012). These reservoirs make up most inland water bodies and have a diversity of fish species, but until now have been neglected for fisheries assessments. This has resulted in data bias skewed towards large reservoirs such as Lake Gariep and Vanderkloof dam and subsequently the user groups which frequent them, potentially neglecting a portion of the fish populations and their harvest.

The current data available of usage patterns of fisheries in South Africa are largely disparate and come from either recreational angling or commercial ventures. For example, Ellender *et al.* (2010) used angler counts, interviews, and household surveys to estimate angler effort in Lake Gariep, South Africa. Another study was compiled using tournament angler data in South Africa to assess the invasion status of *Micropterus spp.* (Hargrove *et al.,* 2015). An attempt to obtain historic data for commercial fisheries in 11 dams located in the Free State province demonstrated a broad lack of catch and effort data, despite some harvest information being available (Barkhuizen *et al.,* 2016). Tournament data has proved to be a reliable source of data retrieval in the Free State and were once again used to assess recreational angling in the province (Barkhuizen *et al.,* 2017). There have also been several studies in the North-West province and the Northern province which quantified the use of fish as a food resource for the local communities. For example, Van der Waal (2000) identified the Mutshindudi River valley as a key resource for food and fishing related activities for the community, which is an important factor in rural settlements. The importance of fisheries in the urban settlements seems to be for recreational purposes, whilst for rural communities it appears to be primarily to provide food security (per obs).

3.1.1 Fishers utilisation of the fisheries resource

Subsistence anglers (Figure 3.1) surveyed in the study depend on the fisheries resource for food, as a source for protein, as a source of income generation and to improve their livelihoods. They live within walking distance of the fisheries and use simple, low technology to fish (such as hook lines and home-made fishing gear); most are unemployed or casual labourers. Recreational anglers are those that utilize the resource primarily for leisure purposes but may sell some of their catch. They access the resource by vehicle and sometimes use a lift system; they have permanent employment, use high technology gear, and may consume or sell a portion of their catch. Recreational anglers mostly use high technology gear consisting of fiberglass graphite rod, and a multiplying or spinning reel (Figures 3.2 and 3.3).

Figure 3.1. **Subsistence angler at Ndlambe dam catching moggel with a gill net on his small canoe**

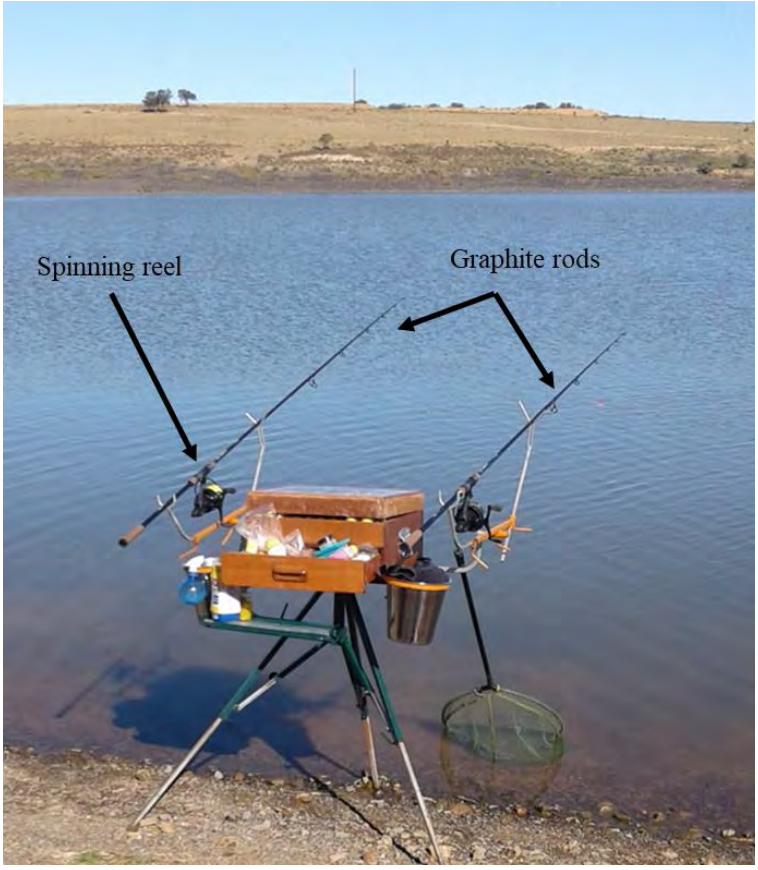


Figure 3.2. The use of high technology spinning reel and graphite fishing rods at Sinqumeni dam

Figure 3.3. Recreational anglers utilising vehicles and holding nets for fishing

Another method that could be deployed to help provide for food security is effective monitoring of the fisheries in developing countries by performing creel surveys which could improve our understanding of social-ecological systems (SES). SESs combine ecological knowledge together with human knowledge to better understand the fisheries system dynamics (Nieman *et al.,* 2021). Creel surveys are done to provide data on fishing patterns, availability of fisheries resource, anglers' perception on fisheries, motivation for fisheries and the importance of the fishery (Molai *et al.*, 2019), which is what this study aimed to achieve in the community of Committees Drift.

The aim of this chapter is therefore to determine fisheries-dependent catch data and better understand the demographic use patterns of small dams in urban and rural settings in the Eastern Cape Province of South Africa. The specific objectives were to undertake a one-year survey to (1) assess catch and fishing effort; (2) estimate annual harvest; (3) describe the demography of anglers and (4) examine their motivation for fishing and describe their fishing practices in Makhanda and Committees Drift, South Africa.

3.2 MATERIALS AND METHODS

The study dams in this chapter are three dams found in Makhanda (urban) and the four dams situated in Committees Drift (rural) (described in Chapter 2). The dams range in size from 1 ha to 33 ha. Both a roving creel survey and a creel survey were used to estimate catch composition and fisher effort count.

3.2.1 Effort and catch assessment

To estimate catch and effort a randomly stratified Roving Creel Survey (RCS) was conducted every second week in a month between April 2018 and April 2019. The RCSs are used in the monitoring of fisheries for catch and effort and are effective in retrieving information such as angler catch, harvest, fishing effort, target species, socio-demographics and economic impacts (Pollock *et al.,* 1994). It is a design widely used in freshwater inland waterbody surveys (Pollock *et al.,* 1994). It is usually used in areas where the water body has multiple access points (Figure 3.4). The schedule is set out in a pre-determined manner (two weekdays and two weekend days), yet with randomised times and entry points. Thus, within the two pre-determined days, the time for the survey is random, including the entry points. This is to cater for biasness and uniformity. As anglers are encountered during their time of fishing, and not at the end of the fishing trip, it is not possible to calculate total catch rates, one can only estimate them. Anglers who fish frequently and for long time periods have a high likelihood of being sampled more than once. The RCS is a reliable method to use because it is conducted on-site, thus eliminates recall and prestige bias by eliminating any repetition of data. The RCS is designed to monitor fishing effort and can be used to evaluate management implications such as regulation changes (Alexandia *et al.,* 2015), or determine the economic value of a fishery (Pollock *et al.,* 1994).

Each survey consisted of a two-week sampling period during which eight sampling events were undertaken (four randomly selected weekdays and four weekend days). On each sampling day a bus-route survey method was employed whereby all seven dams were visited. Entry to the dam was randomised either through entry 1 or entry 2 (Figure 3.4).

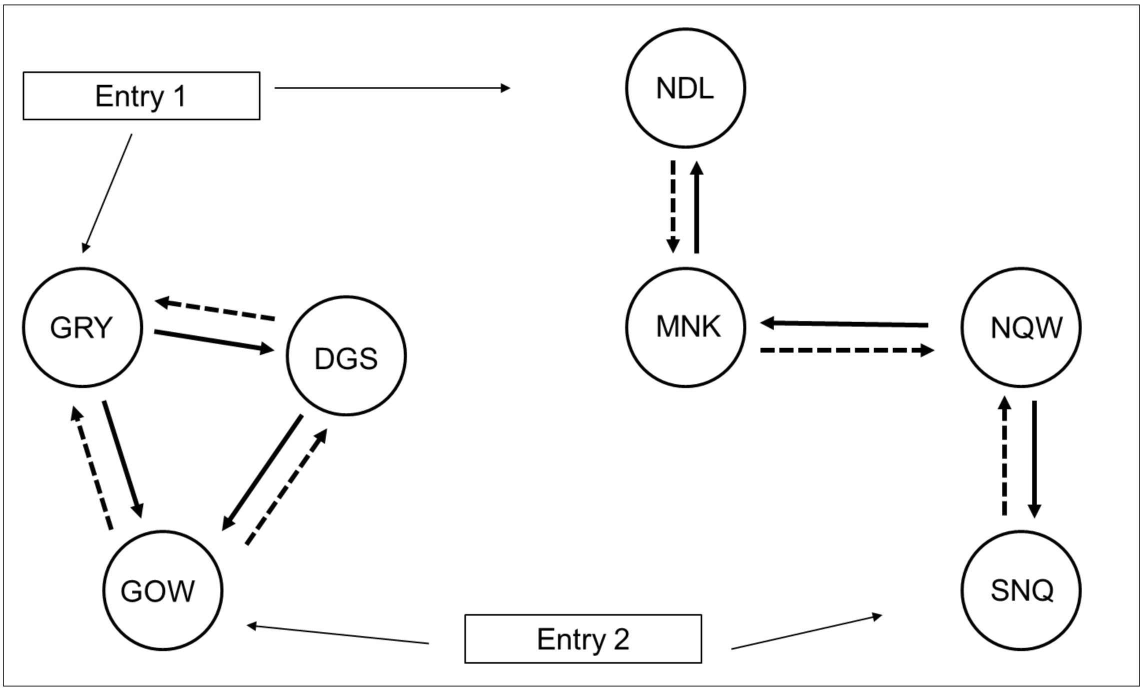


Figure 3.4. Creel survey demonstrating two possible entry points utilised in the study dams with ———— being a possible direction and - - - - - - - - being another direction. GRY - Grey dam; DGS – Douglas dam; GOW – Gowie dam; NDL – Ndlambe dam; MNK – Mankazana dam; NQW – Nqwelo dam and SNQ – Sinqumeni dam.

