Contrasting impact of alien invasive sport fish in the Cape Floristic Region: a focus on *Micropterus dolomieu*

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Thesis presented in fulfilment of the requirements for the degree of Masters of Conservation Ecology in the Faculty of Agriscience at Stellenbosch University

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December 2014

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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ABSTRACT

The number of introductions of alien species is on the rise globally. The resulting impacts on the invaded environments are diverse and often contrasting. Many deliberately introduced species have positive social and economic impacts as people use them to achieve a goal. These goals can be recreational, such as mountain biking in a plantation of alien trees or commercial such as harvesting alien trees for timber. Conflict often arises when the goals of the individuals using the alien species clash with the goals of those trying to mitigate negative impacts of the introductions. As many scientists are more inclined to favour native over alien species, the negative impacts of alien species are better documented in scientific literature. It is valuable to document contrasting impacts of alien species so that they may be managed in a way which does not cause unnecessary conflict. This thesis documents contrasting impacts of *Micropterus dolomieu* (smallmouth bass) within the Cape Floristic Region (CFR). It does this using the Rondegat River in the Olifants-Doring River system and the Clanwilliam Dam, in the same system, as case studies. Smallmouth bass, *Micropterus dolomieu,* were removed from the Rondegat River using a piscicide called rotenone by the Western Cape nature conservation authorities; CapeNature. This thesis documents the results of snorkel observations and underwater filming of the river. Native fish densities increased from 0.29 fish/100m^2 to 11.81 fish/100m^2 following smallmouth bass removal. Documenting the recovery of the native fish population following smallmouth bass removal provides further insight into the negative ecological impacts of the species. The results of the monitoring show that smallmouth bass had extirpated three native species from the invaded reaches and was preying heavily upon juveniles that were dispersing downstream. The removal of the smallmouth bass from the Rondegat River was a project which cost CapeNature both money and time. Through personal communication with implementers of the project and through access to CapeNature financial records, this thesis documents the costs of the Rondegat River smallmouth bass eradication project. It cost CapeNature R 358 068 per kilometre of river to eradicate smallmouth bass from the Rondegat. An estimated 5079 man hours were spent on the final planning and implementing of the two rotenone treatments. These costs represent a negative economic impact of smallmouth bass and are useful in estimating the costs of future eradication projects. These two negative impacts are contrasted with the positive socio-economic impacts of the species. The Clanwilliam Dam, further downstream, hosts a large smallmouth bass population and is considered to be one of South Africa's premier smallmouth bass fishing destinations. Anglers who travel to the dam in order to catch smallmouth bass often spend money at local businesses, thus contributing to the local economy. This expenditure is a positive economic impact of smallmouth bass. Anglers were interviewed at the dam and it was estimated that they spend R2 000 721.61 in the town of Clanwilliam every year. This is taken as the economic impact of smallmouth bass angling upon the town. This expenditure has a positive impact on local businesses and their employees. Smallmouth bass therefore, have contrasting impacts within the CFR and it is important that they are all considered in the management of the species. The Rondegat River smallmouth bass eradication project is an example of how the negative impacts of smallmouth bass can be mitigated without affecting its positive impacts and is a case study that could potentially inform how management of the genus proceeds in South Africa.

Key words: Alien species, invasion, impacts, rotenone, economic impact, conflict species, Clanwilliam, Rondegat.

OPSOMMING

Die aantal toevoegings van nie-inheemse spesies is besig om wêreldwyd te vermeerder. Die gevolglike impakte op nuwe omgewings is divers en ook gereeld kontrasterend. Baie spesies wat doelbewus toegevoeg word het positiewe sosiale en ekonomiese impakte omdat mense hierdie spesies gebruik met ’n spesifieke doelwit in gedagte. Sodanige doelwitte kan met ontspanning te doen hê, byvoorbeeld om in ’n plantasie nie-inheemse bome met ’n bergfiets te kan ry, of kan kommersieel van aard wees, byvoorbeeld die inoesting van nie-inheemse bome vir werkhout. Daar ontstaan egter gereeld konflik as die doelwitte van die individue wat die nie-inheemse spesies gebruik bots met die doelwitte van diegene wat hierdie spesies se negatiewe inpakte probeer teëwerk. Aangesien baie wetenskaplikes geneig is meer gunstig teenoor inheemse as teenoor nie-inheemse spesies te wees, word die negatiewe impakte van nie-inheemse spesies beter gedokumenteer in die wetenskaplike literatuur. Dit is waardevol om die kontrasterende impakte van nie-inheemse spesies te dokumenteer sodat hierdie spesies op so ’n manier bestuur word dat onnodige konflik vermy kan word. Hierdie tesis dokumenteer kontrasterende impakte van swartbaars (*Micropterus spp.*) in die Kaapse Floraryk deur van die Rondegat-rivier in die Olifants-Doring-rivierstelsel en die Clanwilliam-dam (in dieselfde stelsel) as gevallestudies gebruik te maak. Kleinbekbaars, *Micropterus dolomieu,* is deur die Wes-Kaapse natuurbewaringsowerhede, CapeNature, met ’n gifstof genaamd rotenone uit die Rondegat-rivier verwyder. Hierdie tesis dokumenteer die resultate van visuele en fisiese monitering van die rivier. Die herstel van inheemse vis ná die verwydering van kleinbekbaars word verstaan om ’n gemeenskap te wees, en inheemsevisdigtheid is soortgelyk aan wat die geval was voor die kleinbekbaars-indringing. Daarom bied dokumentering van die herstel van die inheemse vis verdere insig in die negatiewe ekologiese impakte van swartbaars. Die resultate van die monitering toon dat kleinbekbaars drie inheemse spesies uitgeroei het in die rivierrakke waar hierdie spesie ingedring het, en ook dat kleinbakbaars besig was om hewig jag te maak op jongvisse wat stroomaf uitswerm. Die verwydering van die kleinbekbaars uit die Rondegat-rivier was ’n projek wat CapeNature geld, sowel as tyd, gekos het. Deur gebruik te maak van persoonlike kommunikasie met implementeerders van die projek en deur toegang tot CapeNature- finansiële rekords, dokumenteer hierdie tesis die koste van die projek om kleinbekbaars uit die Rondegat-rivier te verwyder. Dit het CapeNature R 358 068 per kilometer van die rivier gekos om kleinbekbaars in die Rondegat uit te wis. Dit het verder ’n beraamde 5079 man-ure gekos om die twee rotenone-behandelings toe te dien. Hierdie koste verteenwoordig ’n negatiewe ekonomiese impak van swartbaars en is waardevol om die koste van toekomstige uitwissingsprojekte te beraam. Hierdie twee negatiewe impakte word in kontras gestel met die positiewe sosio-ekonomiese impakte van die spesie. Die Clanwilliam-dam, verder stroom af, het ’n groot swartbaarspopulasie en word gesien as een van Suid-Afrika se topbestemmings vir swartbaarshengel. Onderhoude is met hengelaars gevoer om te bepaal hoeveel hulle elke jaar in die dorp Clanwilliam spandeer. Dit is geneem as die ekonomiese impak van swartbaarshengel op die dorp. Dit het ’n positiewe impak op plaaslike besighede en hulle werknemers. Swartbaars het dus kontrasterende impakte in die Kaapse Floraryk en dit is belangrik dat al die impakte in oorweging geneem word met die bestuur van die spesies. Die kleinbekbaars-uitwissingsprojek in die Rondegat-rivier is ’n voorbeeld van hoe negatiewe impakte van swartbaars teëgewerk kan word sonder om die positiewe aspekte van die spesies te beïnvloed, en die projek dien as ’n model vir hoe om die bestuur van die genus in Suid-Afrika voort te sit.

Sleutelwoorde: Nie-inheemse spesies, indringing, impakte, rotenone, ekonomiese impak, konflikspesies, Clanwilliam, Rondegat.

ACKOWLEDGEMENTS

I would firstly like to thank God for giving me the opportunity to study his beautiful world.

Then there are numerous people who I would like to thank:

- To Mr Dean Impson and Mr Riaan van der Walt: thank-you for taking time to talk me through the Rondegat River Rehabilitation Project and for providing crucial information regarding the effort and costs of the project.
- To CapeNature for allowing me to monitor and be involved in their project.
- To Prof. James Blignaut and Prof. Theo Kleynhans: thank-you for reviewing my third chapter and giving valuable feedback and advice.
- To Dr. Justin Harvey: thank-you for assisting me with my statistics, without your help I would still be analysing data.
- Thank-you to the Water Research Commission and the DST-NRF Centre of Excellence for Invasion Biology for the financial support which they provided.
- Thank-you to the National Research Foundation of South Africa (NRF), the South African Institute for Aquatic Biodiversity (SAIAB) and the Water Research Commission (K5/2261) for funding my field work.
- Thank-you to the anglers who participated in the interviews as well as Mr Donovan Greenway, Mr Max Maxwell-Haven and Mr Craig Fraser for their support at the events which enabled me to conduct interviews.
- Thank-you Lauren de Kock, Lauren Barrow and Jordache Fortuin for reading through and helping me to edit my thesis.
- To Lorraine Steyn, Jordache Fortuin, Claudette Meijering, Charissa Noble, Duane Stacey, Francois Pauw and Etienne Slabbert for their help to conduct angler interviews.
- Thank-you Liana de Araujo and Fezile Mhlanga for helping to watch underwater video footage.
- To my mother-in-law: Thank-you for translating questionnaires into Afrikaans for me.
- To my parents: Thank-you for helping Adele and I financially while I studied.
- To my wife, Adele: Thank-you for supporting me, especially when things got busy near the end.
- To my supervisors:
    - Prof. Karen Esler: Thank-you for taking me on as a student and always being able to offer valuable advice. Thank-you for being so efficient at responding to questions and giving back feedback on my work.
    - Dr. Olaf Weyl: Thank-you for taking me on as a student before you knew me. Thank-you for all your feedback on work I did and for really helping me construct the contents of the thesis.
    - Dr. Martine Jordaan: Thank-you for introducing me to the Western Cape's native fish. Thanks for always being available to meet up and talk about how things were going. Thank-you for helping conduct angler interviews.

Table of Contents

CHAPTER 1: INTRODUCTION

1.1 Global context

There are approximately 5 ± 3 million species on the planet (Costello et al. 2013). This biodiversity is especially concentrated in areas known as biodiversity hotspots. There are 35 identified hotspots and combined they host at least 50% of earths plant species and 42% of its vertebrate species (Mittermeier et al. 2011)

The International Union for the Conservation of Nature (IUCN) considers over 20 000 species to be threatened and listed as Critically Endangered, Endangered or Vulnerable (IUCN, 2014). Threats facing these species are complex and mostly anthropogenic. They include habitat loss and degradation, climate change, nutrient loading, pollution, over exploitation and invasive alien species. There is a need to mitigate the impacts of these threats, on both ethical and economic grounds, in order to reduce loss of biodiversity components from the level of genetic diversity to that of habitats, biomes and ecosystems (Secretariat of the Convention on Biological Diversity, 2010). This will be the focus of the 12th meeting of the Conference of the Parties in October 2014. Within this global context it is important to continue to document the impacts of these threats. This thesis considers both ecological and socio-economic impacts of smallmouth bass *Micropterus dolomieu* (Lacepède) in one of South Africa's biodiversity hotspots, the Cape Floristic Region (CFR), using the Rondegat River and the Clanwilliam Dam, both in the Olifants-Doring system, Western Cape as case studies.

1.2 Invasive alien species

The number of known invasive species has increased around the globe in recent years (Ricciardi, 2007). Although this may be a result of an increase in awareness and research, introductions are still on the rise in regions, such as Europe, where the introduction of alien species has been documented for a number of decades (Secreteriat of the Convention on Biological Diversity, 2010). The driver behind the rise in introductions is largely the increase in global trade (Ricciardi and Rasmussen, 1998). It has become easier to move anything, whether intentionally or unintentionally, across continents and oceans. Although only a small proportion (<10%) of introduced species cause significant negative impacts, those that do can have considerable ecological and economic consequences (Ricciardi and Rasmussen, 1998). For an alien species to become invasive it must progress from simply occurring outside its native range, to moving into the novel but natural environment by either escaping captivity or cultivation, or by intentional or unintentional release. The alien species needs to be able to withstand the conditions of the novel environment and to be able to reproduce, with its offspring being capable of dispersing away from the original point of introduction. Once dispersal is achieved, and if the newly established populations are also capable of reproducing and dispersing from multiple sites, the alien species would be classified as invasive (Blackburn et al. 2011). It is difficult to anticipate or predict the impacts of an invasive species. Even the species that are highly invasive (capable of establishing and spreading rapidly) do not always necessarily have dramatic impacts (negative or positive) outside their native range (Ricciardi and Cohen, 2006). While other species may have dramatic impacts upon the novel environment before they become established and widespread (Jeschke et al. 2013; Ricciardi et al. 2013). Better prediction of the impacts of alien species has become a highly researched topic of invasion biology (Pyšek and Richardson, 2010; Ricciardi et al. 2013; Dick et al. 2014).

1.3 Defining the impact of invasive alien species

In the context of alien species, the term "impact" is largely used to describe the change to the invaded environment caused by the alien species. This impact or change may be simple or complex, but when documented, the impact needs to be properly defined in order for it to be best understood and most useful to the scientific community and stakeholders (Parker et al. 1999; Jeschke et al. 2014). When discussing impacts of an alien species one must consider a number of aspects including: the directionality (positive or negative) of the impacts, the classification and measurement of the impacts, whether the impacts are ecological, socio-economic or both and the scale of the impacts (Jeschke et al. 2014). Figure 1.1 shows how an invasive species can have contrasting impacts.

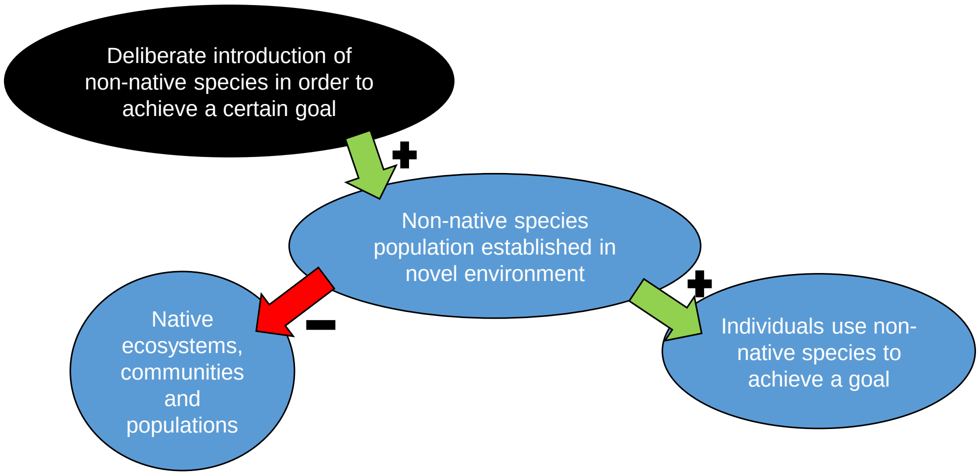

Figure 1.1: A diagram showing the socio-economic benefits and ecological drawbacks of a deliberate introduction. Blue shapes are impacted groups. Arrows indicate flow of impact; the red arrow and – indicates negative impacts, while green arrows and + indicate positive impacts. This thesis will further develop this diagram for smallmouth bass in the Cape Floristic Region.