To determine fishing effort, counts of anglers in the sampling region were conducted. On arrival at each dam, the time was recorded, and an activity count was conducted with the aid of binoculars (Nikon Prostaff 7s 8x42). This was completed from predetermined vantage points which allowed the observer to view the entire dam and count the number of people present along the shore or on boats at each dam. This was further subdivided by the activity type, i.e., either fishing (mostly angling) or other. Other activities included swimming for leisure, aesthetics (people appreciating nature), party venue (people gathering for year-end party) and for social gatherings on weekends for relaxation purposes. For anglers the mode of transport and the gear used were also recorded.

Creel survey interviews were collected after the angler counts. This was completed in the order of each dam on the specific day, and all angler encounters were recorded during the daytime through a creel survey questionnaire (Appendix 1). The study area was divided into two strata, Committees Drift (CD) was stratum 1 and Makhanda (MKN) was stratum 2, which encompasses all dams found in each stratum. Movement through the stratum was uniform.

Annual angling effort (hours fished per dam per year) for each dam was calculated by first determining the mean effort (average number of people per day), then determining the number of angling days per year. Total effort (h) was derived from the results of Equation 3 and the mean length of angling day determined from the creel survey interviews.

$$\text{Angler days. year}^{-1} = \text{mean effort} \times 365 \qquad \text{(Equation 3.1)}$$

$$\text{Total effort (h)} = \text{mean length of angling day} \times \text{angler days. year}^{-1} \qquad \text{(Equation 3.2)}$$

Catch assessments were also recorded with all fish measured using either fork length (FL) or total length (TL) depending on the species and in what state it was found (frozen, or head cut off, or partially eaten), otherwise I wouldn't have been able to measure it.. In cases where it was not possible to weigh the fish (such as already processed by being gutted or dried), the remaining part of the fish was weighed and an approximate weight given based on the length–weight relationship ratio obtained for that species from other weighed fish from Chapter 2. Catch rate was then expressed as a catch per unit effort:

$$\overline{CPUE} = \frac{\sum_{i=1}^{n} \left(C_i / E_i \right)}{n}, \qquad \text{(Equation 3.3)}$$

Where, C_i is the catch (in weight), E_i is the effort expended i and n is the number of people.

3.2.2 Creel survey questionnaire

A creel survey questionnaire was administered to all anglers encountered in the dams of the two strata (Committees Drift and Makhanda). The questionnaire was designed to understand the dynamics of anglers and fishing behavior between rural and urban locations. A variety of questions were thus asked covering fisher demographics (age and gender), transportation to the site, type of fish caught, price at which they sold the fish and the type of gear they utilized (Appendix 1). During the questionnaire and creel surveys, groups of several people fishing together were encountered. This resulted in multiple people being on one creel entry or questionnaires. This was a common practice in both rural and urban settings. Chi square contingency tables were used to explore relationships between locations with regards to fishing effort, catch composition and dam usage.

3.3 RESULTS

3.3.1 Fisher demographics

The fisher demographics between Committees Drift and Makhanda were significantly different between race ($\chi^2 = 2.91$; df = 2; $p < 0.05$) and gender ($\chi^2 = 3.92$; df = 1; $p < 0.05$). For anglers found in Committees Drift, Black Africans were the dominant user group (48.1%), followed by Whites (37.5%) and Coloured people made up only a small proportion (14.4%) (Table 3.3). All anglers in Committees Drift were male (Table 3.3). More than two-thirds of anglers in the rural settlement of Committees Drift were between the age group of 21 and 40, and the remaining were above the age of 60 years (33.2%) (Table 3.3). Subsistence anglers comprised mostly of South African Blacks, whilst recreational anglers comprised of South African Black, Coloureds and Whites (Figure 3.3).

In Makhanda, the most dominant racial group was South African Coloureds (48.2%), followed by South African Black (27.2%), and South African White (24.6%). The majority of anglers in Makhanda were male (63.2%). Similarly, anglers in Makhanda were dominated by those aged between 21–40 years (Table 3.2). South African Coloureds and South African Black were subsistence anglers and whites were recreational anglers. No child anglers, i.e., those under eighteen years, were recorded in either location.

3.3.2 Catch composition for roving creel surveys

Species composition was recorded in each creel survey questionnaire from all anglers encountered (421 entries). The catch composition between the urban and rural settlement had a notable difference as there was no catch obtained from the Makhanda dams (Table 3.1). There was no difference between fisheries-dependent catch data species composition of the dams in the rural settlement ($\chi^2 = 1.84$; df = 6; $p < 0.1$). The creel surveys of those who experienced fish catch comprised the alien invasive species common carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*), as well as the indigenous moggel (*Labeo umbratus*).

Largemouth bass dominated the catch composition numerically and by weight, contributing 41% and 47% respectively of the total catch composition (Table 3.3). CPUE for the urban dams was zero, with very low angler activity in comparison to the dams found in the rural area (Table 3.2).

Carp, moggel and largemouth bass were all found in the rural settlement of Committees Drift. Although it is evident that there are fish in the Makhanda dams, none were caught during the creel surveys (see Chapter 2 for fish community summary).

Table 3.1. Committees Drift (CD) and Makhanda (MKN) species composition by anglers by numbers and weight

Species	Committees Drift		Makhanda	
	Number	Weight	Number	Weight
Cyprinus carpio (%)	20	17	0	0
Micropterus salmoides (%)	41	47	0	0
Labeo umbratus (%)	39	36	0	0

Table 3.2. Angling activity obtained from the creel surveys conducted on 88 days between April 2018 and March 2019

Dam	Anglers interviewed	Mean ± SD length of time fishing(min)	Total catch (number)	Total catch (weight)	CPUE number/ hr	CPUE weight/hr
Gowie	19	20 ± 23	0	0	0	0
Grey	1	17 ± 10	0	0	0	0
Douglas	0	0 ± 0	0	0	0	0
Sinqumeni	30	24 ± 20	16	21.4	0.7	0.9
Mankazana	35	23 ± 20	15	15.5	0.6	0.7
Ndlambe	4	23 ± 15	8	1.9	0.3	0.08
Nqwelo	1	22 ± 20	2	2.0	0.1	0.09

The catch per unit effort was used as a proxy for general fish species abundance and combined all fish species encountered during the survey season. The highest CPUE by weight for fish caught was 0.9 g ± 0.2 g.net.day^{-1} in Sinqumeni dam, with the lowest CPUE being 0.08 g ± 0.02 g.net.day^{-1} in Ndlambe dam, both of which are in Committees Drift.

Table 3.3. Committees Drift and Makhanda angler characteristics by user group and region

Characteristics	Committees Drift (%)	Makhanda (%)
Race (%)		
Black African	48.1	27.2
Coloured	14.4	48.2
White	37.5	24.6
Gender (%)		
Male	100	63.2
Female	-	36.8
Age (%)		
<20 yrs	0	0
21-40 yrs	66.8	100
41-60 yrs	0	0
>60 yrs	33.2	0
Origin (%)		
<10	60.5	100
10-100 km	21.0	0
>100 km	18.5	0
Transport (%)		
Vehicle	51.3	38.2
Lift	0	0
Walk	48.7	61.8
Bicycle	0	0
Fishing time (%)		
Weekday	60.5	52.6
Weekend	39.5	47.4
Employment (%)		
Unemployed	26	46.3
Casual	52.7	0
Permanent	21.3	30.6
Student/Scholar	0	23.1
Pensioners	36.8	0
Use of fish (%)		
Eat	30	40.3
Catch and release	19	27.2
Sell	51	32.5

3.3.3 Resource utilisation

Dam usage in the rural and urban settlements was significantly related to subsistence angling ($\chi^2 = 2.89$; df = 7; $p < 0.05$). In Committees Drift only 15% of anglers were recreational, whilst the rest of the anglers were subsistence anglers (85%) (Table 3.3). All subsistence anglers originated from the area, within a 10 km radius. In contrast, none of the recreational anglers were residents of the area but were from Makhanda located more than 10 km away from the fishery. All the recreational anglers were from a local angling club.

In the Makhanda urban dams found in Makhanda, subsistence anglers were the most dominant user group and few recreational anglers were encountered. However, when comparing Makhanda and Committees Drift, Makhanda had a lower percentage of subsistence users (31.5%) than Committees Drift (85%). The majority of water bodies found in Makhanda were utilised for recreational purposes and picnics (Table 3.4).

3.3.4 Transport

The usage of transport was not different between the urban and the rural dams ($\chi^2 = 2.35$; df = 3; p = 0.3). Vehicles and walking were the most frequent mode of transport in Committees Drift (51.3% and 48.7% respectively), whilst walking was the most frequent in Makhanda (Table 3.3). A smaller percentage of vehicles (38.2%) were used in Makhanda, primarily by recreational anglers (Table 3.3), whereas 61.8% of anglers walked to access the resource. No anglers reported using a lift or bicycle as a mode of transportation in either area. About 61.8% and 48.7% of subsistence anglers walked in Makhanda and Committees Drift respectively to access the resource. The secondary mode of transportation for subsistence anglers was vehicles. All recreational anglers utilised vehicles when accessing the resource in both areas.

3.3.5 Employment and use of fish

Unemployment rates were significantly higher in the urban dams area than in the rural dams area ($\chi^2 = 25$; df = 6; $p < 0.05$). In Committees Drift 26% of the anglers were unemployed, and only 5.3% had permanent jobs. Most anglers in Makhanda were unemployed (26%) and (52.7%) were casual workers (Table 3.3). A reasonably large percentage of anglers in Committees Drift were pensioners (36.8%). No children under 18 were found using the fishery in the Committees Drift region. The rural settlement had mostly casual workers and some permanent workers. In Makhanda students above eighteen years of age comprised 23.1% of the fishery users, all over the age of 18. Subsistence anglers were predominantly made up of scholars and unemployed adults. Recreational anglers comprised a minority of anglers in the area. A substantial proportion of anglers in the rural (30%) and urban (40.3%) areas consumed the fish they caught (Table 3.3). No anglers gave away all their catch. A portion of anglers released their catch (19% in the rural area and 27.2% in the urban area), whilst some anglers sold their catch, 51% in the rural area and 32.5% in the urban area, with there being no difference as to the fate of fish between the two areas ($\chi^2 = 2.13$; df = 4; p = 0.3).

3.3.6 Overall trends

Anglers were encountered in all dams, although fish were only retrieved in the rural dams of Committees Drift (Tables 3.2 and 3.3). In the rural areas, subsistence anglers comprised the majority, who utilised the fish to sustain themselves and their families and for a better livelihood. Anglers who did not originate from the area utilised the rural dams for recreational purposes ($\chi^2 = 2.89$; df = 7; $p < 0.05$) compared to those who were residents in the settlement who were all subsistence anglers. Similarly, dams found in the urban area were also mostly used by subsistence anglers ($\chi^2 = 2.94$; df = 6; $p < 0.05$), despite seemingly infrequent catches, although there were a few reports of dam use for aesthetic purposes. The urban dams were utilised recreationally (picnics, year-end functions and swimming), as opposed to the rural dams which were reported only to be used for fishing-related activities.

3.3.6.1 Fishing effort and dam usage of the fisheries

The total fishing effort was significantly different between the rural dams and the urban dams ($\chi^2 = 2.89$; df = 7; $p < 0.05$), with angling being higher in Gowie dam (urban settlement) than in Mankazana dam (rural settlement). Annual estimated angling effort was higher in Gowie dam, while three dams (Douglas, Ndlambe and Nqwelo) had no recorded annual angling effort (Table 3.4). When comparing the estimated annual effort found in each dam and the total number of anglers found in each dam, there was a significant difference between the two ($\chi^2 = 1.94$; df = 6; $p < 0.05$). This means that the fishing time or the number of anglers needs to increase to reach the estimated annual effort, which in turn, means that the fisheries are not under threat. A very small portion of anglers released the fish back into the fisheries, which revealed that the main motivation for angling was food provision in both the urban and the rural dams.

Effort counts were conducted on 88 days, comprising 44 weekdays and 44 weekend days between April 2018 and March 2019 (Tables 3.4 and 3.5). Of the 88 days on which activity counts were conducted, only 54 days (61.3%) had any human activity present. A total number of 239 users were recorded across all dams, with more than half (54%) being non-anglers and the remaining proportion (46%) being anglers (Table 3.4). This reduced the number of anglers per day, resulting in a single angler per dam across all the dams, even though the average time fished per hour year^{-1} was above two hours for each dam, except for Douglas Dam. Annual estimated angling effort was highest in Gowie Dam.

Table 3.4. Angling activity obtained from the creel surveys conducted on 88 days between April 2018 and March 2019

Aspect	Dam						
	Gowie	Grey	Douglas	Sinqumeni	Mankazana	Ndlambe	Nqwelo
Days with human activity	14	5	10	6	15	2	2
Days with angling	14	1	0	6	15	2	2
Total aesthetic users	0	116	12	0	0	0	1
Total anglers	45	1	0	20	38	2	4
Anglers/day	0.55	0.01	0	0.23	0.43	0.02	0.04
Anglers/year	201	4	0	84	157	7	15
Mean time fished (min)	6.4	6.0	0	5.1	4.8	4	8
Fishing effort (hrs/year)	584	21.9	0	395	274	0	0

Table 3.5. Interview activity obtained from the creel surveys conducted on 88 days between April 2018 and March 2019

Dam	Species present	Sum of people interviewed	Total interviews
Gowie	None	7	21
Grey	None	1	3
Douglas	None	0	0
Sinqumeni	Common carp, Moggel, Largemouth bass	12	20
Mankazana	Largemouth bass	13	15
Ndlambe	Moggel	5	5
Nqwelo	Largemouth bass	1	2

3.4 DISCUSSION

3.4.1 Overall report

Assessing the user group's specific needs, usage and pressures on is imperative prior to creating equitable and meaningful inland spatially explicit water resources fisheries policy. The contribution of the Makana fishery to the socio-economic wellbeing of the community was evident in the diversity of user groups, races, age groups and type of anglers utilising the dams. Differences such as age, race and gender were visible across the user groups. However, there were some similarities between the two regions with regard to user groups, purposes and uses of the dams. Committees Drift and Makhanda were both dominated by subsistence anglers. Unemployment rates in both areas were generally very high, more so in the rural community than in the urban area. The recreational anglers found in the rural dams came from outside the settlement to fish. Therefore, transport is more important to recreational anglers than to subsistence anglers.

3.4.2 Catch and effort monitoring of the anglers in Committees Drift and Makhanda

Sustainability monitoring requires the knowledge of certain factors such as the catch and effort estimation of a particular region. Both rural and urban dams support a number of species, however, each area clearly experiences different user and exploitation dynamics. Fish species found in Committees Drift are mostly utilised for food security or recreational fishing depending on user origin and demographic. Global trends are mirrored in this data subset, where freshwater fish which are utilised for recreational angling are mainly alien species (Ellender *et al*., 2014), whilst subsistence fishery species are non-specific and comprise both native and indigenous fish species (Inda-Diaz *et al*., 2009). Species composition was greater in the rural area than in the urban area, with the rural dams accounting for both highest and lowest CPUE records in this survey. However, this is due to an inability to derive CPUE for dams found in Makhanda, as no fish were caught during the survey. Overall, the CPUE numbers were very low across the strata, which predicts a low annual harvest across Makhanda. Of note, the angler CPUE was very low compared to the CPUE data retrieved from the fisheries survey conducted in Chapter 2. Despite the recorded presence of these species, anglers in Makhanda did not catch any fish during the creel survey, which indicates that they potentially lack access to the appropriate equipment such as surface lures, suitable bait or nets (McCafferty *et al*., 2012). The average angling activity in the study was approximately 18 min for each dam, resulting in low CPUE levels. Management recommendations require all this information to create a cohesive plan and to be able to decipher which strategies would best suit the fishery without disadvantaging one group disproportionately (Cooke *et al.*, 2021a).