1.3.1 Negative impacts

There are numerous examples of the negative impacts of invasive alien species, such as; changes in ecosystem functioning, hybridization, changes to soil processes, species richness and competition between native and alien plants (Pyšek and Richardson, 2010). Invasive alien species can also directly cause extinction (Ricciardi, 2007). Two notable examples would be Nile perch, *Lates niloticus* (Linnaeus) which are responsible for the extinction of numerous cichlids in Lake Victoria (Witte et al. 1992) and small Indian mongoose, *Herpestes javanicus* (É. Geoffroy Saint-Hilaire) that caused the extinction of 18 native reptile species in the West Indies (Parker et al. 1999). The rate of species introductions is higher than the rate at which species are going extinct and so it can be argued that species richness is being increased on a local scale. This view is short sighted, as on a global scale species richness is decreasing (Pyšek and Richardson, 2010).

A decrease in species richness caused by alien species is an impact which is not always directly felt by humans. The loss of native species is not always easily expressed in monetary terms and it is therefore often difficult to motivate adequate management actions. When an alien species alters an ecosystem and affects ecosystem services there is a greater incentive to take action. Alien plants in South Africa have been shown to affect ecosystem functioning and services, resulting in economic losses amounting to billions of US dollars (Van Wilgen et al. 2001). In turn this has justified the extensive control methods which cost R3.2 billion between 1995 and 2008 (Van Wilgen et al. 2012) and these methods have had positive results (Esler et al. 2010). Negative economic impacts of invasive alien species can be directly caused by the species (by impacting ecosystem services) but also includes the costs of controlling the invasive alien species (Parker et al. 1999; Lovell et al. 2006). Alien species cost the United States of America (USA) an estimated $137 billion annually (Pimentel et al. 2000). Additionally, the costs of controlling, monitoring or eradicating aquatic invasive alien species in the USA are significant (Lovell et al. 2006) (Table 1.1).

Table 1.1: From Lovell et al. (2006), selected examples of the costs of control of aquatic invasive alien species to the United States of America (2003 dollar value).

Authors	Time period	Species	Geographic area	Dollar value	Outcomes
Lupi et al. (2003)	2003	Sea lamprey (*Petromyzon marinus*)	St. Mary's River	$4.2 million per treatment	Lampricide
Lupi et al. (2003)	2003	Sea lamprey (*Petromyzon marinus*)	St Mary's River	$ 300 000 per year	Sterile male release and trapping
Leigh (1998)	1985-1995	Ruffe (*Gymnocephalus cernua*)	Great Lakes	$13.6 million cumulative	Estimated total cost of 11-year control program
Pimentel et al. (2000)		European loosestrife (*Lythrum salicaria*)		$ 48 million annually	Estimated control costs and forage losses

1.3.2 Positive impacts

It is incorrect to assume that the introduction of an alien species will have only negative effects (Glozan, 2008). Alien species can have positive impacts and these are largely socio-economic, if a deliberately introduced species achieves the purposes for which it was introduced. The use of invasive black wattle, *Acacia mearnsii* (De Wild) in South Africa generated over US$ 552 million in 2000 (De Wit et al. 2001). Cost-benefit analysis is a common method in comparing the contrasting impacts of an invasive species (Headrick and Goeden, 1993; Sharov and Liebhold, 1998; Odom et al. 2003;). Furthermore, although this study has referred to the costs of control as a negative impact of alien species, it has been argued that the control efforts can result in job production for low income groups (Van Wilgen et al. 2012). Therefore in some cases, costs of control are difficult to place as wholly negative or positive. In order to avoid conflict both the negative and positive impacts of an invasive alien species must be considered when making management decisions (Schlaepfer et al. 2011).

1.4 Conflict species

When proposing management of an invasive alien species, the goals of various stakeholders may differ and conflict often arises. This is because a deliberately introduced invasive alien species may be beneficial to certain stakeholder groups (Pascuel et al. 2009). The goals of those with interests in mitigating the negative impacts of the species clash with the goals of those who introduced the species deliberately in order to gain some value or benefit from it (Schlaepfer et al. 2011). A conflict-generating species is associated with both high negative ecological impacts and high benefits (Figure 1.2).

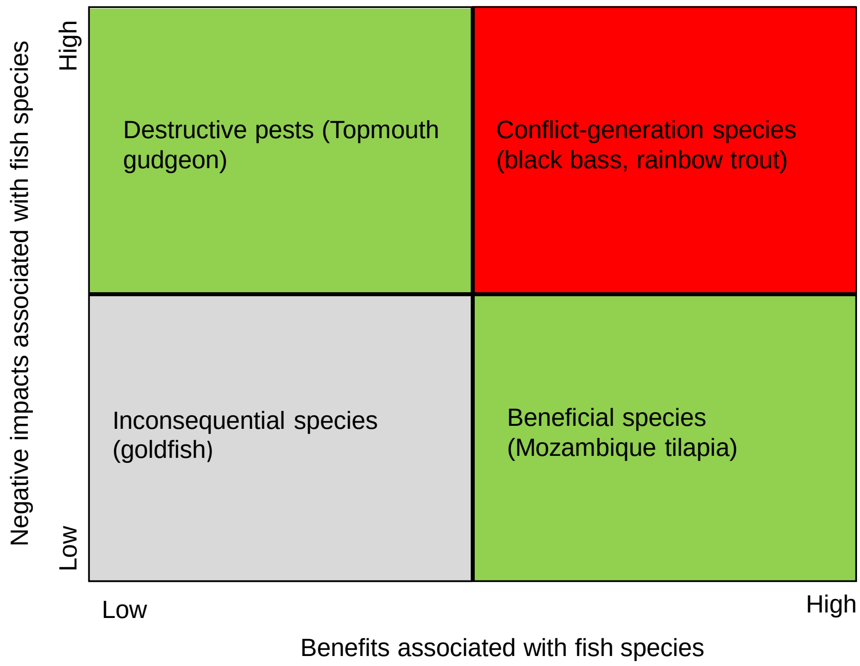

Figure 1.2: Invasive alien aquatic fauna and their relative degree of negative ecological impact and the benefits associated with their use. Colours represent difficulty in making management decisions, grey representing a case where management is not a high priority, green where the decision is fairly simple and red represents a complex scenario. (Adapted from Van Wilgen and Richardson, 2014)

The decisions regarding the management of a pest species or a beneficial species are relatively straight forward as the impacts are in one direction and stakeholders are generally in agreement. The management of a conflict species is more complex than other invasive alien species as the conflict stems from differences in value systems of the involved individuals or groups. Values are diverse, variable and difficult to measure, but the only way to overcome difficulties in controlling alien conflict species is by acknowledging the different environmental values and by promoting communication between between stakeholders (Estévez et al. 2014).

1.5 The Cape Floristic Region

The Cape Floristic Region (CFR) is one of the 35 identified global biodiversity hotspots with an original extent of 83 946 km^2 (Raimondo and von Staden, 2009). The CFR has high floral species richness with 13 000 described plant species of which 70% are endemic to the region (Linder et al. 2010). With only 24.3% of its original geographic extent still intact, the CFR's biotic diversity is highly threatened (Myers et al. 2000) and 1736 (of which 1690 are endemic) of its plant species are currently threatened with extinction (Raimondo and von Staden, 2009). There are many threats facing the CFR but perhaps the most widespread and recognized are habitat loss and threats associated with invasive alien species (Cowling et al. 2003; Rouget et al. 2003). Habitat loss can be driven by agricultural transformation or urbanization, but can also be a result of an alien species establishing and altering the ecosystem. Similarly, habitat loss often facilitates invasion.

The CFR is also a hotspot of threatened endemic freshwater fish species (Linder et al. 2010; Tweddle et al. 2009). With 24 recognized species of which 17 are endemic, the freshwater fish of the CFR mirror its level of floral endemicity, but not its floral species richness. 61% of the CFR's freshwater fish are considered threatened (Linder et al. 2010). This is largely due to habitat loss and invasive alien species (Rouget et al. 2003).

1.6 Impacts of a conflict species: the example of black bass

The majority of alien fish in the CFR are conflict species as their introduction was driven by a perception that the CFR's native fish fauna lacked value (Coke, 1988). Common carp *Cyprinus carpio* (Linnaeus), Brown trout *Salmo trutta* (Linnaeus), rainbow trout *Oncorhynchus mykiss* (Walbaum) and black bass *Micropterus* spp. were all introduced to supplement recreational fisheries in South Africa (McCafferty et al. 2012). These alien species were considered to have greater value as a recreational species than the CFR's native fish. This perception persists and the management of these alien angling species are often fraught with conflict (Ellender et al. 2014).

Black bass are aggressive predators (MacRae and Jackson, 2001) and their introduction has had substantial negative impacts (Ellender and Weyl, 2014). Although limited quantitative data exists for native fish distributions before the introduction of alien species, comparisons of invaded and non-invaded waters have shown that black bass often reduce the amount of habitat available for native fish as they prey upon them to the point of causing local extirpation (Ellender and Weyl, 2014). At the same time, habitat transformation in the form of river impoundments are known to facilitate invasions (Johnson et al. 2008). This is in stark contrast with the benefits derived from the recreational fisheries that developed around black bass in South Africa, mostly in large impoundments or rivers. A non-peer reviewed estimate in 2007 of the amount of money bass angling contributed to the national economy annually was R 1.2 billion (Leibold and Van Zyl, 2008). The economic impacts for recreational fisheries in South Africa are poorly documented (McCafferty et al. 2012), whilst documentation of economic benefits derived from recreational fisheries for alien species in the CFR is non-existent. In this thesis the impacts of smallmouth bass are documented. However, at times the implications for the genus are discussed. In this thesis black bass is used to refer to the *Micropterus* genus collectively.

1.7 Environmental legislation relevant to black bass

The movement of invasive alien species is currently governed by both national and provincial legislation. Although initial provincial legislature supported the introduction of alien fishes to the CFR through Act 10/1867, the current Western Cape Nature Conservation Laws Amendment Act 3 of 2000 requires permits for the import, sale and stocking of all freshwater fish species, including invasive alien species. At national level, these species are currently controlled by categorization under the National Environment Management: Biodiversity Act (NEM: BA) alien and invasive species regulations (Government Gazette, 2014). These categories restrict the translocation and introduction of these species into novel ecosystems. Translocation of category 1a or 1b species are prohibited; category 2 species may be translocated if a permit is acquired. Certain species have different categorizations for different geographic locations. Black bass, for example, are category 1b species in protected areas but category 2 outside of protected areas (See Table 1.2). This enables the species to be managed according to the management objectives for each water body.

Table 1.2: Current activities restricted and permitted for black bass in South Africa (after Government Gazette, 2014)

Restricted activities:	In reserves, catchments protected areas, rivers, wetland, natural lakes and estuaries	In dams within discrete catchments where they already occur
a. Importing into the Republic, including introducing from the sea	Prohibited	Permit required
b. Having in possession or exercising physical control over	Exempted	Permit required
c. Growing, breeding or in any other way propagating, or causing it to multiply.	Prohibited	Permit required
d. Conveying, moving or otherwise translocating any specimen of a listed invasive species.	Prohibited	Permit required
e. Selling or otherwise trading in, buying, receiving, giving, donating or accepting as a gift, or in any way acquiring or disposing of.	Prohibited	Permit required
f. Spreading or allowing the spread of	Prohibited	Permit required
g. Releasing any specimen	Prohibited	Permit required
h. The transfer or from one discrete catchment system in which it occurs, to another discrete catchment system in which it does not occur; or, from within a part of a discrete catchment system where it does occur to another part where it does not occur as a result of a natural or artificial barrier.	Prohibited	Permit required
i. Discharging of or disposing into any waterway or the ocean, water from an aquarium, tank or other receptacle that has been used to keep a specimen	Prohibited	Permit required
j. The introduction to offshore islands.	Prohibited	Permit required
k. The release into a discrete catchment system in which it already occurs.	Prohibited	Need a provincial permit

1.8 The Rondegat River and Clanwilliam Dam: a case study for assessing the impacts of smallmouth bass in the CFR

In order to identify mitigation measures for some of the negative ecological impacts of invasive alien fish in the CFR, a series of workshops were hosted by the South African Institute for Aquatic Biodiversity (SAIAB) in Grahamstown (Weyl et al. 2014). These workshops identified four rivers of high conservation priority and where eradication of invasive fish was considered feasible (Marr et al. 2012). An environmental impact assessment conducted following the workshops deemed the eradication of alien fish necessary and supported the use of piscicides for this purpose (Enviro-Fish Africa, 2009).

Figure 1.3: Smallmouth bass have invaded both **A**. the Rondegat River and **B**. the Clanwilliam Dam in the Western Cape Province, South Africa.

Following the impact assessment, the Rondegat River (Figure 1.3) was selected as the first of the four rivers on which to carry out initial pilot eradication efforts. Five kilometres of the river was invaded by smallmouth bass (Figure 1.4) up to a waterfall which prevented smallmouth bass from moving upstream. The negative ecological impacts of the invasion are well documented and show the local extirpation of three native species (Figure 1.4) from the invaded reach and that this has had impacts upon lower trophic levels (Woodford et al. 2005; Lowe et al. 2008). The geography of the Rondegat River makes it a good case study of invasive alien species management as it flows 20km down from its source in the Cederberg Wilderness Area into Clanwilliam Dam, one of South Africa's premier smallmouth bass angling destinations.

Figure1.4: Fish of the Rondegat River, Western Cape, South Africa. **A**. Clanwilliam yellowfish *Labeobarbus capensis* (Smith) and a school of Clanwilliam redfin *Barbus calidus* (Barnard). **B**. A school of fiery redfin *Pseudobarbus phlegethon* (Barnard). **C**. Invasive alien smallmouth bass, the target of rotenone treatments. (Photos courtesy of O. Weyl)

Clanwilliam Dam (Figure 1.3) was built in 1935, but the dam wall was only raised to its current height in 1964. The dam has a capacity of 121.8 million m^3 and its water is mainly used for irrigation purposes (Holtzhausen, 2006). The town of Clanwilliam is on the shores of the dam, with the main access to the water being from the municipal campsite on the outskirts of the town. Apart from being a popular water sports destination, the dam also hosts numerous angling competitions that target smallmouth bass. The anglers who travel from outside the region to take part in these competitions spend money at local businesses, such as fuel stations, and this provides an economic benefit to the town of Clanwilliam.

1.9 Study aims and objectives

The aim of the present study was to investigate the impacts of smallmouth bass as an example of a conflict species in the CFR. The study used the Rondegat River and the Clanwilliam Dam as case studies to document the contrasting positive and negative impacts of smallmouth bass at a regional scale.

The objectives of the study were as follows:

- To determine whether interventions by CapeNature were successful as eradicating smallmouth bass from the Rondegat River
- To document response of native fish populations in the Rondegat River following the eradication of this species using the piscicide rotenone.
- To conduct a cost analysis of the eradication exercise in order to provide decision support to future conservation interventions relating to alien fish management.
- To document the expenditure of recreational anglers who travel to and from the Clanwilliam Dam to fish for smallmouth bass, specifically focusing on angler expenditure within the town of Clanwilliam.
- To use the recovery of the native fish community following smallmouth bass removal and angler expenditure within Clanwilliam town to infer the nature and magnitude of the negative ecological- and positive socio-economic impacts of the introduction of smallmouth bass associated with this locality.