3.4.3 Subsistence and recreational anglers' usage dynamics

Both recreational and subsistence anglers were encountered in the survey, with the two groups showing different demographic and usage patterns. Recreational anglers fish for leisure, and because they perform the practice as a sport, they may keep the fish for consumption, sell it or release it back into the water. Recreational anglers were encountered in Committees Drift due to the suitability of the sport angling species (carp and largemouth bass) and location. Recreational anglers were more willing to travel to Committees Drift to use their fisheries because of the availability of suitable sporting fish, instead of using the local ones, even though the sport fish are indeed present in the Makhanda dams. This may have the potential to put more fishing pressure on the rural fisheries, possibly causing overexploitation or unsustainable usage for the already dynamic structure of subsistence fisheries in the rural area. Committees Drift is used by recreational anglers from the urban areas, i.e., Makhanda and Peddie, as well as local subsistence anglers who reside in the area, and by gill net anglers (Chapter 4). Depending on fishing intensity, over time such a small area would not be able to sustain the local community who rely directly on the resource for food provisioning, due to external usage (see Chapter 2 for inland fishery recommendations). Regarding usage of the fisheries for subsistence purposes, all species found were suitable for harvesting. This may lead to possible conflicts between the two user groups in the rural dam fisheries, where one group is invested in the maintenance of sport fish population for leisure and the other is invested in catching enough to consume or sell for survival (Ellender *et al*., 2014; Woodford *et al*., 2017). Another concern that could arises is that subsistence anglers could overly harvest sports fish that are present in the fisheries, presumably, as they harvest and consume all types of fish species and are not specific. Therefore, conflict will not only be between the different user groups, but also buy the fact that resource usage is not properly managed, so the sustainability of the resource is in danger for all user groups.

At both locations, fishing activities were predominantly for subsistence purposes, indicating that the water resources across the Eastern Cape provide a substantial resource for communities to feed households or accumulate household income, a necessity compounded by the high levels on unemployment in the area. This situation in turn creates local markets and can potentially contribute to the local economy in order to provide better livelihoods and to assist in decreasing the high levels of hunger. Unlike at the rural dams, users of the urban Makhanda dams all resided in the area but again, were mostly subsistence anglers. Recreational anglers in Makhanda were not in abundance, likely as a result of poor catch rates, although popular fish species such as carp and largemouth bass are present in the fisheries (Chapter 2). This demonstrates the importance of small-scale fisheries in supporting a developing nation's food security, and thus contributing directly to the sustainable development goal SDG 2: No hunger. However, social values are also satisfied by these water bodies, and should be factored into management recommendations. The majority of people in the creel survey utilised the Makhanda dams solely for aesthetic purposes during their leisure time as opposed to fishing. Fishing in the urban sector was not considered a necessity by the bulk of the user groups, but merely as a hobby activity. Other pastime activities practised included using the dams as a picnicking area, as well as for running and taking walks.

Transportation is a major factor to consider in recreational angling, to accommodate the vast numbers of different equipment used. Recreational anglers encountered in the study were all employed and only fished with the intention of consuming the fish or solely taking a picture with it and putting it back in the fishery, and so recreational anglers are most likely to utilise a vehicle. This is an advantage to them as they are able to move between different locations in search of suitable angling fish species (Woodford *et al*., 2017). Subsistence anglers utilising the rural settlement predominantly walked and resided less than 10 km from the fishery because they are unable to drive to the fisheries, however, they are the ones who are more dependent on the resource. The use of low-cost transport is preferred for most anglers (Branch *et al*., 2002), for those who can afford it. This is a clear indication of the accessibility and affordability of Committees Drift as a resource location. The sustainability challenge is that over time, the fisheries may not be able to sustain the local community who rely directly on the resource for food provisioning, due to external usage (see Chapter 2 for inland fishery recommendations), requiring resources to be managed in a proper manner.

3.4.4 Socio-economic factors and effects of inland fisheries on the local economy

The age range of anglers surveyed in both Committees Drift and Makhanda indicates a predominance of anglers between the ages of 21 and 40 years old. This is the age group that is considered the 'working age class' in South Africa. This could possibly be an indication of the high level of unemployment within the country, as the residents of both regions were utilising the fishery as a means of obtaining an income. Committees Drift also had an age group of greater than 60 years utilising the fisheries as subsistence anglers. Reasons for the large subsistence sector within the study area could be due to the high level of unemployment and poverty in Committees Drift. Although rural dams had users with a lower unemployment rate, these anglers were still under the South African food poverty line, which is the amount of money that an individual will need to afford the minimum required daily energy intake (Yu *et al*., 2020).The anglers from the urban dams area were not able to reach the lower-bound poverty line (LBPL) of R840 per person per month (Ruch, 2021), even if they had some form of employment. The purpose for angling also varied by location, race and target species. From the interview data, the same anglers were encountered several times, especially in Makhanda.

The general trend in angling in the urban area was to go in moderate groups of 3–10 and seldom alone, however they still had no catch. Committees Drift users employed different methods, with more individual anglers, such as at Ndlambe dam, where there was a total of five people utilising the dam, which tallied with the number of interviews obtained. This should be taken into account when management and government facilities make recommendations and stock monitoring, as catch can be distributed within the groups in some areas.

The vast majority of interviewees were unemployed and were using the water resources for subsistence angling. In addition, only a portion of anglers were casual workers in Committees Drift. With the high unemployment rates found in both regions, fishing was a key source of livelihood for individuals unable to find alternative employment. Again, this emphasises the importance of a healthy and well managed fishery in rural South Africa to support the daily needs of the population according to the sustainable development goals of 'No Hunger' and 'Life Below Water' (Lynch *et al.,* 2020). No fishermen encountered during the survey period gave away their catch in either the urban or the rural strata. Generally, in the rural area, if anglers caught surplus to their household needs, the excess was sold. However, in the urban area fewer anglers sold their catch compared to the rural area. With the low employment figures in both areas, it is plausible to argue that the cheapest way to acquire protein for the household would be through angling.

The data here indicate an avenue for development and social upliftment, with the implementation of a correct and equitable management structure. For example, revenue for the local economy in the Eastern Cape province of South Africa is received mostly through agricultural value chains; economic development; environmental affairs and tourism (Province of the Eastern Cape, 2020), which have benefits to the individual and community, but those related to inland fisheries are currently relatively low due to a lack of infrastructure (Hampton, 2000). However, small scale-tourism is being initiated by rural communities in the area by providing guided hikes, local cuisine experiences and partnering up with the local government to create mini resorts located next to dams to contribute to a more fulfilling fishing experience for all fishermen. All these local economic experiences need to be monitored for sustainability, while instilling a sense of custodianship in all users towards the resources that make the value chains possible (Seyfang, 2007).

CHAPTER 4: Small-scale gill net fishery on small impoundments in the Eastern Cape.

4.1 INTRODUCTION

In freshwater fisheries a variety of methods and gears can be utilized to exploit a fishery, depending on target species, personal resources and fishing location (Fratto *et al.,* 2008). Determining the different gears appropriate for fishing at a certain location is essential for policy and management recommendations, as each has different efficiencies and selectiveness, which alters the outcome and sustainability of the fishery. The gear types vary from trawls, longlines, seine nets, pole and line, pots and traps, dredges, fykes and gillnets. These gears can be classified into passive and active gears, the former being considered the most efficient (Silvano *et al.,* 2017). Active gear is typically dragged through the water body by humans, animals or power engines, such as seine nets and trawls, whilst passive gears are those which can be left inside the water column, unattended, to catch fish, such as fykes and gillnets (Olin *et al.*, 2009; Tweddle *et al.,* 2015). Species selectivity and size depends on the type of gear that is used (Mitchell *et al.,* 2019).

Gillnets are a common and very effective fishing gear, however, the use of these in commercial or non-experimental settings is rather controversial. Gillnets consist of a wall of netting that hangs vertically in the water column, and are typically made of monofilament or multifilament nylon (Lucchetti *et al.,* 2020) (Figure 4.1.). They generally consist of weights/sinkers which are attached to the bottom of the net to keep it down, and have a series of floats along the surface line. Gillnets can target multiple size classes by having several panels with different mesh sizes. thus, the size of the fish caught depends on the mesh size of the net. However, gillnets are not species-selective, and are a highly destructive gear type incurring high mortality. In South Africa, gill-netting is usually used in small-scale fishing, although the fact that they have high bycatch is an issue, which can include threatened species, birds and reptiles(Tweddle *et al.,* 2015).

Gillnet fishing has been illegal since 1908 in most parts of the world, including in many African countries (Munubi and Nyakibinda, 2020). When used illegally, the netting can have severe impacts on estuarine fish populations. In most cases the nets are set to maximise catches, are not monitored, and are left in the water for extensive periods of time (Jurajda *et al.,* 2018). Typically, they are set at night and left in the water for several days and checked intermittently. The mesh size is generally small, which means there is a high potential for many juvenile fish to be caught (Fiedler *et al.,* 2020). Despite gill net fishing being illegal in South Africa, the community of Committees Drift use the gear and have started an informal fishery controlled by the local community (detected in Chapter 3). The use of gill nets is not only environmentally destructive but has a negative impact on both recreational and subsistence anglers. By removing large quantities of fish, including fingerlings, the catch rates from the more responsible and sustainable fishing practises are reduced, and with it the sustainability of local fisheries is threatened (Lynch *et al.,* 2020).

Despite these negative connotations, if used correctly, gill nets can be a very efficient method for scientists to monitor fish communities and population changes over time. This exploits the lack of species selectivity to assess the entire fishery simultaneously. By limiting the time the net is in the water, selecting certain time periods to sample, and using continuous monitoring of the net, scientists can develop an idea of the number of species, relative abundance, and size structure of the fish community, whilst minimising and even preventing any unnecessary fish mortality (in contrast to using gears such as small mesh seine netting) (Bettoli and Scholten, 2006).

Another factor to consider for a successful fishery is the existence of economically friendly fish species, such as *O.mossambicus*, *C. carpio* and so on (Sara *et al.*, 2017). In this manner, if a formalized fishery was created and monitored, the fisheries-dependent data generated from this endeavour could be a highly informative citizen science approach to inland fisheries management in South Africa (Hara *et al.,* 2021).

Another method, besides performing creel surveys and ichthyological surveys, which is an effective monitoring tool of the fisheries in developing countries, and could assist in planning for food security, is by administering questionnaires which provide a better understanding of the social-ecological systems (SES) around a fishery. These SESs combine ecological knowledge with human dimension knowledge to better explore the fisheries system dynamics (Nieman *et al.,* 2021). Questionnaires provide data on fishing patterns, availability of fisheries resource, anglers' perception on fisheries, motivation for fisheries and the importance of the fishery (Molai *et al.,* 2019), which is what this study hoped to achieve in the community of Committees Drift. The cumulative data on the knowledge of fish composition, favourable fish species, abundance of fish species, the social information of the anglers, motivation for fishing and the importance of fishing in Committees Drift will be important in guiding the narrative of whether a fishery could develop in an area or not (Sara *et al.,* 2017; Barkhuizen and Weyl, 2020).

The aim of this chapter was to characterize the small-scale gill net fishery from the dams in Committees Drift, detected and reported on in Chapter 3. Given the potential positive developmental capacity of such a fishery it is essential to characterise the demographics of the user group, user perception, household dependency and their primary motivation for fishing.

4.2 METHODS

4.2.1 Semi structured questionnaire

Semi structured questionnaires (Appendix 2) were conducted, together with a Roving Creel Survey (for specific methods see Chapter 2). The respondents were selected based on the fact that they were using gillnets to fish. A total of 10 questionnaires were completed. During these interviews, the following socio-economic information was recorded:

- Origin of the fisher/fishers,
- Angler demographics (race/gender/age),
- Primary motivation for fishing (sale/recreation/subsistence),
- Means of transport used to get to the dams,
- Employment and
- Household dependence.

The semi structured interviews also included a few questions regarding importance of fishing to the angler, ownership of the resource and the sustainability of the fisheries resource. This was completed to ascertain a clearer picture of use patterns from anglers who repeatedly accessed the dam.

4.2.2 Key informants

The questionnaires were given to key-informant users, the most frequently encountered anglers who only used gill nets as a fishing gear type. Key informants are the people/anglers who regularly use the different dams and are residents of the community being surveyed A total of 10 questionnaires were given. Four from Sinqumeni dam, three from Mankazana dam, 3 from Ndlambe dam and none from Nqwelo dam. These anglers were identified from the roving creel surveys (Chapter 3). These questionnaires were used to define the gill netting community sectors and determine how fruitful these were. We used the following socio-economic information: (1) Permanent employment/occupation, (2) Fate of fish, (3) Mode of transport, (4) Distance travelled, (5) Fishing gear. Participants could be separated into two user groups: subsistence and recreational anglers (Figures 4.2 and 4.3).

4.2.3 Logbooks

A logbook was given to the most frequent gill net user of each dam except Nqwelo dam, as it had no frequent angler. A total of 3 logbooks were distributed. These gill net anglers were requested to record the date of their catch, the composition of the catch and the number of fish caught in each dam for all fishers using gill nets. Logbooks were given to the anglers who resided next to the dam for a period of 12 months. In Ndlambe the angler recorded for a total of 85 days, catching fish every time he visited the dam. In Sinqumeni dam the angler recorded a total of 12 days. The angler was a casual worker and often forgot to record when he caught something. In Mankazana dam the angler lost the logbook and discontinued recording anything due to lack of catch in the dam. The books were checked every second week for new entries.

4.2.4 Direct observations

Direct observations were made throughout the entire year of the study. There were no additional gill net users encountered throughout the study besides the 10 who were given questionnaires.

4.2.5 Catch data

To estimate mean CPUE, procedures outlined by Pollock *et al*., 1994 were followed. Catch per unit effort was estimated using the equation:

$$\overline{CPUE} = \frac{\sum_{i=1}^{n} \left(Ci \middle/ Ei \right)}{n} \qquad \text{(Equation 4.1)}$$

Where *Ci* is the catch obtained on day sampling day *i* and *Ei* is the time spent fishing on the day *i.* Due to *daily* and regional differences in catch rates, CPUE was calculated by dam for the Committees Drift region for the duration of the study area.

4.2.6 Analysis

Descriptive statistics in the form of proportions, tables, and graphs were used to calculate frequencies, including species composition, species catch composition and socio-economic demographics. Socio-economic data were tested for independence between different variables using χ^2 contingency tables at a significance level of $p \leq 0.05$.

4.3 RESULTS

Only 10 interviews were administered to key respondents in the form of an interview (Appendix 2). Catch documented from the questionnaires, interviews and the logbooks comprised 1238 species and 978 020 kg (Table 4.1). For all the anglers encountered, the effectiveness of the gill nets was dependent on the dams for species caught ($\chi^2 = 32$, df = 3, p

≤ 0.05 (Figure 4.1). The fate of fish caught by anglers proved to be dependent on employment ($\chi^2 = 42$, df = 3, $p \leq 0.05$), with most unemployed anglers selling their fish for income and most employed anglers consuming their catch.

Table 4.1. Catch composition by number and weigh for all five species encountered through the questionnaires, interviews and the logbooks administered throughout the study, except for Catfish as it was not encountered throughout the study, so no estimate could be made. * Catfish was not found throughout the study or by the other anglers but was entered by the angler in Ndlambe dam.

	Tilapia	**Moggel**	**Carp**	**Bass**	**Catfish***
Book	**30 (26.1kg)**	**1097 (882.0kg)**	**8 (5.3kg)**	**32 (30.0kg)**	**37**
Ndlambe	30 (26.1kg)	892 (717.4kg)	0	29 (27.3kg)	37
Sinqumeni	0	205 (164.4kg)	8 (5.3kg)	3 (2.7kg)	0
Interviews	**0**	**20 (24.2kg)**	**9 (6.2kg)**	**5 (4.5kg)**	**0**
Mankazana	0	0	0	4 (3.5kg)	0
Ndlambe	0	8(11.0kg)	0	0	0
Sinqumeni	0	12(13.2kg)	9 (6.2kg)	1 (1.0kg)	0
	30 (26.1kg)	**1117 (906.2kg)**	**17 (11.5kg)**	**37 (34.5kg)**	**37**

4.3.1 Access and ownership of fisheries resources

Access to the dam is generally open for everyone who wants to access it and apply through the hierarchical set up within the community, with the Chief being the key decision maker. Committees Drift consists of four smaller homesteads, and each homestead uses the dam nearest to it. Each dam has a custodian, which is the gill net angler who uses it the most frequently. Should an angler from another village have an interest in using another dam for whatever reason, they need to consult this custodian. Anglers residing outside the community need to obtain permission from the chief to utilize any of the dams. These are usually recreational anglers who are there for tournaments or other personal use.

4.3.2 Gear usage in Committees Drift fishery

Fishing in the Committees Drift community is usually done using a gill net and/or handlines. The focus of this chapter will be gill net users. A gill net consists of nylon material stretched over varying lengths (Figure 4.1). The mesh size of the gillnet varies from 30 mm to 120 mm. The variance is due to wear and tear, and subsequently anglers having to manually fix the net themselves. The nets are then anchored with rocks as sinkers and bottles used as floaters. The nets are checked by the anglers every day to see if there are any fish caught in the net. Caught fish are removed and the net is left immersed in the dam for several days. These observations were based on the gill net fishery at Committees Drift. Subsistence gill netting is informal and it occurred throughout the study period.