Thesis structure

In order to achieve these objectives this thesis consists of the following chapters:

- **Chapter 1**: an introduction to the issues which are raised in this thesis in order to place the work in its context and to raise the important topics which are later discussed.

- **Chapter 2**: documents the recovery of fish communities of the Rondegat River following two annual treatments with rotenone. This chapter shows how the native species occurring in the Rondegat River have responded to smallmouth bass removal.
- **Chapter 3**: a study of the smallmouth bass anglers using the Clanwilliam Dam recreational fishery. The chapter documents expenditure within Clanwilliam town which is a direct consequence of having the smallmouth bass recreational fishery in Clanwilliam Dam.
- **Chapter 4**: briefly summarizes the costs of the Rondegat River smallmouth bass removal efforts during the financial years of the treatments. This cost is taken as a negative economic impact of the species.
- **Chapter 5**: a final discussion and conclusion of the issues which are dealt with in this thesis and the implications of its findings.

1.10 References

Baltz DM, Moyle PB (1993) Invasion resistance to introduced species by a native assemblage of California stream fishes. Ecological Applications. 3: 246–255.

Blackburn TM, Pyšek P, Bacher S, Carlton JT, Duncan RP, Jarošík V, Wilson JRU, Richardson DM (2011) A proposed unified framework for biological invasions. Trends in Ecology and Evolution. 26: 333–339.

Britton JR, Brazier M (2006) Eradicating the invasive topmouth gudgeon, *Pseudorasbora parva*, from a recreational fishery in Northern England. Fisheries Management and Ecology. 13: 329-335.

Caffrey JM, Baars JR, Barbour JH, Boets P, Boon P, Davenport K, Dick JTA, Early J, Edsman L. Gallagher C, Gross J, Heinimaa P, Horril C, Hudin S, Hulme PE, Hynes S, MacIsaac HJ, Mcloone P, Millane M, Moen TL, Moore N, Newman J, O'Conchuir R, O'Farrell M, O'Flynn C, Oidtmann B, Renals T, Ricciardi A, Roy H, Shaw R, van Valkenburg JLCH, Weyl OLF, Williams F, Lucy FR (2014) Tackling invasive alien species in Europe : the top 20 issues. Management of Biological Invasions. 5: 1–20.

Chakona A, Swartz ER (2013) A new redfin species, *Pseudobarbus skeltoni* (Cyprinidae, Teleostei), from the Cape Floristic Region, South Africa. Zootaxa. 3686: 565-577.

Clavero M, García-Berthou E (2005) Invasive species are a leading cause of animal extinctions. Trends in Ecology and Evolution. 20: 110.

Coke M (1988) Freshwater fish conservation in South Africa: A rising tide. Journal of the Limnological Society of Southern Africa. 14: 29-34.

Costello MJ, May RM, Stork NE (2013) Can we name Earth's species before they go extinct? Science. 339:413–416

Cowling, R, Pressey RL, Rouget M, Lombard AT (2003) A conservation plan for a global biodiversity hotspot—the Cape Floristic Region, South Africa. Biological Conservation. 112: 191–216.

Cowx IG, Portocarrero Aya M (2011) Paradigm shifts in fish conservation: moving to the ecosystem services concept. Journal of Fish Biology. 79: 1663 1680.

De Wit M.P, Crookes DJ, van Wilgen BW (2001) Conflicts of interest in environmental management : estimating the costs and benefits of a tree invasion. Biological Invasions. 3: 167–178.

Dick JTA, Gallagher K, Avlijas S, Clarke HC, Lewis SE, Leung S, Minchin D, Caffrey J, Alexander ME, Maguire C, Harrod C, Reid N, Haddaway NR, Farnsworth KD, Penk M, Ricciardi A (2013) Ecological impacts of an invasive predator explained and predicted by comparative functional responses. Biological Invasions.15: 837–846.

Dick JTA, Alexander ME, Jeschke JM, Ricciardi A, MacIsaac HJ, Robinson TB, Kumschick S, Weyl OLF, Dunn A, Hatcher MJ, Paterson RA, Farnsworth KD, Richardson DM (2014) Advancing impact prediction and hypothesis testing in invasion ecology using a comparative functional response approach. Biological Invasions. 16: 735–753.

Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Lévêque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ, Sullivan CA (2006) Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews of the Cambridge Philosophical Society. 81: 163–182.

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

Ellender BR, Woodford DJ, Weyl OLF, Cowx IG (2014) Managing conflicts arising from fisheries enhancements based on non-native fishes in southern Africa. Journal of Fish Biology. In press.

Enviro-Fish Africa (2009) Environmental impact assessment of the proposed eradication of invasive alien fishes from four river sections in the Cape Floristic Region. Enviro-Fish Africa (Pty) LTD, Grahamstown.

Esler KJ, van Wilgen BW, te Roller RS, Wood AR, van der Merwe JH (2010) A landscape-scale assessment of the long-term integrated control of an invasive shrub in South Africa. Biological Invasions 12: 211–218.

Estévez RA, Anderson CB, Pizarro JC, Burgman MA (2014) Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. Conservation Biology. Early online: DOI: 10.1111/cobi.12359.

Finlayson B, Somer W, Duffield D, Propst D, Mellison C, Pettengill T, Sexauer H, Nesler T, Gurtin S, Elliot J, Partridge F, Skaar D (2005) Native inland trout restoration on national forests in the Western United States. Fisheries. 30: 10-19.

Gozlan RE (2008) Introduction of non-native freshwater fish: is it all bad? Fish and Fisheries Management. 10: 109-110.

Government Gazette (2014) National Environmental Management: Biodiversity Act (10/2004): Alien and Invasive Species Lists. Pretoria.

Havel JE, Lee CE, vander Zanden MJ (2005) Do reservoirs facilitate invasions into landscapes? BioScience. 55: 518–525.

Headrick DH, Goeden RD (1993) Biological control as a tool for ecosystem management. Biological Control. 21: 249–257.

Holtzhausen L (2006) Dam project could improve aquatic environment. The Water Wheel. 5: 14-16.

IUCN (2014) The IUCN Red List of Threatened Species. Version 2014.2. http://www.iucnredlist.org. Downloaded on 8 August 2014.

Jeschke JM, Bacher S, Blackburn TM, Dick JTA, Essl F, Evans T, Gaertner M, Hulme PE, Kühn I, Mrugała A, Pergl J, Pyšek P, Rabitsch W, Ricciardi A, Richardson DM, Sendek A, Vilà M, Winter M, Kumschick S (2014) Defining the impact of non-native species. Conservation Biology. 28: 1188–1194.

Jeschke JM, Keesing F, Ostfeld RS (2013) Novel organisms: comparing invasive species, GMOs, and emerging pathogens. Ambio. 42: 541–548.

Johnson PT, Olden JD, vander Zanden MJ (2008) Dam invaders: impoundments facilitate biological invasions into freshwaters. Frontiers in Ecology and the Environment. 6: 357–363.

Leibold ML, van Zyl CJ (2008) The economic impact of sport and recreational angling in the Republic of South Africa, 2007. Unpublished report. Development Strategies International (Pty) LTD, Cape Town.

Leigh P (1998) Benefits and costs of the Ruffe control program for the Great Lakes fishery. Journal of Great Lakes Research. 24: 351-360.

Linder PH, Johnson SD, Kuhlmann M, Matthee CA, Nyffeler R, Swartz ER (2010) Biotic diversity in the Southern African winter-rainfall region. Current Opinion in Environmental Sustainability. 2: 109-116.

Lintermans M (2000) Recolonization by the mountain galaxias *Galaxias olidus* of a montane stream after the eradication of rainbow trout *Oncorhynchus mykiss*. Marine and Freshwater Research. 51: 799-804

Lovell SJ, Stone SF, Fernandez L (2006) The economic impacts of aquatic invasive species: a review of the literature. Agricultural and Resource Economics Review. 35: 195–208.

Lowe SR, Woodford DJ, Impson DN, Day JA (2008) The impact of invasive fish and invasive riparian vegetation on the invertebrate fauna of the Rondegat River, Cape Florisitic Region, South Africa. African Journal of Aquatic Science. 33: 51-62.

Lupi F, Hoehn JP, Christie GC (2003) Using an economic model of recreational fishing to evaluate the benefits of Sea Lamprey (*Petromyzon marinus*) control on the St. Mary’s River. Journal of Great Lakes Research. 29: 742–754.

MacRae PSD, Jackson DA (2001) The influence of smallmouth bass (*Micropterus dolomieu*) and habitat complexity on the structure of littoral zone fish assemblages. Canadian Journal of Fisheries and Aquatic Science. 58: 342-351.

Marr SM, Marchetti MP, Olden JD, García-Berthou E, Morgan DL, Arismendi I, Day JA, Griffiths CL, Skelton PH (2010) Freshwater fish introduction in Mediterranean-climate regions: are there commonalities in the conservation problem. Diversity and Distributions. 16: 606-619.

Marr SM, Impson ND, Tweddle D (2012) An assessment of a proposal to eradicate non-native fish from priority rivers in the Cape Floristic Region, South Africa. African Journal of Aquatic Science. 37: 37–41.

Mccafferty JR, Ellender BR, Weyl OLF, Britz PJ (2012) The use of water resources for inland fisheries in South Africa. Water SA. 38: 327-344.

Mittermeier RA, Turner WR, Larsen FW, Brooks TM, Gascon C (2011) Global biodiversity conservation: the critical role of hotspots. In Zachos FE, Habel JC (Eds.). Biodiversity Hotspots: Distribution and Protection of Conservation Priority Areas. Springer, Heidelberg.

Myers N, Mittermeier RA, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature. 403: 853–858.

Odom DIS, Cacho OJ, Sinden JA, Griffith GR (2003) Policies for the management of weeds in natural ecosystems: the case of scotch broom (*Cytisus scoparius*, L.) in an Australian national park. Ecological Economics. 44: 119–135.

Parker IM, Simberloff D, Lonsdale WM, Goodell K, Wonham M, Kareiva PM, Williamson MH, Von Holle B, Moyle PB, Byers JE, Goldwasser L (1999) Impact : toward a framework for understanding the ecological effects of invaders. Biological Invasions. 1: 3–19.

Pascuel MA, Lancelotti JL, Ernst B, Ciancio JE, Aedo E, García-Asorey M (2009) Scale connectivity, and incentives in the introduction and management of non-native species: the case of exotic salmonids in Patagonia. Frontiers in Ecology and the Environment. 7: 533-540.

Pham L, West D, Closs GP (2013) Reintroduction of a native galaxiid (*Galaxias faciatus*) following piscicide treatment in two streams: response and recovery of the fish population. Ecology of Freshwater Fish. 22: 361-373.

Pimentel D, Lach L, Zuniga R, Morrison D (2000) Environmental and economic costs of nonindigenous species in the United States. BioScience. 50: 53–65.

Pyšek P, Richardson DM (2010) Invasive species, environmental change and management, and health. Annual Review of Environment and Resources. 35: 25–55.

Raimondo D, von Staden L (2009) Patterns and trends in the Red List of South African plants. In Raimondo D, von Staden L, Foden W, Victor JE, Helme NA, Turner RC, Kamundi DA, Manyama PA (eds). Red List of South African plants - Strelitzia 25. South African National Biodiversity Institute, Pretoria.

Ricciardi A, Rasmussen JB (1998) Predicting the identity and impact of future biological invaders : A priority for aquatic resource management. Canadian Journal of Fisheries and Aquatic Sciences. 55: 1759–1756.

Ricciardi A, Rasmussen JB (1999) Extinction rates of North American freshwater fauna. Conservation Biology. 13: 1220–1222.

Ricciardi A, Cohen J (2006) The invasiveness of an introduced species does not predict its impact. Biological Invasions. 9: 309–315.

Ricciardi A (2007) Are modern biological invasions an unprecedented form of global change? Conservation Biology. 21: 329–336.

Ricciardi A, Hoopes MF, Marchetti MP, Lockwood JL (2013) Progress toward understanding the ecological impacts of nonnative species. Ecological Monographs. 83: 263–282.

Richardson DM, van Wilgen BW (2004) Invasive alien plants in South Africa : how well do we understand the ecological impacts ? South African Journal of Science. 100: 45–52.

Rouget M, Richardson DM, Cowling RM, Lloyd JW, Lombard AT (2003) Current patterns of habitat transformation and future threats to biodiversity in terrestrial ecosystems of the Cape Floristic Region, South Africa. Biological Conservation. 112: 63–85.

Schlaepfer MA, Sax DV, Olden JD (2011) The potential conservation value of non-native species. Conservation Biology. 25: 328-437.

Secretariat of the Convention on Biological Diversity (2010) Global Biodiversity Outlook 3. Montréal.

Sharov AA, Liebhold AM (1998) Bioeconomics of managing the spread of exotic pest species with barrier zones. Ecological Applications. 8: 833–845.

Tweddle D, Bills R, Swartz E, Coetzer W, Da Costa L, Engelbrecht J, Cambray J, Marshall B, Impson D, Skelton P, Darwall WRT, Smith KG (2009) The status and distribution of freshwater fishes. In Darwall WRT, Smith KG, Tweddle D, Skelton P (Eds.). The status and distribution of freshwater biodiversity in southern Africa. Internation Union for Conservation of Nature, Gland, Switzerland and South African Institute for Aquatic Biodiversity, Grahamstown, South Africa.

Van Wilgen BW, Richardson DM, Le Maitre DC, Marais C, Magadlela D (2001) The economic consequences of alien plant invasions: examples of impacts and approaches to sustainable management in South Africa. Environment, Development and Sustainability. 3: 145–168.

Van Wilgen BW, Forsyth GG, Le Maitre DC, Wannenburgh A, Kotzé JDF, van den Berg E, Henderson L (2012) An assessment of the effectiveness of a large, national-scale invasive alien plant control strategy in South Africa. Biological Conservation. 148: 28–38.

Van Wilgen BW, Richardson DM (2014) Challenges and trade-offs in the management of invasive alien trees. Biological Invasions. 16: 721-734.

Weyl OLF, Finlayson BJ, Impson ND, Woodford DJ, Steinkjer J (2014) Threatened endemic fishes in South Africa’s Cape Floristic Region: A new beginning for the Rondegat River. Fisheries. 39: 270-279.

Witte F, Goldschmidt T, Wanink J, Vanoijen M, Goudswaard K, Wittemaas E, Bouton N (1992) The destruction of an endemic species flock – quantitative data on the decline of the haplochromine cichlids of Lake Victoria. Environmental Biology of Fishes. 34: 1-28.

Woodford DJ, Impson ND, Day JA, Bills IR (2005) The predatory impact of invasive alien smallmouth bass, *Micropterus dolomieu* (Teleostei: Centrarchidae), on indigenous fishes in a Cape Floristic Kingdom mountain stream. African Journal of Aquatic Science. 30: 167-173.