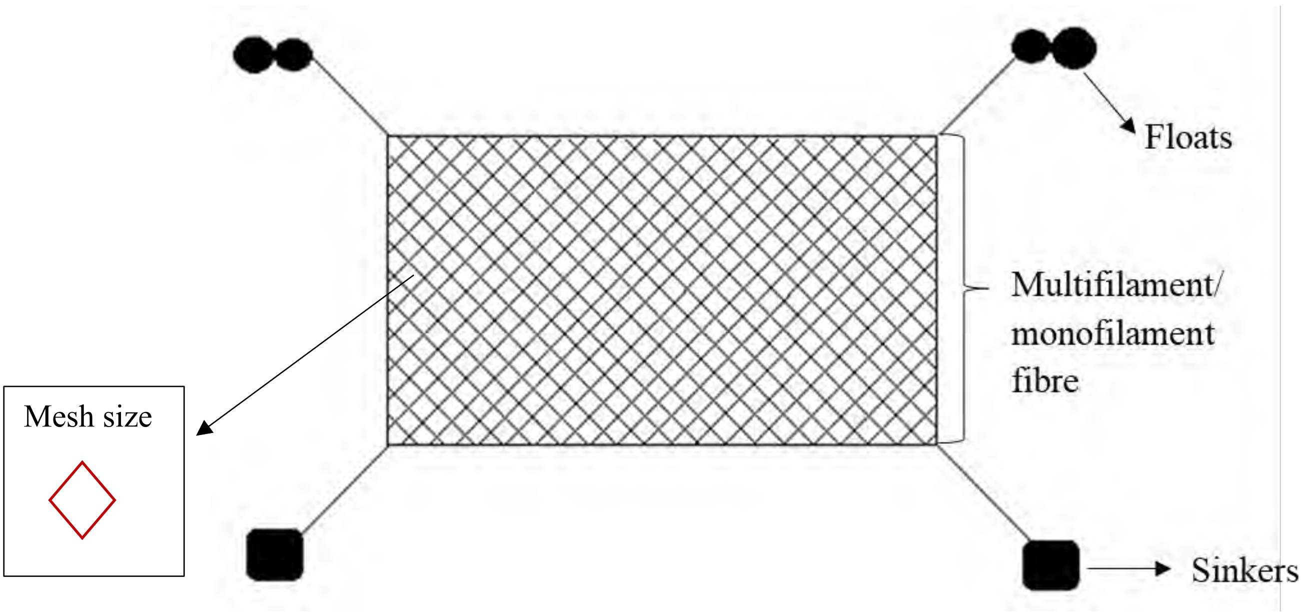


Figure 4.1. Diagram of a gillnet and its components

4.3.3 The socio-demographic profile of gill net anglers in Committees Drift

Subsistence anglers comprised 78% of total anglers encountered, 75% of whom were unemployed, all males, within three racial groups namely, South African Black (75%), South African Coloured (12.5%) and South African White (12.5%), with 75% of them walking to the dams because their origin was within the community (Table 4.2). The primary reason for fishing for subsistence anglers was, income generation through selling the fish, followed by food provision for their households.

Table 4.2. Demographic information obtained from key respondent interviews on the subsistence gill net anglers found in Committees Drift

Aspect	Subsistence angers (n = 8)	Recreational anglers (n=2)
Employment status		
Employed	25%	25%
Unemployed	75%	
Gender		
Males	100%	100%
Females		
Race		
Black	75%	
Coloured	12.5%	
White		12.5%
Transport		
Walk	75%	
Vehicle		25%

Table 4.3. Demographic information (Race and gender were 100%) on the key respondents encountered in the questionnaire with the dominant species caught by gill net anglers in their respective dams. Race and gender were 100% for all the interviews. Nqwelo dam had no key respondents, only two anglers met during the creel survey*.

Dams	Race	Gender	Gear used	Dominant Fish species caught
Sinqumeni	Black	Male	Gill net Hook and line	*Labeo umbratus* *Cyprinus carpio*
Mankazana	Black	Male	Gill net Hook and line	*Oreochromis mossambicus*
Ndlambe	Black	Male	Gill net	*Labeo umbratus*
Nqwelo*	White	Male	Hook and line	*Micropterus salmoides*

4.3.4 Species composition

A total of four species were recorded from the logbooks and interviews: Carp, Largemouth bass, Mozambique Tilapia and Moggel. Species composition by number was far greater than species composition by weight (Table 4.3). Numerically and by weight, Moggel dominated the catch composition, contributing 90% to the total numbers (Table 4.4). *M.Tilapia, L.umbratus, C.carpio O.mossambicus* and *C.gariepinus* were all recorded from gill netanglers encountered from the creel surveys which had an additional species of the African sharptooth catfish

Table 4.3. Species composition of fish by number and weight retrieved by gill net anglers in Committees Drift for the duration of the study from creel surveys

Species	Proportion/% (n = 1238)	Proportion/% (weight = 26.9 kg)
Mozambique Tilapia (%)	2.4	0.0
Labeo umbratus (%)	90.2	60.2
Cyprinus carpio (%)	1.3	23.1
Oreochromis mossambicus (%)	3.0	16.8
Clarinus gariepinus (%)	3.0	0

Table 4.4. CPUE for entries received from book-logs and interviews of gill net fishers

Dam	CPUE (kg/day)	Entry	Days recorded
Ndlambe	9.1± 10 kg/day	Book log	85
Ndlambe	9.1± 8.5 kg/day	Interview	5
Mankazana	0± 0kg/day	Book log	0
Mankazana	0± 0kg/day	Interview	5
Sinqumeni	14± 7.0 kg/day	Book log	12
Sinqumeni	3.1± 2.7 kg/day	Interview	7

CPUE for gill net fishers in Ndlambe was the highest and with the greatest number of days recorded (Table 4.5). Mankazana had no CPUE for gill net fishers, as no data was available for extraction from the fisherman.

4.3.6 Sales obtained from the fisheries resource

According to the interview data, 98% of the subsistence gill net fishers sold their catch either within the rural community, in Peddie (the nearest town), or provided to vendors in nearby towns who would come and collect on a weekly basis and sell the catch on the busy N2 road to motorists travelling on the road. The remaining 2% consumed all their fish as a source of protein. This means that the majority of fishers are actually selling the greater proportion of their catch, which means the gill net fishers fall between being subsistence fishermen (fish to eat) and fishermen who fish for to earn a living. They also revealed that this was a cheaper source of protein and was essentially free. Fish were sold according to their size class. There was no standardized costing system and fish were measured according to hand length. For an adult hand, the cost varied from 0.62USD–0.94USD and for a fish sized from the tip of the finger to the elbow would range from 3.12USD–6.24USD. The price of the fish was lower among the local community members than when it was taken to be sold on the N2 road and in the nearby towns.

4.4 DISCUSSION

Despite the negative and problematic characteristics surrounding gill netting, there is a potential for use in small-scale fisheries where local management structures have been put in place with a clear understanding of the specific fishery in question, with regard to monitoring and standards maintained to ensure sustainable usage. The most apparent problems with gill nets are their incorrect design parameters, which causes varied species bycatch, these nets also often leave behind monofilament yarn (ghost nets) in the water that is harmful to the ecosystem, and these ghost nets can cause post-harvest losses and improper stocking and monitoring (Sandhya, 2019). Of all the gear types, regardless of legality, gillnet fisheries are utilised the most throughout Africa, although mesh size usage is generally regulated and monitored by fisheries authorities. With small-scale fisheries heavily dependent on the gillnets, alternative monitoring systems might have to be introduced in South Africa. Small-scale, multi-species inland fisheries are an important source of food and income for millions of people, especially in developing countries and areas with low food security (Mulumpwa *et al.,* 2020; Osuka *et al.,* 2021). The survey data indicates potential for a small-scale gillnet fishery to be instigated in Committees Drift, if appropriately managed. Therefore, gillnets could be an effective method that can help provide food security, especially in rural areas.

The survey data showed that the Committees Drift region has fish fauna that includes species of potential commercial interest (*M.Tilapia, L. umbratus, C.carpio, O. mossambicus and C.gariepinus*) and no conservation priority species (Weyl and Barkhuizen., 2020). The cichlids, part of the *Oreochromis* genus, are found in the Zambezi community and are the basis for commercial fisheries in the Zambezi River catchment and in Lake Liambezi *(Tweddle et al.,* 2015). Other large cyprinids of the genera *Labeo* are harvested in small-scale fisheries in Mozambique (Ellender *et al.*, 2010a). With an estimated yield of almost 1 $t \cdot yr^{-1}$ in three dams, the prospects of a fishery were not exaggerated. The highest CPUEs were obtained in Sinqumeni and Ndlambe dams with the utilisation of gill net fishing, with the fisheries varying in size. Although these CPUE were high, they are not enough to sustain a gill net fishery within the community. A lot of African inland fisheries tend to suffer from overfishing, which affects both large and small fish species. Therefore, it is very important for fisheries development to be guided by the concept of sustainable utilisation (Asche *et al.,* 2018).

The most common type of management method for inland fisheries is the classification of effort, gear type and catch data (Cooke *et al.,* 2016). These are usually restrictions placed on the fishery for sustainability. Effort restrictions are based on seasons, and gear restrictions are based on gear dimensions and type of gear (Haigh *et al.,* 2008). Information on appropriate harvests often rely on information from the fisheries themselves. Due to the moderate CPUE obtained from the dams in this study, the use of gill nets may be a viable option for Committees Drift, with relatively high catch rates experienced in Ndlambe and Sinqummeni dams. The harvest information on the region shows prospects for a gill net fishery but further research needs to be done on the biology, ecology and recruitment strategies (Sara *et al.,* 2017).

Gill nets however, are currently illegal, and are regarded as highly destructive and indiscriminate fishing gears. They also are often lost and left as aquatic pollution and ghost nets, which further enhances their negative ecological impact on fisheries' sustainability. Organisations in South Africa are participating in gill net cleaning in a number of places. In 2021 South African National Parks (SANParks) Wilderness Rangers destroyed 3 363 m of gill nets removed from the Touws River and Swartvlei Estuary over a 36-month period, and the South Coast Conservancy used volunteers to remove nets as long as 400 metres from the South Coast in KwaZulu-Natal (SANParks, 2021). Therefore, provisions and education around the use and disposal of nets should be put in place as part of any management scheme.

In conclusion, the results of this study have demonstrated that gillnet fishery in Committees Drift is possible in Ndlambe dam for moggel, and in Sinqumeni dam for carp and moggel, due to the high yield found in the area, relative to the size of community and the people who utilise the fisheries. The dams all consist of fish species that are suitable for small-scale fisheries and are marketable, with a relatively high CPUE and estimated yield for the area. The three dams where catch was recorded had one frequent user per dam. If access management in the area continued as is, sustainable fishing practices would occur. No over-fishing would persist. What the current informal fishery requires is equipment and a formalised fishing structure that will not exclude the locals. This will prevent development that is unrealistic as well as stakeholder interference, which usually ends up in mismanagement and the closing of most fisheries (Barkhuizen *et al.,* 2016). However, further studies need to be done that look at other aspects of a fishery for a full picture to emerge.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 GENERAL DISCUSSION

The development of inland fisheries is an important issue that was not addressed properly during the apartheid era (Weyl *et al.*, 2007). A lack of legislation and governance has driven the need to develop a well-structured policy which can deal with issues arising from inland fisheries that are different from the concerns of marine fisheries. Since the apartheid era, South African inland fisheries have been in a state of transition. Recent research by McCafferty *et al*. (2020) and Hara *et al.* (2021) shows some evidence that inland fisheries play an important role in poverty alleviation and growth in rural communities. Therefore, it is important that these fisheries resources are used in a sensible, sustainable manner. This will require an ecosystem approach that engages all stakeholders (government, scientists, researchers, ichthyologists and community members) to 'plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by freshwater/ inland water ecosystems' (FAO 2003).

The Inland fisheries sector needs to be formalised and developed. In order for this to happen, management strategies need to be in place along with the relevant legislation. Findings from projects such as these will begin to lay out a picture of inland fisheries in the different provinces. These findings will lead to appropriate managements strategies which can assist the country in dealing with its NDP goals. The development of inland fisheries is one of the ways in which rural livelihoods could be improved for the present and future generations. They also hold potential to increase the local and national economic value and to provide jobs for the communities associated with them.

The Eastern Cape province has the lowest economic growth, with poverty levels being one of the highest in South Africa (Stats, 2017). Fisheries are a way in which food security levels could be increased. In order for this sector to uplift the province, formalised fisheries need to be created that are well managed and controlled by a third party. This will resolve user conflict problems as these are one of the factors of failed fisheries attempts (Potts *et al.*, 2007).

Fisheries availability is far greater now as it was in the past, as the government has given open access user rights to these waterbodies (Adams *et al.*, 2007). Currently the fisheries resources are utilised by anyone who has means of getting to these resources, as well as the suitable gear. As revealed by this study, the majority of user groups are subsistence anglers, small scale anglers and recreational anglers, all of which are informal uses. There are problems which arise from informal fisheries, such as illegal use of equipment and possible unsustainable use of the resources. The dams surveyed in the study showed low potential to be able to develop a formal fishery, except for Ndlambe dam and Sinqumeni dam, both found in committees Drift. Most of the dams could be used for subsistence, recreational or small-scale fisheries, which could successfully contribute to improving the poor food security within the province. Organised fisheries development would still need to take place for biological sustainability and cohesive management, led by the state in collaboration with other institutions.

5.2 MANAGEMENT CRITERIA FOR INLAND FISHERIES

A blanket approach to manging inland fisheries in South Africa, such as the Inland fisheries policy, will not work in all the provinces. Sub-management criterion needs to be formulated, either at provincial or municipal level. Provinces such as the North-West province, Free-State province and the Western province are already conducting research on species availability and species composition in inland fisheries. With this criterion, they would be looking at managing resources through stock assessments and fish productivity (Chapter 3) supports, requiring information on the biological and physiological characteristics of the impoundment, the type of species available in the region and an overall knowledge of those species, including their conservation status. Another criterion is gathering information about the consumers and users of the fishery resource through stakeholder consultations, interviews and questionnaire distribution (Chapter 2) which can be used to make more informed decisions regarding fisheries management. A third criterion is management of resources by the usage of one gear type within the community (examination of use of gill nets in Chapter 4). Managed properly, this could ensure that juveniles would remain in the dam to grow, thus enabling sustainability and preservation of the resource. Having these sub-management criterions through the relevant legislation, and governance structures in all provinces, will make it easier to detect endangered or alien species as they move through inter-provincial water bodies.

5.2.1 Gillnetting as an effective method for monitoring fish populations: A SANParks example

If used correctly, gill nets can be a very efficient method for scientists to monitor fish communities and population changes over time. By limiting the time that the net is in the water, selecting certain time periods to sample, and through continuous monitoring of the net, scientists can determine the number of species, relative abundance, and size structure of the fish community, whilst minimising or even preventing unnecessary fish mortality.

However, when used illegally by poachers, gill netting can have severe impacts on estuarine fish populations. Poachers set nets to maximise catches; these nets are not monitored and are left in the water for long periods of time (typically at night) and the mesh size is generally small, which means many juvenile fish are caught. Otters, terrapins and various bird species including cormorants and greater crested grebes are also caught from time to time in these nets. The unmanaged use of gill nets is not only environmentally destructive but has a negative impact on both recreational and subsistence anglers. By removing large numbers of fish, the catch rates of these more responsible and sustainable fishing practises will become reduced and the sustainability of local fisheries will be threatened.

The gill nets that SANParks remove have typically been constructed by sewing discarded netting material that is used to secure pockets of vegetables to pallets while being transported to retail and distribution centres. Discarded polystyrene, plastic bottles and just about anything that can float is used to float the top part of the net, and stones are used as weights to create the wall of net. The poachers that set gill nets make use of stolen or borrowed canoes that are kept on the water's edge or at slipways. The canoes are used to row to a concealed place where the nets are set. Canoes are then hidden in the reed beds to be used at a later opportunity.

To try and prevent the usage of this packaging material SANParks has been engaging with local vegetable suppliers and creating greater awareness around the problems associated with illegal gill netting. This approach has been beneficial. Unfortunately, some of this material still slips into the wrong hands. Limiting the availability of boats also hinders the poachers. A valid SANParks vessel permit assists greatly with tracking the owners of a canoe that is found abandoned and they encourage all boat owners to register their boats and canoes with SANParks (SANParks, 2021).

Another way that inland water bodies can be managed in the Eastern Cape could be through education, providing access to proper fishing gear, community management and awareness. Performing outreaches to those communities that have an active fishing community and providing them with the proper gear and knowledge on fishing practices and fishing value chains would have a positive outcome on the usage of the fishery.

5.3 FISHERIES DEVELOPMENT

Fisheries development within the Eastern Cape is well understood and several initiatives have been attempted, but without success due to the lack of a governing body with specific rules and regulations of how to best manage the fisheries (McCafferty *et al.*, 2012). In order for longevity and sustainability of the resource to occur for economic and social well-being, which are the ultimate objective of a fisheries development scheme (Charles, 2001), there needs to be proper management strategies, management policy and clear guidelines on how to obtain the set objectives in a rational manner, through biological sustainability and optimising the economic benefits for the surrounding communities. My study addressed these issues by designing an ichthyological survey on the biological data on the fish species available in the dams. The study also focused on obtaining both biological and social data from the users of the dam through interviews and questionnaires. This was necessary to obtain a more comprehensive usage, from all viewpoints, which is not done in many studies. These studies need to be interdisciplinary.

5.3.1 Biological sustainability

In order for biological sustainability of a fish resource to be obtained, species need to be protected and utilised in a sustainable manner (Charles, 2001) for both subsistence and recreational fisheries to conserve them for future generations. In order for this to occur, fish species must not be endangered or threatened in the IUCN data list, they need to be protected, and harvest levels need to be controlled. There were no endangered species encountered in this study, although *S. bansii* (IUCN 2003) was expected. *O.mossambicus*, *M. salmoides* and *L. machrochirus* species dominated and are considered suitable for commercial, recreational and subsistence fisheries due to their fast growing ability (Decline, 1992). Access to these resources for subsistence and recreational fishing also needs to be regulated, to control harvesting and prevent the use of illegal gears and promote long-term sustainable utilisation (Charles, 2001; Potts *et al.*, 2007). Long-term fisheries development needs to monitor harvest levels in order for them to correlate with sustainable yield.

5.3.2 Optimal economic benefits

The main national objectives for inland fisheries in South Africa is currently to provide food security, economic growth and poverty eradication, which are all aligned with the National Development Plan (National Planning Commission, 2011). The main objectives for the Draft Inland Policy is to create an opportunity for socio-economic benefits including jobs, rural livelihoods, food security, SMME opportunities and economic development based on small scale fisheries and recreational fishing value chains (DAFF, 2018). Both of these are aligned. Food security, economic growth and poverty eradication are at the top of the priority list in both policies.