CHAPTER 2: RESPONSE OF NATIVE FISH COMMUNITIES TO SMALLMOUTH BASS REMOVAL IN THE RONDEGAT RIVER

2.1 Introduction

The Cape Floristic Region (CFR) is a global biodiversity hotspot which is renowned for its floral diversity (Cowling et al. 2003; Linder et al. 2010). The area is also unique from an aquatic perspective as it is one of the six aquatic ecoregions of southern Africa (Skelton, 2001). With only 24 indigenous species, the freshwater fish fauna of the CFR does not mirror the high levels of species richness of its plants. These 24 species belong to the families Cyprinidae (16), Anabantidae (1), Galaxidae (1), Anguillidae (3) and Austroglanididae (2) (Weyl et al. 2014) (Table 2.1). This fauna is however unique and 17 species are endemic to the region (Weyl et al. 2014). These high levels of endemism are attributed to geographic isolation brought about by the deeply incised character of the CFR drainage basins (Linder et al. 2010) and genetic variations within fish populations has been used to better understand the drainage history of the CFR's rivers (Swartz et al. 2009). Ten of the 24 species indigenous to the CFR occur in the Olifants-Doring river system (Weyl et al. 2014). Eight of these species are endemic to the system.

Ten of the CFR's endemic fish species have been classified as endangered and three as vulnerable using the International Union for the Conservation of Nature (IUCN) Red-List criteria (Tweddle et al. 2009). The major threats to the CFR's native fish are the presence of predatory alien fish, habitat destruction, pollution (Tweddle et al. 2009). In most cases indigenous fish are exposed to a combination of these threats resulting in many threatened species being restricted to short reaches of rivers or mountain tributaries (Marr et al. 2009). It is widely agreed that the most severe and extensive threat to the CFR's indigenous ichthyofauna is that of alien fish (Tweddle et al. 2009).

Table 2.1: Native freshwater fishes of the Cape Floristic Region, Western Cape, South Africa, their maximum length, IUCN Red list status[a] , and main threat (From Weyl et al. 2014)

Species	Maximum length (cm SL)	IUCN status	Main threat
	Anguillidae		
African mottled Eel (*Anguilla bengalenis labiate*)	145	LC	0
Shortfin Eel (*Anguilla bicolor bicolor*)	80	LC	0
Marbled Eel (*Anguilla marmorata*)	185	LC	0
Longfin Eel (*Anguilla mossambica*)	120	LC	0
	Austroglaniidae		
Barnard's Rock Catfish (*Austroglanis barnardi*) [b]	8	EN	1, 2
Barnard's Rock Catfish (*Austroglanis barnardi*) [b]	13	VU	1, 2
	Cyprinidae		
Berg-Breede River Whitefish (*Barbus andrewi*)[b]	60	EN	1, 2, 4, 5
Chubbyhead barb (*Barbus anoplus*) [b]	12	LC	0
Clanwilliam redfin (*Barbus calidus*) [b]	8	VU	1, 2
Twee River Redfin (*Barbus erubescens*) [b]	10	CR	1, 2, 3
Goldie Barb (*Barbus pallidus*)	7	LC	0
Sawfin (*Barbus serra*) [b]	50	EN	1, 2, 4
Clanwilliam Sandfish (*Labeo seeberi*) [b]	36	EN	1, 2
Moggel (*Labeo umbratus*)	50	LC	5
Clanwilliam Yellowfish (*Labeobarbus capensis*) [b]	100	VU	1, 2, 4
Eastern Cape Redfin (*Pseudobarbus afer*) [b]	11	EN	1
Smallscale Redfin (*Pseudobarbus asper*) [b]	8	EN	1, 2
Burchell's Redfin (*Pseudobarbus burchelli*) [b]	14	CR	1, 2, 3
Berg River Redfin (*Pseudobarbus burgi*) [b]	12	EN	1, 2, 5
Fiery Redfin (*Pseudobarbus phlegethon*) [b]	7	EN	1, 2
Giant Redfin (*Pseudobarbus skeltoni*) [b, c]	17	NA	1, 2
Slender Redfin (*Pseudobarbus tenuis*)[b]	8	NT	1, 2
	Galaxiidae		
Cape Galaxias (*Galaxias zebratus*)[b]	8	DD	1, 2, 5
	Anabantidae		
Cape Kurper (*Sandelia capensis*) [b]	20	DD	1, 2, 5

[a] SL = standard length, LC = least concern, EN = endangered, VU = vulnerable, CR = critically endangered, NA = not assessed, NT = near threatened, DD = data deficient. Main threats (0 = no dominant threat identified; 1 = alien fish; 2 = habitat destruction; 3 = pollution; 4 = utilization; 5 = genetic integrity) in the Cape Floristic Region South Africa (after Skelton 2001; Tweddle et al. 2009).

[b] Endemic

[c] The recently described Giant Redfin has not been formally assessed but is considered endangered (Chakona and Swartz 2013).

Alien fish introductions to the CFR were initially driven by a perception that native fish offered no service or value to man and this was supported by government in Act 10/1867 (Coke, 1988). Brown trout *Salmo trutta* (Linnaeus) and rainbow trout *Oncorhynchus mykiss* (Walbaum) were introduced at the end of the 19th century and black bass between 1928 and 1940 (De Moor and Bruton, 1988). The effects of these species had gone unnoticed until Barnard (1943) produced the first call for surveys of native fish in the CFR in order to discuss 'possible changes in the river systems'. The negative impacts of alien fish in South Africa include hybridisation, competition, predation and the introduction of associated parasites and diseases (Ellender and Weyl, 2014).

Predation by black bass is particularly severe but the sub-lethal impacts (e.g. impacts upon behaviour or population structure of native fishes) of this species are poorly documented because in most cases black bass cause local extirpation of the resident fish species (Ellender and Weyl, 2014). Cape galaxias *Galaxias zebratus* (Castelnau) have been observed to occupy deep complex habitats when co-occurring with largemouth bass *Micropterus salmoides* (Lacepède) and this is believed to be predator avoidance behaviour (Shelton et al. 2008). In most cases however, there is no co-existence observed between native fish and black bass (Woodford et al. 2005; Traas, 2009; Ellender et al. 2011). The impacts of black bass can also manifest on different trophic levels, as was illustrated by Lowe et al. (2008). These authors found that black bass do not directly affect invertebrate assemblages, but impact them by feeding on the native insectivorous fishes. Following the introduction of black bass species into the Olifants system in 1943 (Harrison, 1953), native fish have been restricted to headwater streams, upstream of natural barriers to black bass invasion. An example of this would be the Rondegat River (Figure 2.1) which was the recent focus of an alien rehabilitation project implemented by CapeNature, the provincial conservation agency of the Western Cape Province.

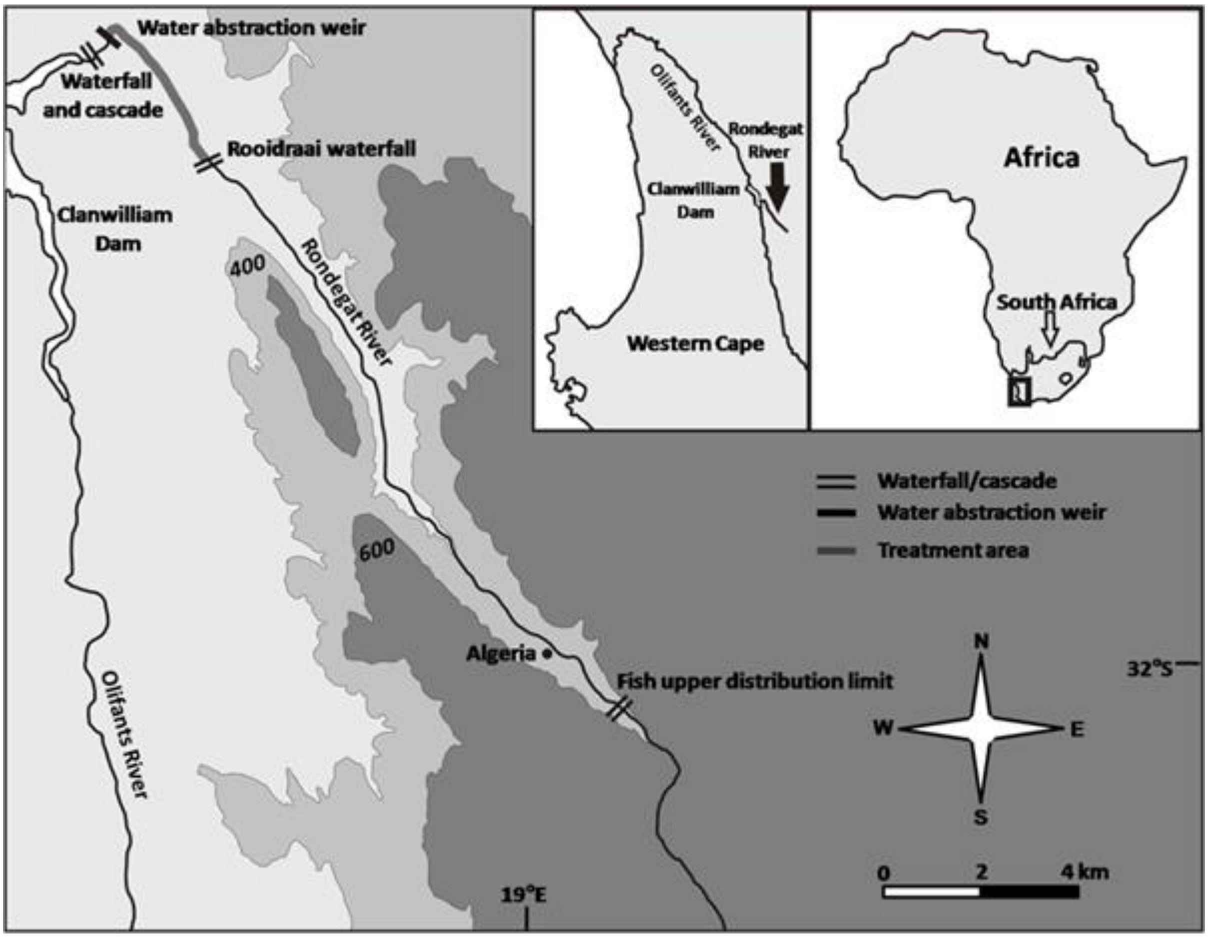

Figure 2.1: The Rondegat River, Western Cape South Africa showing the reach where treatment occurred as well the reaches up- and downstream of the barriers to invasion.

2.1.1. Intervention on the Rondegat

The displacement of native fish communities by alien fish species, as is observed in the Rondegat River, highlighted the need for the control of these species in priority conservation areas. In order to develop criteria for evaluating rivers for alien fish control, a series of workshops were held in 2003 and 2004 at the South African Institute for Aquatic Biodiversity (SAIAB) in Grahamstown. Following these meetings, four rivers were shortlisted as those where eradication of alien species was deemed to be feasible (Marr et al. 2012). It was decided that the application of rotenone would be most effective in removing alien fish from these rivers. Following an environmental impact assessment (EIA) the Rondegat River was recommended as the first of the four rivers on which to initiate a pilot project using rotenone to eradicate the smallmouth bass population and an adjusted in-stream weir (Figure 2.2) as a physical barrier to smallmouth bass reinvasion (Enviro-fish Africa, 2009).

Rotenone is a chemical derived from the roots of several legumes (Brooks and Price; 1961). The compound inhibits oxidative phosphorylation in mitochondria preventing the formation of adenosine triphosphate and causes death via tissue anoxia (Ling; 2003). At concentrations lower than 0.25mg/l rotenone is effective at killing most fish species whilst remaining non-toxic to plants, birds and mammals. The compound degrades readily in aquatic environments and is a useful tool in eradicating an unwanted fish species (Ling, 2003; Mcclay; 2005). Other gilled organisms such as macroinvertebrates and larval amphibians are sensitive to rotenone and so the use of rotenone in eradicating fish populations requires careful determination of a lowest effective dose for the target species (Jordaan and Weyl, 2013). Rotenone has been used successfully to manage fish populations in many areas of the world. It has been used for eradication of alien species in Europe, Australia, New Zealand and the United States of America (Lintermans, 2000; Mcclay 2005; Briton and Brazier, 2006; Pham et al. 2013). The Rondegat River was treated with rotenone in February 2012 and March 2013.

The treatment of the Rondegat River was conducted according to the Standard Operating Procedures (SOPs) of the American Fisheries Society (Finlayson et al. 2010) and a site specific pesticide application plan (Impson and van der Walt, 2013). The piscicide CFT Legumine®, containing 5% rotenone as active ingredient was used to treat the river in 2012 and 2013 at treatment concentrations of 50µg/l and 37.5µg/l respectively (Jordaan and Weyl, 2013; Slabbert et al. 2014). The treated reach consisted of a 4km section of the lower Rondegat River between a waterfall barrier and a neutralization point close to Clanwilliam Dam, henceforth referred to as the treatment reach. The neutralization point was necessary in order to prevent active rotenone entering the Clanwilliam Dam. Neutralization was achieved by applying potassium permanganate to the water from a drip container. The effective concentration of rotenone for smallmouth bass was determined before the first treatment and the flow of the river was measured prior to both treatments. Using these two measurements, rotenone was diluted to the required treatment concentration in 5 gallon drip containers. During the first treatment there were seven treatment stations from which rotenone was applied from the drip containers while the second treatment only had four, as recommended by international rotenone experts (Dr B. Finlayson and Dr J. Steinkjer) that supervised the first treatment. The drip rate was set to maintain the selected treatment concentration for a six-hour treatment period. At the end of every treatment zone, a smallmouth bass individual was kept in a keep net as an indicator that the rotenone concentration in that section of river had reached lethal concentrations.

At the end of the treatment reach (just below the barrier weir), potassium permanganate was applied to the river from a drip can to neutralize the rotenone flowing downstream towards Clanwilliam Dam. Wetlands, irrigation ditches and any other water along the Rondegat River not part of the main flow of the river was treated by four backpack sprayers. A block net was placed across the river immediately upstream of the second, third, fourth drip station and the neutralization station. These nets caught any dead fish drifting downstream. During the treatment each kilometre was patrolled by volunteers and all the dead fish were collected for monitoring purposes. At a large pool between the first and second treatment stations a portable pool was set up and filled with clean water. Any native fish observed to be affected by the rotenone in the river close to the portable pool were placed in the tank to recover (Impson and van der Walt, 2013). It was within the context of this intervention by CapeNature that this study was carried out.

The objectives of the intervention by CapeNature on the Rondegat River were to successfully eradicate smallmouth bass from between the Rooidraai waterfall and the abstraction weir (the treatment reach) and prevent re-invasion by raising and widening the abstraction weir to act as a fish barrier. By achieving eradication, CapeNature was aiming to facilitate the recovery of native fishes within the treatment reach (Enviro-Fish Africa, 2009; Woodford et al. 2012).

The aim of this chapter was to assess the whether the intervention by CapeNature was effective. Therefore, the first objective of this study were to determine whether smallmouth bass were successfully eradicated from the 4km of river between the Rooidraai waterfall and the in-stream weir. The second objective was to determine whether the native fish community recovered in the treatment reach following the eradication smallmouth bass.

Figure 2.2: Two physical barriers to smallmouth bass invasion on the Rondegat River, Western Cape, South Africa. **A:** the Rooidraai waterfall in February 2013. **B:** the raised in-stream weir in September 2013.