The allocation of these resource to outside companies or government entities would result in income generation. In each of the seven dams in this survey, fish supply would not be sufficient for economic growth, but would increase the local economy within the community. Job opportunities would be present for a limited number of individuals, although not in a sustainable manner with the potential yield estimated for the dams (Chapter 3). In the study, Ndlambe dam had the highest estimated potential yield, yet this is not enough to be able to sustain a fishery. However, through the utilisation of the 7 dams, food security could be increased on a local scale. Fish are a more affordable protein source than red meat.

For a formalised fishery unit to be able to tackle poverty, the yield needs to support workers and produce fish yields that can be sold. According to Tweddle *et al.* (2015), a limited number of fishers could be sustained through a small-scale fishery initiative, providing an employment at the current recommended minimum wage (R21 720/annum). The estimation is based on a minimum wage of R11/day on a 40-hour week, using the potential estimated yield Marshal & Mace (1998) MEI model and on a fish price of R15/kg(Booth & Potts, 2006).

Another form of economic upliftment could come through economising the recreational angling sector, which contributes to much of the communities user base. Committees Drift also hosts a number of informal angling competitions for clubs, mostly located in Makhanda (see Chapter 2 on fisher origins). Access to the dams is available through the local chief for a non-refundable fee which varies from 3 USD to 32 USD depending on the number of people per club and how long they intended to utilize the dam(s), which also contributes to the local economy. This payment by external users allows for access control, as the resource is primarily for the local community as a direct food source.

5.4 RECOMMENDATIONS

The structure of this thesis should be replicated on a larger scale to obtain a broader understanding of inland fisheries from all spheres. The combination of natural science (biology and ecology of fishes and the fisheries physical information), the creel surveys, interviews and questionnaires make it easier to get a sense of the sector and how best to manage it. A replicate of this survey on an increased number of water bodies around the country will increase the national knowledge regarding the inland waters of South Africa and in so doing provide answers for which policy can be formed to develop the water bodies.

Management of the sector requires more comprehensive fisheries knowledge. Ongoing surveys are required to monitor changes in fish populations, yield and usage in rural areas such as Committees Drift. These surveys could provide information to determine whether newly introduced species such as *C. gariepinus*, and/or historically introduced species are still established and to determine changes to the environment. Britz *et al.* (2015) stated that it is necessary to do fish surveys on water bodies around the country to develop and create sustainable utilisation of inland fisheries.. The dams are within close vicinity of each other yet don't have the same fish communities, which is likely a result of historical introductions and translocations for different purposes. Variations in fisheries structure in the Eastern Cape will cause issues for management plans for inland fisheries as a whole across the country.

When implementing the Inland policy, government needs to take precaution with already established community-based management styles. Committees Drift is an example of such and sweeping governmental policies could alter the hierarchical management structure which currently works. The implementation process needs to be a joint venture, taking into consideration the consultations that DAFF/DEFF have already conducted. There should be a distinction in the policy recommendations between those who mostly consume, and sell some (subsistence fishers), and those who mostly sell, and consume some (small businessmen, however informal). The difference lies in the development of the policy. One could also go as far as proposing a loan for new equipment to someone who only wants to fish to sell their produce. The loan for new equipment, as well as entrepreneurship training, for example, for someone who is committed to selling the greater part of their catch could be beneficial for the household income.

In this thesis I used a biological survey and a questionnaire survey to analyse local inland fisheries. This is the first study of its kind in the Eastern Cape combining both surveys. Per Weyl *et al*. (2020), strategies need to be put in place to further develop inland fisheries in the Eastern Cape. I show that inland fisheries in each area can support the community, but there is little evidence of economic growth because of unclear management protocols, and a lack of decent access roads and value chains for selling fish within the community and the country at a broader scale.

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Appendix 1

Q. No.	Date.	Weekday.	Area.
Name/ id.			
S ________________ E	Vehicle type	Make	Year
# Group ________________ # Fishing	Race	Sex	Children u.10
Origin		Transport/Cost	
Usual fishing area		Employed /Unemployed/Student	
#HL ________________ #Rods present	Bait (artificial, worms, mealies….)	Feeding Area (Y/N, what?)	Boat (canoe, motor)
#Rods used			
Hook size.	Caught/released/Eaten: Spp; no..; wt.		
Fishing days per area			
Start			
Interview			
Expected End			
Length.			
Comments: Fish price etc.			

Makana Fisheries Project

Creel Survey

AREA ______________________________

DATE ______________________________

NAME __________________________

Appendix 2

Survey Questionnaire

A.	SOCIO-ECONOMIC INFORMATION

GENERAL INFORMATION

A.1 Individual

A.1.1 Age: _______

A.1.2 Sex: Male ☐ **Female** ☐

A.1.3 Race group: Black ☐ White ☐ Coloured ☐ Asian ☐ Other ___________

A.1.4 What is your role in the family? ____

A.1.5 Total number of people in household? ______________ **How many dependents?** ________________

A.1.6 Occupation ____________________________________

A.1.7 Other sources of income in your household?

None ☐ Fixed employment ☐ Pension ☐ Casual labour ☐ Other ____________________

B.	RESOURCE USE INFORMATION

B.1.1 How long have you been fishing for (days, months, years)? ____________________________________

B.1.2 Why do you fish? For Food ☐ To earn living ☐ Recreation ☐ Competition ☐ Other ___________

Crucial ☐ Fairly important ☐ Not very important ☐

B.1.3 How many *other* people in your household fish? ____

B.1.4 How important is your fish/other catch in your household diet?

Crucial ☐ Fairly important ☐ Not very important ☐

B.1.5 What would you do if there were no longer any fish to catch? ____________________________________

____

B.1.6 What do you generally do with your fish catch? ____

	All	Some	Minimal	None
Eat it				

Sell it

Give it away

Return it alive

B.1.7 How many times per week does your household eat fish that you catch?________ or is bought ______?

B.1.8 How many times per week does your household eat meat (red & chicken? ________________________

B.1.9 When do you prefer to fish? Morning ☐ Midday ☐ Afternoon ☐ Evening ☐ Night ☐ Doesn't matter ☐

B.1.10 How often do you fish per week?

Mon Tues Wed Thurs Fri Sat Sun

B.1.11 Does this differ seasonally?________________________

Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Jul	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**

B.1.12 Where else do you fish? ____

____

B.1.13 What is the importance of the current fishing area? ____

____

B.1.14 How many years have you been fishing?______

B.1.15 Which fish species do you prefer eating?_________________________________

B.1.16 Why?____

B.1.17 Do you fish more over? Weekdays ☐ Weekends & public holidays ☐

School holidays ☐ Everyday ☐ Any day ☐

B.1.18 Do you fish at night? Yes ☐ No ☐

B.1.19 If you fish at night how often do you fish at night (per week): in this area____ in other areas_____

B.1.20 How far have you travelled to fish today (one-way)? ____

B.1.21 What method of transport did you use? ____

B.1.22 Which areas do you fish most often now ____________________ in the past ______________________

B. 1.23 Do you belong to a fishing club/group? Yes No **Name:** ______________________________

B.1.24 How much money did you spend for this trip? __________________________________

B.1.25 How much are you prepared to pay to go on a fishing trip like this one?____________________________

C.	OWNERSHIP & ACCESS TO THE LIVING RESOURCES

C.1.1 Who owns the fish resources in the dam?

All SA citizens Anglers God The government People living in the area Ancestors

Other …………………………..

C.1.2 How did you obtain the right to fish in this area?

By inheritance Local traditional chief Permit South African citizen Ancestors

Other ___________________

C.1.3 How did you obtain the right to fish in this area?

By inheritance Local traditional chief God South African citizen Ancestors

Other ___________________________

C.1.4 Who else is allowed to fish in this area? ____

C.1.5 Would more people fishing deplete the fisheries resource? _____________________________________

____

C.1.6 Do you fish with other fisherman? _____

C.1.7 If Yes, from the same area?_____________ Other areas _______________

C.1.8 Who should use this fishing area? Why? ____

____

C1.9 What do you think of other users of the fishing area? ____

____

D.	MAINTAINING BIODIVERSITY

D.1. 4 In which way does your current fish catch differ from the past?

More Less More species Less species

Bigger ☐ Smaller ☐ No difference ☐ Don't know ☐

D. 1.5 Which fish species are noticeably scarcer/more abundant than before?

Organism	Scarcer	More common	Smaller	Larger

D.1.6 Do you think the fish resources are threatened? Yes ☐ No ☐

D.1.7 Have there been noticeable changes? ____

____

D.1.8 What do you think has caused these changes? ____

D.1.9 What do you think can be done to improve the situation? ____

____

D.1.10 What are the main threats to the fish in the dams you fish from?

Agricultural pollution ☐ Littering ☐ Recreational fishing

Subsistence fishing ☐ Commercial fishing ☐ Poor management