2.2 Materials and Methods

2.2.1 Study area

The Rondegat River originates in the Cedarberg mountains and flows into Clanwilliam Dam 20km downstream from its source (Figure 2.1). Fifteen kilometres from the source is the Rooidraai waterfall (Figure 2.2) and four kilometres downstream of the waterfall is an in-stream weir (Figure 2.2). The native fish community of the river is made up of five species, namely Clanwilliam yellowfish *Labeobarbus capensis* (Smith), Clanwilliam redfin *Barbus calidus* (Barnard), fiery redfin *Pseudobarbus phlegethon* (Barnard), Clanwilliam rock catfish *Austroglanis gilli* (Barnard) and Cape galaxias. Clanwilliam sawfin *Barbus serra* (Peters) and Clanwilliam sandfish *Labeo seeberi* (Gilchrist and Thompson) were found in the lower reaches (Van Rensburg, 1966). However, the exact locality of these records is unknown and these species have not been detected in the river since. It is thought that smallmouth bass invaded the river in the 1950’s (Harrison, 1963). Although the abstraction weir on the Rondegat acted as a barrier to invasion by alien fish such as bluegill sunfish *Lepomis macrochirus* (Rafinesque), smallmouth bass invaded the river up to the Rooidraai waterfall which is situated 5km upstream of Clanwilliam Dam (Bills, 1999). With the exception of large Clanwilliam yellowfish (fork length greater than 10cm), none of the native fish species were observed to co-occur with smallmouth bass, below the Rooidraai waterfall (Woodford et al. 2005; Lowe et al. 2008; Weyl et al. 2013).

Monitoring was carried out at 42 sites sampled by Woodford et al. (2012) (See Appendix 1). Fourteen of these sites (29-42) were located above the natural barrier to invasion in the river, the Rooidraai waterfall, and thus have a fish community that has not been influenced by invasive fish species. This reach of the river is henceforth referred to as the control reach and sites within the control reach are referred to as control sites. Twenty sites were within the treatment reach and these are henceforth referred to as treatment sites. Eight sites were below the in-stream weir and downstream of the treatment reach. This reach of river is henceforth referred to as the invaded reach and sites within the invaded reach are referred to as invaded sites (Figure 2.3 and Appendix 1).

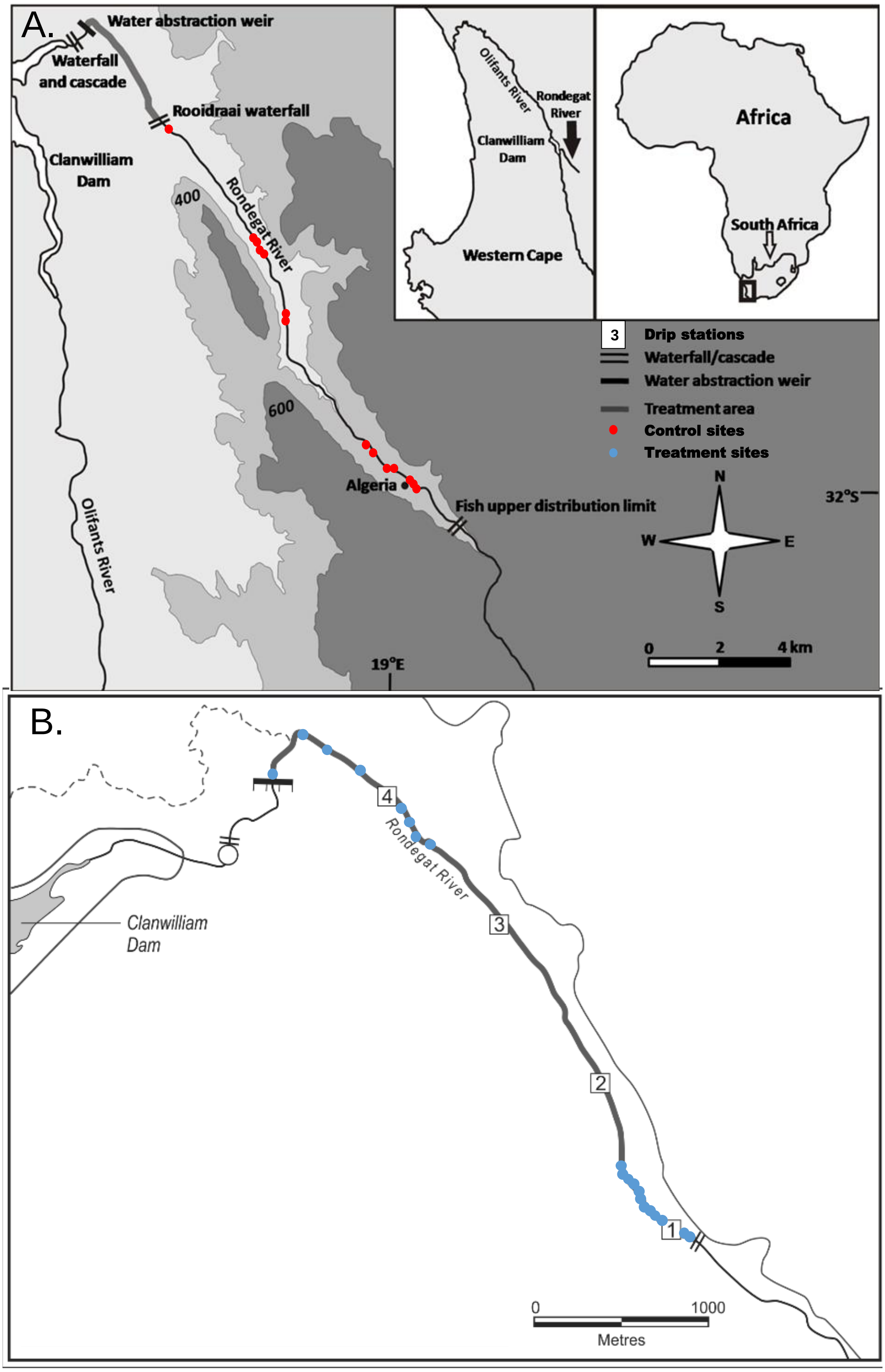

Figure 2.3: The Rondegat River, Western Cape, South Africa, showing the monitoring sites within the and control (A) and treatment (B) reaches, as well as the positions of the drip stations from which rotenone was applied to the river by CapeNature in 2013.

2.2.2 Sampling intervals

Regular river surveys were conducted since 2011. Data from surveys up to February 2012, documenting short term impact of the first rotenone treatment, have been published (Weyl et al. 2013). However, this study includes new data from October 2012 to March 2014 and documents the recovery and present state of the Rondegat River after the final treatment. Sampling trips were made to the river in October 2012, February 2013, two in March 2013 (directly before and directly after the second treatment), October 2013 and March 2014. During the February 2013 and March 2014 trips all 42 sites were monitored, whereas only the treatment and invaded sites were monitored during remaining five trips (Table 2.2).

2.2.3 Data collection

Habitat parameters

During the February 2013 and March 2014 surveys the river's temperature, conductivity and pH were measured using a Hanna HI98129 Combo pH and electrical conductivity meter and turbidity (NTU) was measured using a Hanna HI 98703 turbidimeter (HANNA Instruments Inc. Woonsocket, USA). The dimensions of each site were also measured. One length transect, three to ten width transects and three depth readings per width transect were recorded per site. These dimensions were used to estimate each site's surface area.

Fish density and abundance

Fish abundance at each site was estimated using two independent methods: underwater video analysis (UWVA) and snorkel surveys. These methods follow those described by Ellender et al. (2011) and Weyl et al. (2013). For comparative purposes, estimates of fish density and relative abundance from Weyl et al. (2013) for February 2012 before and after the first treatment were also included in the results of this study. The data were collected using the same methods as this study.

For snorkel surveys, each pool was snorkelled in two consecutive passes. On each pass, fish were counted and the abundance of fish at the site was recorded as the average of the two counts (Figure 2.4). The size of each fish was also estimated during snorkel surveys. The estimated surface area of each site and the number of fish observed per site during the snorkelling was used to estimate the fish density per species at each site.

Underwater filming was carried out using GoPro® HD Hero® cameras as described by Ellender et al. (2012) and Weyl et al. (2013) (Figure 2.4). Cameras were placed in each site and recorded footage for a minimum of 30 minutes. The underwater video footage was analysed as described by Ellender et al (2012). The highest number of fish of a given species observed at the same time (in the same frame) was determined for each 30 minute video. This number is the MaxN; an estimate of relative abundance of the given species at that site. This is done for every species observed at the site. One hundred and eighty videos were filmed from October 2012 till March 2014. A total of 97 hours and 48 minutes of recorded footage was watched. In order to enable accurate counting of the fish in the videos the footage was watched at varying playback speeds (from 20% to 100%).

Fish length

To determine the size distribution of fishes in the different sampled reaches, selected sites within the non-invaded, treatment and below treatment reach were sampled using seine nets (3 mm stretched mesh size), fyke nets and two pass electrofishing using a Samus© 725G backpack electrofisher connected to a 12V battery and the settings standardized at a duration of 0.3 ms and a frequency of 80 Hz. All fish that were caught were identified to species level, measured to the nearest 1 mm fork length (FL) and released at the site of collection (Figure 2.3).

Table 2.2: The two treatments and monitoring trips made to the Rondegat River, Western Cape, South Africa, as well as the sites monitored on those trips.

Date	Sites monitored/treated	Months before or after treatment	Monitoring methods
February 2011 (Weyl et al. 2013)	1-42	12 before	UWVA, snorkel transects, fyke netting, seine netting and electrofishing
February 2012 (Weyl et al. 2013)	1-42	0 before	UWVA, snorkel transects, fyke netting, seine netting and electrofishing
February 2012	9-28		First rotenone treatment
February 2012 (Weyl et al. 2013)	1-28	0 after	UWVA, snorkel transects, fyke netting, seine netting and electrofishing
October 2012	9-28	8 after	UWVA and snorkel transects
February 2013	1-42	12 after	UWVA, snorkel transects, fyke netting, seine netting and electrofishing
March 2013	1-28	13 after	UWVA and snorkel transects
March 2013	9-28		2nd rotenone treatment
March 2013	1-28	0	UWVA and snorkel transects
October 2013	1-28	7	UWVA and snorkel transects
March 2014	1-42	12	UWVA, snorkel transects, fyke netting, seine netting and electrofishing
October 2014	1-28	19	UWVA and snorkel transects

Figure 2.4: Different survey methods used in this study to monitor fish within the Rondegat River, Western Cape, South Africa. **A.** Snorkelling. **B.** Underwater video analysis using a GoPro® HD Hero® camera. **C.** Measuring the fork length of fish caught by electrofishing.

2.2.4 Data analysis

Monitoring took place within the control and treatment reaches before and after the intervention by CapeNature. Therefore, the analysis follows a Before-After-Control-Impact design.

The data were analysed using Microsoft Excel 2013 © and Statistica 12 ©. Tests were conducted at a significance level of $p<0.05$. Following rotenone treatments, fish density within the treatment reach was reduced to below detectable limits.

Fish density

A Wilcoxon matched pairs test was used to compare the density of fish within the treatment reach immediately before treatments, immediately after treatments and a year after treatments. As there were two annual treatments, there were two replicates of a year of recovery within the treatment reach. A Wilcoxon matched pairs test was also used to compare the density of fishes in the control reach before and after CapeNature intervention. Densities between the treatment reach and the control reach sites for Clanwilliam yellowfish, Clanwilliam redfin and fiery redfin were the only three species observed in the control and treatment reaches. The density of these species were compared between reaches using the non-parametric Mann-Whitney *U*-test.

Underwater Video Analysis

MaxN estimates of relative abundance within the treatment reach were compared using 2-tailed t tests. The relative abundance of fish within the treatment reach, before and after intervention were compared. The relative abundance of fish in the treatment reach in March 2014 was also compared with the relative abundance of fish in the control reach in 2014.

Fish length

Mean fork length of native fish species measured in March 2014 was compared between the treatment and the control reaches using a non-parametric Mann-Whitney *U*-test.

2.3 Results

2.3.1 Environment

The morphological and edaphic characteristics of the 42 sites monitored during the March 2014 survey are summarized in Table 2.3. Based on these, the Rondegat River is a small (average of five meters wide) and shallow (average of 0.33 m deep) acidic stream. The Rondegat has low turbidity making it suitable for visual monitoring methods and low conductivity typical of Cape streams. The control reach had lower turbidity and conductivity than the treatment reach.

Table 2.3: The morphological and edaphic characteristics of sites within the control and treatment reaches of the Rondegat River, Western Cape, South Africa, recorded in March 2014. SD = standard deviation

Character	Min.		Max.		Average		SD	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
Length (m)	5.10	7.20	30.00	49.00	15.86	14.25	7.38	8.80
Width (m)	1.70	1.70	7.90	14.52	4.53	5.15	1.33	2.18
Depth (m)	0	0	1.06	1.19	0.33	0.35	0.19	0.26
Surface area (m^2)	15.47	34.72	146.93	478.32	74.79	81.19	45.13	91.76
Volume (m^3)	4.92	3.27	78.94	271.05	25.95	34.01	21.29	56.76
pH	5.95	5.92	6.30	6.53	6.13	6.156	0.25	0.24
Temperature (ºC)	18.30	19.7	23.60	24.5	21.52	20.67	2.37	1.73
Turbidity (NTU)	0.65	1.32	1.85	3.27	1.17	2.46	0.43	0.59
Conductivity (µS/cm)	11.00	45	45	64	23.18	53.21	15.90	8.11

2.3.2 Fish densities

Before

In the treatment reach the snorkel survey estimates (mean ± SE) of smallmouth bass densities were 2.29 ± 0.56 fish/100m^2. Native fish density estimates in the treatment reach were 0.29 ± 6.52 fish/100m^2 prior to intervention (Table 2.4). In comparison, native fish density in the control reach was 41.78 ± 7.24 fish/100m^2 in February 2012, prior to intervention (Figure 2.5).

After first treatment

Six months following the first treatment native fish had begun to recover in the treatment reach, but at low densities (Figure 2.6). However, within the treatment reach, native fish density had increased to 23.81 ± 5.56 fish/100m^2 (Figure 2.5-2.7) a year after the first treatment. This was significantly higher than the density of native fish within the treatment reach before intervention ($p<0.01$). A single smallmouth bass was observed in the treatment reach in February 2013. The density of native fish in the control reach in February 2013 was 23.71 ± 7.24 fish/100m^2.

After second treatment

No smallmouth bass were observed in the treatment reach during any of the surveys following the second treatment. Six months following the second treatment (October 2013), native fish densities were low in the treatment reach. A year after the second treatment (March 2014), native fish density had increased to 11.81 ± 5.99 fish/m^2. The densities of Clanwilliam yellowfish, Clanwilliam redfin and fiery redfin one year after the second treatment were compared between the treatment reach and the control reach (Figure 2.5) and the density of native fish was significantly lower ($p<0.01$) in the treatment reach than the control reach. The density of native fish observed in the control reach during March 2014 was 31.28 ± 7.53. The variation in snorkel survey estimates (mean ± SE) of native fish densities within the control reach between February 2012 (before intervention) February 2013 (a year after the first treatment) and March 2014 (a year after the second treatment) was not significant ($p<0.01$) (Figure 2.5).

Table 2.4: Density estimates (mean ± SE) over time from snorkel surveys within the and control treatment reaches in the Rondegat River, Western Cape, South Africa. Dates refer to date of survey and **BT1**: before first treatment; **PT1**: post first treatment; **PT1.2**: second survey post first treatment; **BT2**: before second treatment; **PT2**: post second treatment; **PT2.2**: second survey post second treatment and **PT2.3**: third survey post second treatment. (N.S.: not surveyed)

Survey	Clanwilliam redfin	Fiery redfin	Clanwilliam yellowfish	Smallmouth bass
Feb-2012 BT1	0.0	0.0	0.81 ± 0.75	1.42 ± 0.41
Feb-2012 PT1	0.0	0.0	2.78 ± 2.78	0.0
Oct-2012 PT1.2	2.93 ± 2.06	0.0	5.70 ± 3.46	0.0
Mar 2013 BT2	14.85 ± 7.79	2.78 ± 1.81	58.00 ± 21.83	0.09 ± 0.09
Mar 2013 PT2	0.0	0.0	0.0	0.0
Oct-2013 PT2.2	0.0	0.0	1.07 ± 0.43	0.0
Mar-2014 PT2.3	6.57 ± 2.97	0.37 ± 0.20	28.48 ± 12.52	0.0

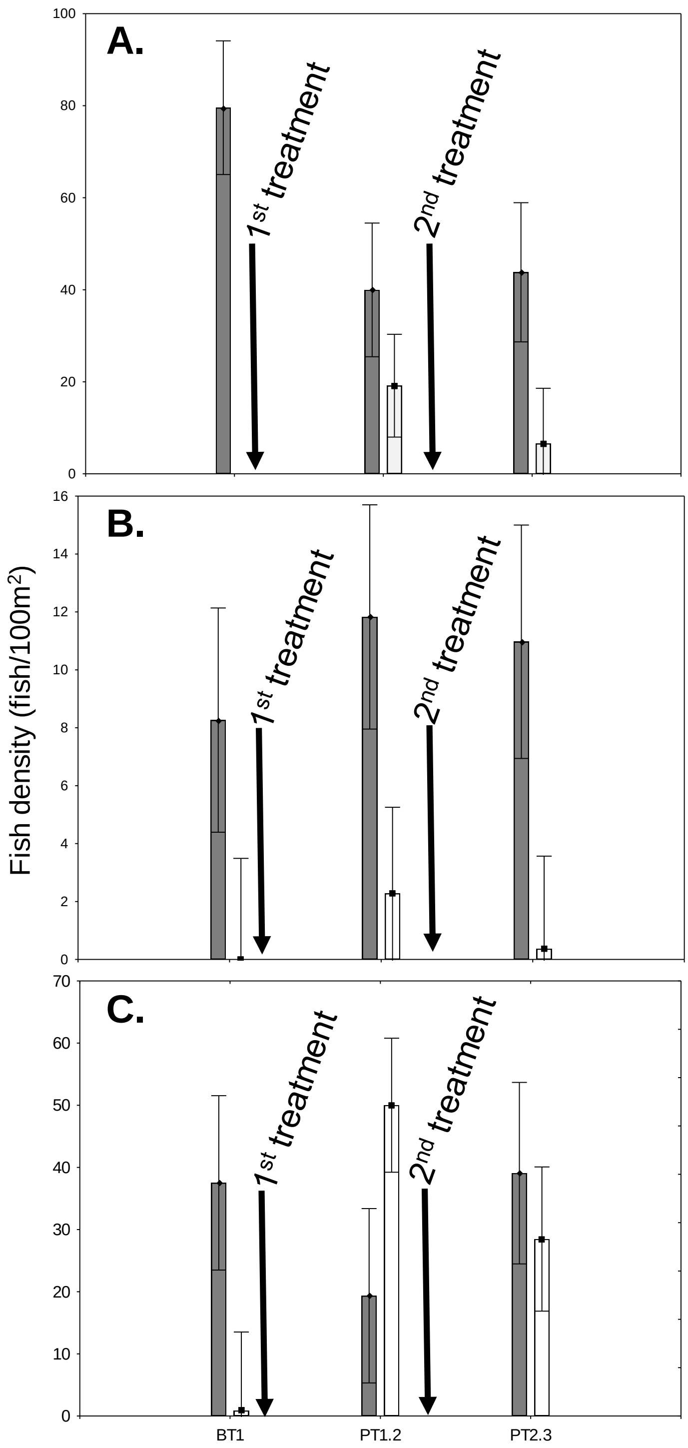

Figure 2.5: The mean density of native fishes before and after CapeNature interventions in control and treatment reaches of the Rondegat River, Western Cape, South Africa, before intervention (BT1), a year after the first intervention (PT1.2) and a year after the second treatment (PT2.3). **A**. Clanwilliam redfin **B.** fiery redfin and **C**. Clanwilliam yellowfish. Error bars denote one standard error.

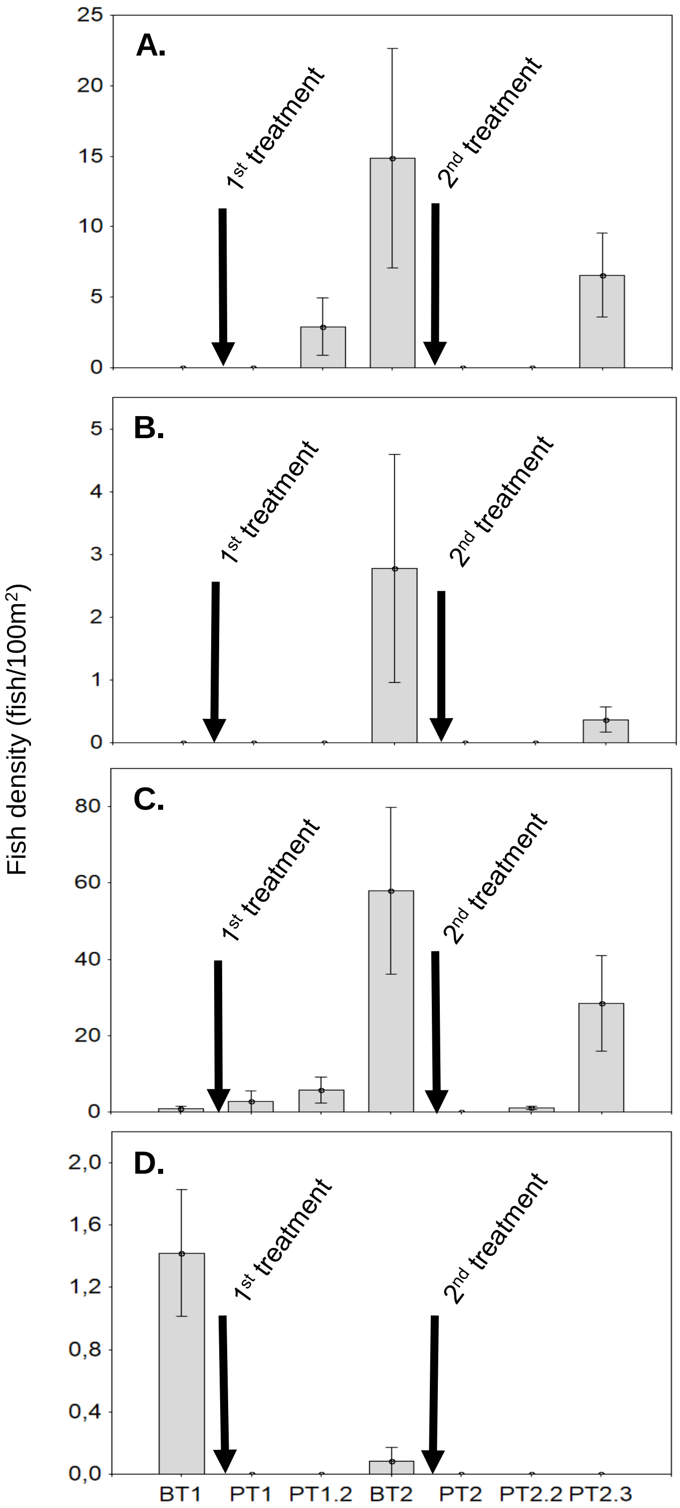

Figure 2.6: Fish density estimates from snorkel surveys within the treatment reach of the Rondegat River, Western Cape, South Africa. **A**. Clanwilliam redfin; **B**. fiery redfin; **C**. Clanwilliam yellowfish; **D**. smallmouth bass. **BT1**: Survey before 1st treatment in February 2012 (From Weyl et al. 2013); **PT1**: Post 1st treatment survey in February 2012 (From Weyl et al. 2013); **PT1.2**: 8 months following 1st treatment in October 2012; **BT2**: 13 months after 1st treatment and before 2nd treatment in March 2013; **PT2**: Post 2nd treatment survey in March 2013; **PT2.2**: 7 months following 2nd treatment survey in October 2013; **PT2.3**: 12 months following 2nd treatment in March 2014. Error bars denote one standard error.

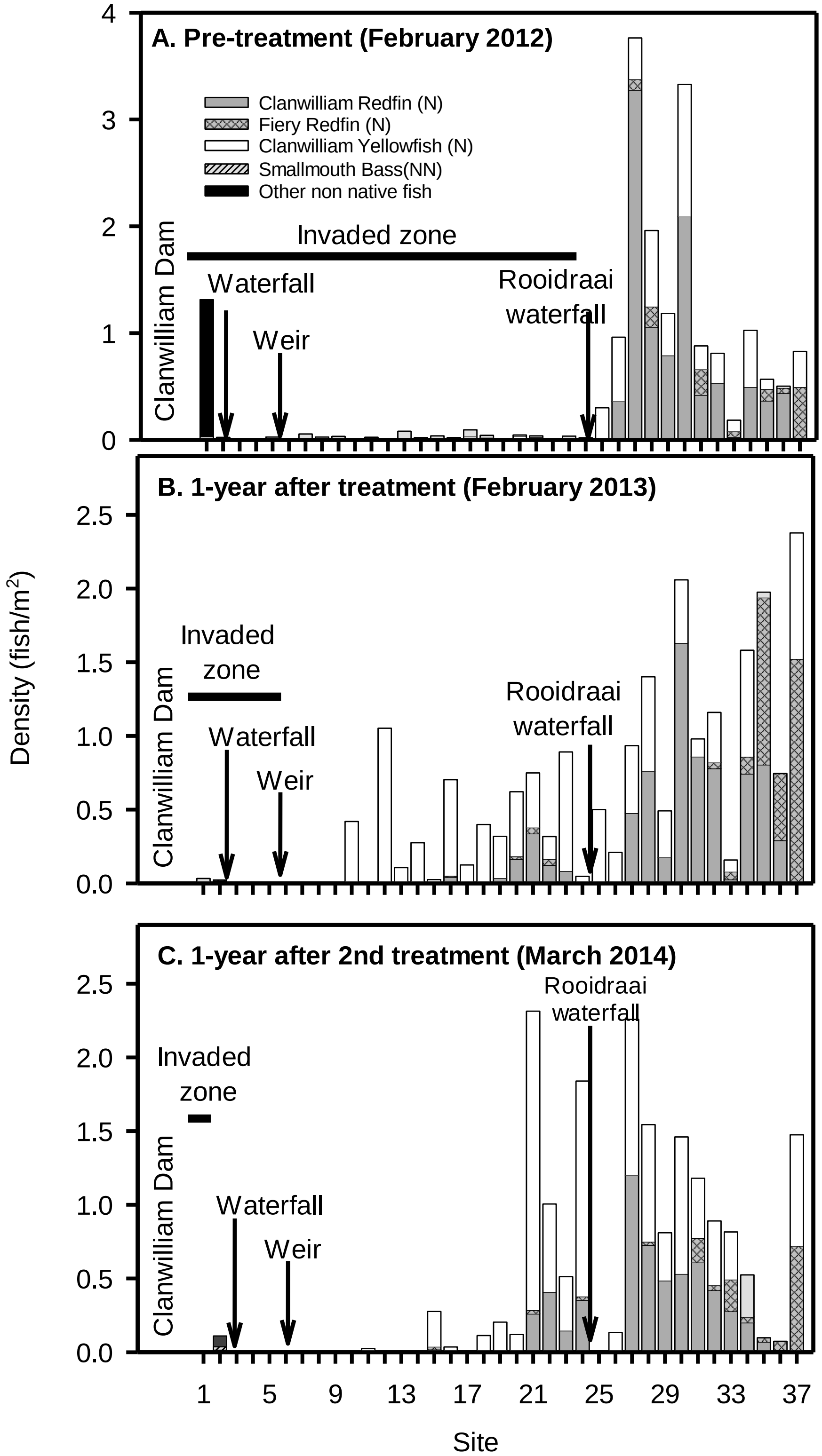

Figure 2.7: Density estimates from snorkel surveys of the Rondegat River, Western Cape, South Africa, showing the change in fish community structure brought about by the eradication of smallmouth bass as well as the recovery within the treatment reach following two annual treatments. **A.** Fish densities estimated from a survey before the first treatment, **B.** Fish densities estimated a year after the first treatment and **C.** Fish densities estimated a year after the second treatment.

2.3.3 Relative abundance

Relative abundance estimates from underwater video analysis within the treatment reach confirmed the recovery illustrated by fish density estimates from snorkel surveys (Figure 2.8). One year after the first treatment (February 2013) and before the second treatment (March 2013) a single smallmouth bass individual was observed in the treatment reach by underwater filming, but following the final treatment, no alien fish were observed in the treatment reach.

Relative abundance estimates (maxN) of native fish from underwater video analysis filmed during March 2014 within the treatment reach were significantly lower than in the control reach. The comparison of these estimates and the levels of significance are shown in Figure 2.7.

2.3.4 Length structure

Fish collected in the treatment reach during the second rotenone treatment and caught in March 2014 were of similar fork lengths (Figure 2.9). However, mean fork length of all three species of native fish were significantly less ($p<0.01$) in the treatment reach compared to the control reach (Table 2.5). This shows that native fish within the treatment reach are significantly smaller than those in the non-invaded reach.

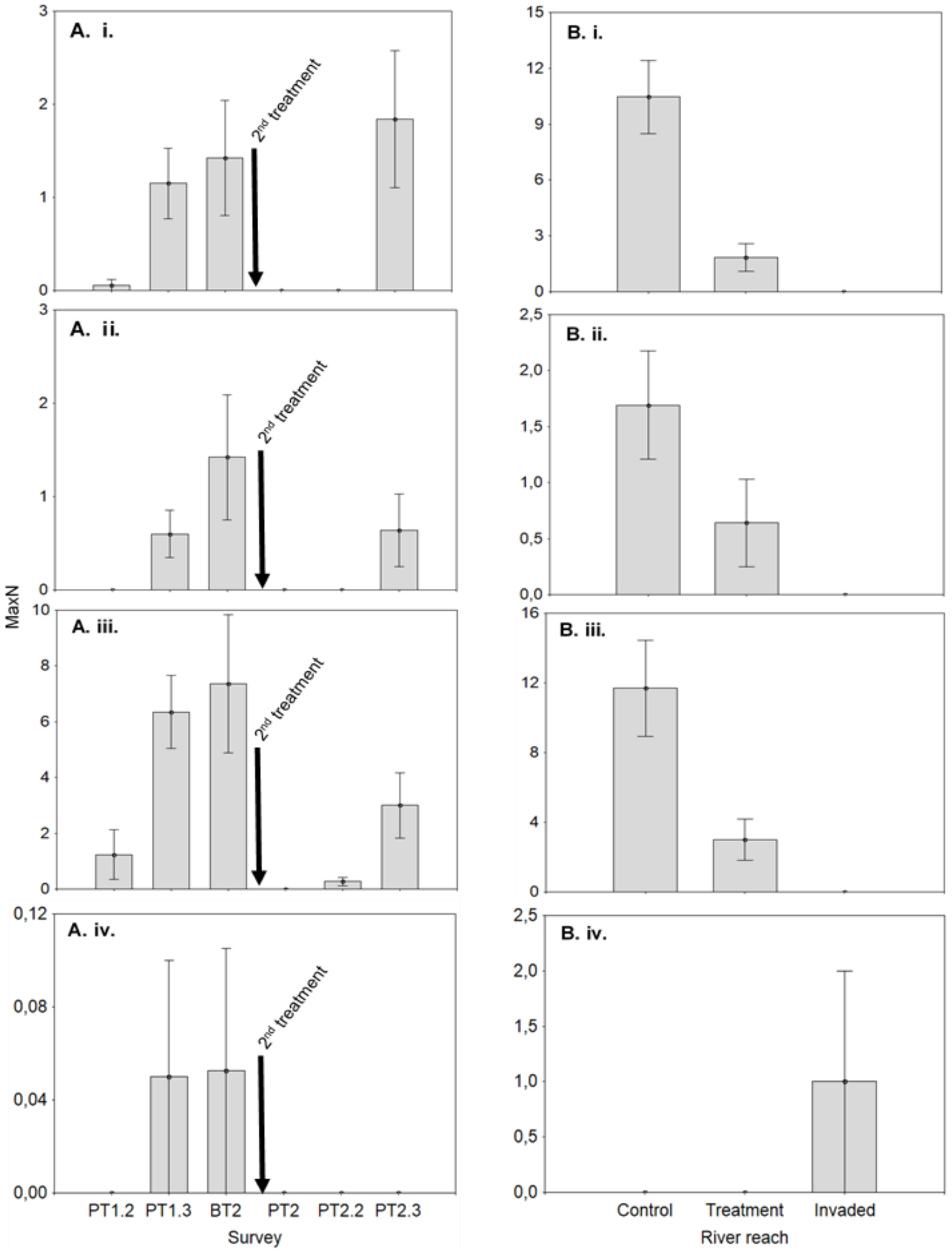

Figure 2.8: Mean MaxN estimates from underwater video analysis of fishes within the treatment reach of the Rondegat River, Western Cape South Africa. **A**. showing the change in relative abundance from October 2012 till March 2014, **i**. Clanwilliam redfin **ii**. fiery redfin **iii**. Clanwilliam yellowfish and **iv**. smallmouth bass (**PT1.2**: October 2012 6 months post 1st treatment; **PT1.3**: February 2013, 12 months post 1st treatment; **BT2**: March 2013 before 2nd treatment; **PT2**: March 2013 post 2nd treatment; **PT2.2**: October 2013 6 months post 2nd treatment and **PT2.3**: March 2014 12 months post 2nd treatment.) **B**. showing the significantly higher relative abundance of native fish in the control versus the treatment reaches from March 2014. **i**. Clanwilliam redfin ($p < 0.01$) **ii**. fiery redfin ($p > 0.05$) **iii**. Clanwilliam yellowfish ($p < 0.01$) and **iv**. smallmouth bass (not present in treatment reach in March 2014).

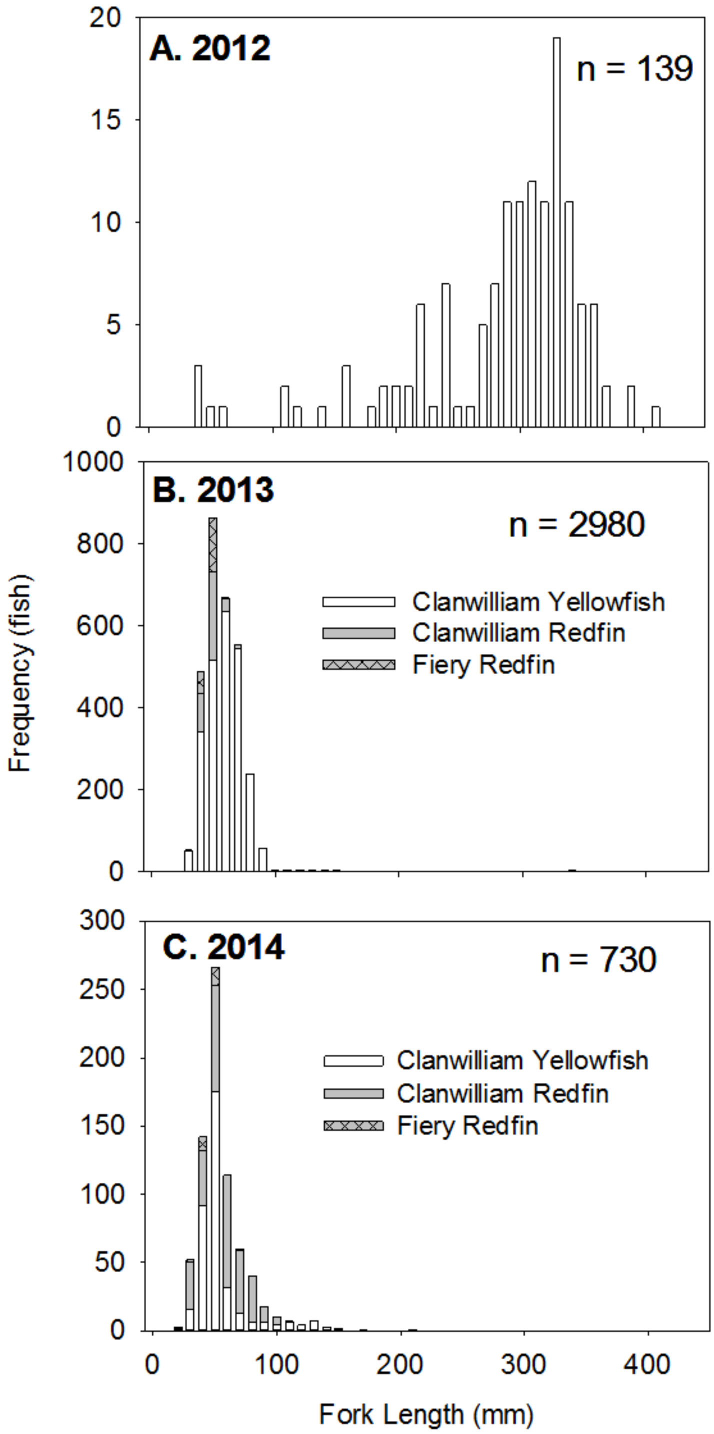

Figure 2.9: The mean fork length of native fishes in the treatment reach of the Rondegat River, Western Cape, South Africa. **A**. before any rotenone treatments **B**. a year after the first treatment and **C.** a year after the second treatment.

Table 2.5: The mean fork length comparison of native fishes within the treatment reach and the control reach of the Rondegat River, Western Cape, South Africa.

	Clanwilliam redfin		Fiery redfin		Clanwilliam yellowfish	
	Control	Treatment	Control	Treatment	Control	Treatment
Mean FL (mm)	59.06	43.10	47.38	39.79	44.95	89.89
SE	0.84	0.02	1.70	1.32	0.71	6.19
N	112	256	21	24	61	314
p	$p<0.001$		$p<0.001$		$p<0.001$	
U	5237.00		97.50		3789.50	

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2.4 Discussion

Removal of smallmouth bass

Although the results provide strong evidence for the successful removal of the target species, this was only fully achieved following a second treatment. A single smallmouth bass individual was observed in the treatment reach directly above the abstraction weir a year after the first treatment. It is possible that the fish could have survived the initial treatment by finding refuge or it could have invaded from downstream. There are also numerous wetland areas adjacent to the treatment reach and while these were subject to rotenone poisoning, its efficacy was not fully assessed. The wetlands were also treated with liquid rotenone which, according to Ling (2003) is not an optimal method for treatment of static water bodies. Alternately, the fish could have moved upstream of the weir after the first treatment but before the alterations to the weir were completed, or it could have been deliberately introduced to the treatment reach. This individual was not recovered during the second treatment. However the remains of a large fish were found in an irrigation pipe leading from the weir. No smallmouth bass have been observed in the river since the second treatment. This suggests that rotenone is efficient at eradicating smallmouth bass from streams within the CFR and secondly, that the raised weir structure does provide a barrier to upstream movement of smallmouth bass. Continued monitoring of the Rondegat would be required to determine whether the weir acts as a long term barrier to invasion.

Response of native fish to removal of smallmouth bass

Smallmouth bass have had significant negative ecological impacts on native fish in the Rondegat River, however snorkel observations and underwater footage of the same system following the removal of smallmouth bass show that recovery of native fish populations is indeed possible. Similar levels of recovery are documented a year after both rotenone treatments. Before the rotenone interventions, the treatment reach was characterized by low fish density and diversity (two species). There were no juvenile native fish and the growth of the smallmouth bass was stunted (Weyl et al. 2013). However, after the first rotenone treatment the species richness and native fish density within the treatment reach increased.

Data indicates that responses of native fishes to smallmouth bass removal differed between species. Clanwilliam yellowfish was the first native fish to be detected in the treatment reach following both rotenone applications. It was observed at a number of sites within the treatment reach only a week after the first treatment and seven months after the second. Individuals that were observed in October 2013 (seven months after the second treatment) were large (between 50-150mm) and were probably not born in. By October 2013, densities of Clanwilliam yellowfish were still low compared to March 2014. Fish density within the treatment increased notably between the October 2013 and March 2014 for all three cyprinid species known to occur in the river. Findings therefore suggest that recovery of the treatment reach by the cyprinids is primarily linked to juveniles moving downstream following spawning in spring or summer. These indigenous cyprinids spawn in late spring and summer (Skelton, 2001; Whitehead et al. 2007). Paxton and King (2009) found that adult Clanwilliam sawfin overwintered in deeper pools, and then dispersed (both up- and down-stream) to shallower pools and riffles at the start of spring for feeding and spawning. Following spawning, fish which had hatched that year dispersed downstream. This appears to be the case with the cyprinids of the Rondegat River and would explain the low density of native fish within the treatment reach in October and the high density of juveniles within the treatment reach in March. This was supported by size distribution data which shows that that the mean fork length of fish observed within the treatment reach was significantly lower than of those within the control reach. Many of the fish observed in the treatment reach in March 2014 had hatched that year. These results are similar to the observed recovery of a galaxid population in an Australian stream following the removal of rainbow trout, however, it took three years for a breeding population to establish (Lintermans, 2000).

Based on length of fish which were observed to co-exist with smallmouth bass prior to intervention by CapeNature documented by Weyl et al. (2013) it is likely that, with the exception of a few large Clanwilliam yellowfish, the juvenile fish observed in the treatment reach following the two annual treatments would have been predated upon and extirpated by smallmouth bass if it were not for the rotenone treatments. This suggests that smallmouth bass not only decreased native fish density in the invaded reaches of the Rondegat, but also negatively impacted the reproductive success of individuals upstream of the invaded reach by preying upon downstream dispersing juveniles. The colonization of native fish fauna within the treatment reach provides further evidence that smallmouth bass were having a negative impact upon the native fish population in the Rondegat River.

The single smallmouth bass which was observed in the treatment reach following the first treatment was first detected by video surveys. This highlights the value of underwater video analysis as well as the use of more than one survey method when attempting to determine species absence. However, a short-coming of this study is that not all species were equally well enumerated using the techniques applied. For example, Clanwilliam rock catfish were under surveyed by visual survey techniques as they are nocturnal and hide under rocks during the day. Electrofishing of four sites in March 2014, where Clanwilliam rock catfish were not observed during snorkel surveys, picked up numerous individuals. Whilst underwater video filming did detect the presence of Clanwilliam rock catfish, it did not detect them in all sites where they were detected using electrofishing. Electrofishing of several sites in the treatment reach detected no Clanwilliam rock catfish. In March 2014 a single adult individual was caught in a fyke net in the treatment reach. This suggests that the dynamics of the recolonization of the treatment reach by Clanwilliam rock catfish may be different to that of the cyprinids. Recolonization by Clanwilliam rock catfish into the treatment reach has been a slower process than that observed for the other native species. Instead of recruitment into the treatment reach being linked to the mass downstream dispersal of juveniles, it would appear to occur as adult individuals move downstream. This slow recovery following depletion is to be expected as the life history of Clanwilliam rock catfish is typically *K*-selected (Mthombeni, 2009). Night snorkelling is a possible additional survey method which might increase visual detection of Clanwilliam rock catfish.

Rotenone has been used to eradicate invasive alien fish in Great Britain (Britton and Brazier, 2006), Australia (Lintermans, 2000), New Zealand (Pham et al. 2013) and extensively in the United States of America (Finlayson et al. 2005; Mcclay, 2005). The findings of this study illustrate the effectiveness of rotenone as a biodiversity restoration tool within the context of the CFR. In New Zealand, numbers of invertebrates was not reduced by rotenone treatments to the point that food availability and as a result the growth of native fishes were hampered even though native fish were reintroduced immediately after the treatments (Pham et al. 2013).

This study provided evidence that rotenone and the construction of in-stream barriers are effective tools in controlling smallmouth bass and restoring native fish communities in the CFR. The monitoring of such projects are useful as they guide evidence-based restoration (Ntshotsho et al. 2011). Future monitoring of the Rondegat River and other rivers in the CFR where similar projects are implemented is important so that these restoration efforts can be most effective.

2.5 References

Barnard KH (1943) Revision of freshwater fishes of the S.W. Cape region. Annals of the South African Museum. 36: 101-263.

Bills IR (1999) Biology and conservation status of the Clanwilliam rock catfish and spotted rock catfish. Investigational report No. 60. JLB Smith Institute of Ichthyology, Grahamstown.

Britton JR, Brazier M (2006) Eradicating the invasive topmouth gudgeon, *Pseudorasbora parva*, from a recreational fishery in Northern England. Fisheries Management and Ecology. 13: 329-335.

Brooks IC, Price RW (1961) Studies on the chronic toxicity of Pro-Noxfish, a propriety synergized rotenone fish toxicant. Toxicology and Applied Pharmacology. 3: 49-56.

Chakona A, Swartz ER (2013) A new redfin species, *Pseudobarbus skeltoni* (Cyprinidae, Teleostei), from the Cape Floristic Region, South Africa. Zootaxa. 3686: 565-577.

Coke M (1988) Freshwater fish conservation in South Africa: A rising tide. Journal of the Limnological Society of Southern Africa. 14: 29-34.

Cowling, R, Pressey RL, Rouget M, Lombard AT (2003) A conservation plan for a global biodiversity hotspot—the Cape Floristic Region, South Africa. Biological Conservation. 112: 191–216.

De Moor IJ, Bruton MN (1988) Atlas of alien and translocated indigenous aquatic animals in southern Africa. South African National Scientific Programmes Report No. 144. Council for Scientific and Industrial Research, Pretoria.

Ellender BR, Weyl OLF, Swartz ER (2011) Invasion of a headwater stream by non-native fishes in the Swartkops River system, South Africa. African Zoology. 46: 39-46.

Ellender BR, Becker A, Weyl OLF, Swartz ER (2012) Underwater video analysis as a non-destructive alternative to electrofishing for sampling imperilled headwater stream fishes. Aquatic Conservation: Marine and Freshwater Ecosystems. 22: 58-65.

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

Enviro-Fish Africa (2009) Environmental impact assessment of the proposed eradication of invasive alien fishes from four river sections in the Cape Floristic Region. Enviro-Fish Africa (Pty) LTD, Grahamstown.

Finlayson B, Somer W, Duffield D, Propst D, Mellison C, Pettengill T, Sexauer H, Nesler T, Gurtin S, Elliot J, Partridge F, Skaar D (2005) Native inland trout restoration on national forests in the Western United States. Fisheries. 30: 10-19.

Government Gazette (2014) National Environmental Management: Biodiversity Act (10/2004): Draft Alien and Invasive Species Lists. Pretoria.

Harrison AC (1953) The acclimatisation of smallmouth bass. Piscator. 27: 89-97.

Harrison AC (1963) The Olifants/Doorn River system and its fishes. Piscator. 57: 25-39.

Impson ND, Marriott MB, Bills IR, Skelton PH (2007) Conservation biology and management of a critically endangered cyprinid, the Twee River redfin, *Barbus erubescens* (Teleostei: Cyprinidae), of the Cape Floristic Region, South Africa. African Journal of Aquatic Science. 32: 27-33.

Impson ND, van der Walt R (2013) Rondegat River rehabilitation operational plan for the second rotenone treatment. Unpublished CapeNature internal report.

Jordaan MS, Weyl OLF (2013) Determining the minimum effective dose of rotenone for eradication of alien smallmouth bass *Micropterus dolomieu* from a South African river. African Journal of Aquatic Science. 38: 91-95.

Linder PH, Johnson SD, Kuhlmann M, Matthee CA, Nyffeler R, Swartz ER (2010) Biotic diversity in the Southern African winter-rainfall region. Current Opinion in Environmental Sustainability. 2: 109-116.

Ling N (2003) Rotenone - a review of its toxicity and use for fisheries management. DOC science investigation no. 3414. DOC Science Publishing, Wellington.

Lintermans M (2000) Recolonization by the mountain galaxias *Galaxias olidus* of a montane stream after the eradication of rainbow trout *Oncorhynchus mykiss*. Marine and Freshwater Research. 51: 799-804.

Lowe SR, Woodford DJ, Impson DN, Day JA (2008) The impact of invasive fish and invasive riparian vegetation on the invertebrate fauna of the Rondegat River, Cape Florisitic Region, South Africa. African Journal of Aquatic Science. 33: 51-62.

Marr SM, Sutcliffe LME, Day JA, Griffiths CL, Skelton PH (2009) Conserving the fishes of the Twee River, Western Cape, South Africa: revisiting the issues. African Journal of Aquatic Science. 34: 77-85.

Marr SM, Impson ND, Tweddle D (2012) An assessment of a proposal to eradicate non-native fish from priority rivers in the Cape Floristic Region, South Africa. African Journal of Aquatic Science. 37: 37–41.

Mcclay W (2005) Rotenone use in North America (1988-2002). Fisheries. 30: 29-31.

Mthombeni VG (2009). The biology of *Austroglanis gilli* and *Austroglanis Barnardi* (Siluriformes: Austroglanididae) in the Olifants River system, South Africa. Unpublished Msc thesis Rhodes University, Grahamstown.

Ntshotsho P, Reyers B, Esler KJ (2011) Assessing the evidence base for restoration in South Africa. Restoration Ecology. 19: 578-586.

Paxton BR, King JM (2009). The influence of hydraulics, hydrology and temperature on the distribution, habitat use and recruitment of threatened cyprinids in a Western Cape river, South Africa. WRC report No. 1483/1/09. Water Research Commission, Pretoria.

Pham L, West D, Closs GP (2013) Reintroduction of a native galaxiid (*Galaxias faciatus*) following piscicide treatment in two streams: response and recovery of the fish population. Ecology of Freshwater Fish. 22: 361-373.

Shelton JM, Day JA, Griffiths CL (2008) Influence of largemouth bass, *Micropterus salmoides*, on abundance and habitat selection of Cape galaxias, *Galaxias zebratus*, in a mountain stream in the Cape Floristic Region, South Africa. African Journal of Aquatic Science. 33: 201-210.

Skelton P. (2001) A complete guide to the freshwater fishes of southern Africa. Struik Publishing, Cape Town.

Slabbert E, Jordaan MS, Weyl OLF (2014) Analysis of active rotenone concentration during treatment of the Rondegat River, Cape Floristic Region, South Africa. African Journal of Aquatic Science. In press.

Swartz ER, Skelton PH, Bloomer P (2009) Phylogeny and biogeography of the genus *Pseudobarbus* (Cyprinidae): Shedding light on the drainage history of rivers associated with the Cape Floristic Region. Molecular Phylogenetics and Evolution. 51: 75-84.

Traas GRL (2009) The conservation and management of freshwater fishes in the greater Addo Elephant national park. Unpublished Msc thesis Rhodes University: Grahamstown.

Tweddle D, Bills R, Swartz E, Coetzer W, Da Costa L, Engelbrecht J, Cambray J, Marshall B, Impson D, Skelton P, Darwall WRT, Smith KG (2009) The status and distribution of freshwater fishes. In Darwall WRT, Smith KG, Tweddle D, Skelton P (Eds.). The status and distribution of freshwater biodiversity in southern Africa. International Union for Conservation of Nature, Gland, Switzerland and South African Institute for Aquatic Biodiversity, Grahamstown, South Africa.

Van Rensburg KJ (1966) Die vis van die Olifantsrivier (Weskus), met spesiale verwysing na die Geelvis (*Barbus capensis*) en Saagvin (*Barbus serra*). Investigational report 10: 1-14. Cape Department of Nature Conservation.

Weyl OLF, Ellender BR, Woodford DJ, Jordaan MS (2013) Fish distributions in the Rondegat River, Cape Floristic Region, South Africa, and the immediate impact of rotenone treatment in an invaded reach. African Journal of Aquatic Science. 28: 201-209.

Weyl OLF, Finlayson BJ, Impson ND, Woodford DJ, Steinkjer J (2014) Threatened endemic fishes in South Africa's Cape Floristic Region: A new beginning for the Rondegat River. Fisheries. 39: 270-279.

Whitehead A, Weyl OLF, Bills IR (2007) Reproductive and feeding biology of the endangered fiery redfin, *Pseudobarbus phlegethon* (Barnard 1938) (Teleostei: Cyprinidae) in the Noordhoeks River, South Africa. African Journal of Aquatic Science. 32: 281-290.

Woodford DJ, Impson ND, Day JA, Bills IR (2005) The predatory impact of invasive alien smallmouth bass, *Micropterus dolomieu* (Teleostei: Centrarchidae), on indigenous fishes in a Cape Floristic Kingdom mountain stream. African Journal of Aquatic Science. 30: 167-173.

Woodford DJ, Weyl OLF, Cunningham M, Bellingan T, de Moor FC, Barber-James J, Day J A, Ellender BR, Richardson N (2012) Monitoring the impact and recovery of the biota of the Rondegat River after the removal of alien fishes.WRC Report No. KV 304/12. Water Research Commission, Pretoria.

CHAPTER 3: FINANCIAL ASSESSMENT OF SMALLMOUTH BASS ANGLING IN CLANWILLIAM DAM

3.1 Introduction

Fish are one of the world's most introduced groups of aquatic animals (Gozlan, 2008) and a major driving force behind introductions of alien fish has been the desire to establish recreational fisheries (Cambray, 2003) Sports fishing accounts for up to 12 % of fish introductions globally (Gozlan, 2008). In particular, areas which lack native predatory fish (Marr et al. 2010) have seen the introduction of piscivorous sports fish, such as black bass (*Micropterus* spp.).

The general perception that the introduction of an alien species can only have negative impacts is often incorrect. Salmonids are not native to Chile, but the country is responsible for 30% of the world's farmed salmonids, and the industry employs 30 000 people (Pascuel et al. 2009; Gozlan et al. 2010). The most widely dispersed sports fish are brown trout *Salmo trutta* (Linnaeus), rainbow trout *Oncorhynchus mykiss* (Walbaum) and largemouth bass Micropterus salmoides (Lacepède) (Glozan et al. 2010). Where a recreational fishery has developed around these species so has culture and industry. These impacts are tangible and quantifiable in monetary terms. The estimated annual contribution of angling for introduced species to the economy of the United States of America (USA) is $ 69 million (Gozlan et al. 2010). When management decisions are made regarding their control, the socio-economic value of these alien sports fish cannot be ignored.

Another major consideration in the management of alien sports fish is their ecological impact. The introduction of alien fish has resulted in predation upon and competition with native fish, as well as habitat modification. Common carp *Cyprinus carpio* (Linnaeus) is known to modify habitat as it forages, causing increases in turbidity and preventing plant regrowth (Gozlan et al. 2010; Khan et al. 2003). A well-known example of the threat which predatory fish pose to native fish fauna is that of Nile perch *Lates niloticus* (Linnaeus). Introduced to Lake Victoria to increase the yield of the fishery, the population increased rapidly and is responsible for the extinction of up to 200 endemic species (Witte et al. 1992). As Goldsmidt et al. (1993) describe: 'the complex ecosystem of Lake Victoria has been irreversibly destroyed by the irruption of the introduced perch'. When it comes to sports fish, global homogenization has taken place, as desired species such as rainbow trout and largemouth bass have been widely distributed.

Cambray (2003) points out that an angler can travel to over 82 countries across the world and catch the same species of trout. Introduced trout have been shown to affect faunal assemblages, extirpate native fish populations and reduce benthic invertebrate biomass and abundance resulting in a cascading effect on the stream ecosystems on four different continents (Flecker and Townsend, 1994; McIntosh and Townsend, 1996; Townsend, 1996; Bradford et al. 1998; Cambray, 2003; Buria et al. 2007). Similarly largemouth bass in Japan altered ecosystems by preying upon grazers and caused trophic cascades (Maezono et al. 2005), while smallmouth bass *Micropterus dolomieu* (Lacepède) have reduced the numbers of cyprinids through predation in Canadian lakes (MacRae and Jackson, 2001).

South Africa has a long history of introductions of alien fish species and the majority of these were originally introduced for angling purposes (Ellender and Weyl, 2014). Common carp were introduced as early as the 18th century (De Moor and Bruton, 1988), brown trout *Salmo trutta* (Linnaeus) and rainbow trout were brought from Scotland in 1890s and black bass were introduced in the first half of the 20th century (Table 3.1). Much of the distribution was carried out by conservation authorities, from hatcheries such as Jonkershoek in the Western Cape (McCafferty et al. 2012).

Table 3.1: Alien sports fish and the year of their introduction to South Africa.

Species	**Scientific name**	**Year of introduction**
Common carp	*Cyprinus carpio*	1700s
Brown trout	*Salmo truta*	1890
Rainbow trout	*Oncorhynchus mykiss*	1897
Largemouth bass	*Micropterus salmoides*	1928
Smallmouth bass	*Micropterus dolomieu*	1937
Spotted bass	*Micropterus punctulatus*	1939

There are numerous publications documenting the economic impacts of recreational black bass fisheries in the USA, the native range of black bass. The economic impact of all recreational angling (both fresh- and saltwater) within the Everglades Region of South Florida was estimated to be worth over USD1.2 billion (Fedler, 2009). Angling for largemouth bass specifically, had a total economic impact of more than $82 million (Fedler, 2009). Chen et al.

(2003) estimated that the total economic impact of a recreational largemouth bass fishery on Lake Fork, Texas was USD18 559 871 in 1994/5. In 2014 the value estimated by Chen et al. (2003) would be the equivalent of more than R300 million. Myles and Swaim (2010) focused on specific black bass tournaments in North Alabama. They estimated that four tournaments hosted by Auburn University in 2009 had a direct economic impact of USD152 484, the equivalent of approximately R 1.8 million in 2014.

The economic impacts of recreational angling for black bass in North America are not only better documented than in South Africa, they also tend to be at least one order of magnitude higher than those generated by South African black bass fisheries (e.g. Fedler (2009) vs Leibold and Van Zyl, (2008); Myles and Swaim (2010) versus Kinghorn (2013)). A national study of aquatic and marine recreational fisheries by Leibold and Van Zyl (2008) estimated the total economic impact of recreational angling to be R18.8 billion in 2007 and the total economic impact of recreational angling for black bass in 2007 was estimated at R1.2 billion. As this report was never peer-reviewed, it should be considered an estimate. On a smaller geographic scale, the direct economic impact to the Amathola region of two bass angling competitions held on Wrigglewade Dam in the Eastern Cape was estimated to be R85 867 in 2012 (Kinghorn, 2013). This is the only work to date which documents the economic impacts of the black bass angling fishery, however the estimate was restricted to two specific tournaments.

No estimate has been made of the annual local economic impact of a recreational bass fishery. Du Preez and Lee (2010) calculated that in 2010 fly fishing for rainbow trout, in the rivers around Rhodes in South Africa's North Eastern Cape, generated a direct gross economic impact of approximately R5.6 million per annum. These authors stated that this impact is significant because of the low income per capita in the region, as well as the fact that the fishery directly generated employment of guides and individuals in the hospitality sector. Such a study has not been carried out for a South African black bass recreational fishery. For optimal development and management of inland recreational fisheries in South Africa, more research into their economic impacts is required.

To contribute towards understanding the economic value of alien sport fishes, this study documented the expenditure of recreational black bass anglers in the town of Clanwilliam. Expenditure by participants, organisers and spectators of a specific event is used to estimate the economic impact of events (Tyrrell and Johnson, 2001) and angling related expenditure has been used to infer economic impact by several authors (Chen et al. 2003; Fedler, 2009; Du

Preez and Lee, 2010; Myles and Swaim, 2010; Kinghorn, 2013). This study is the first to estimate the annual local expenditure of black bass anglers of a specific recreational fishery in the Western Cape and from it to infer the economic impact.

3.2 Methods

3.2.1 Site description

The study area was Clanwilliam Town has a population of approximately 7700 people (Frith, 2014) is situated approximately 250 km north-west of Cape Town. The town is on the shores of Clanwilliam Dam, which was constructed in 1935 and is a popular angling venue that hosts numerous angling competitions each year. Two of these are the Winter and Summer Bass Classics. These are held annually during August and October respectively.

The Winter Classic is fished in teams of two and each team is permitted to weigh in five fish per day. Fishing occurs between 07h00 and 16h00 on the Saturday and 07h00 and 12h00 on the Sunday. There are prizes for the team which has the heaviest bag (weight of all ten fish which they weighed in) as well as for the individual who catches the largest fish on the weekend. The Winter Classic is organized by the Western Cape Bass Anglers Association.

The Summer Classic is not fished in teams. Fishing only takes place on the Saturday between 06h30 and 16h00. Only smallmouth bass are considered for the weigh in. The angler may select two fish whose summed weight is entered into the bag competition, whilst a third fish may be entered into the biggest fish competition. Cash prizes of between R10 000 and R100 000 were given to any anglers who caught one of five tagged fish. The Summer Classic is organized by a committee appointed by its sponsors.

3.2.2 Experimental design

Anglers competing in the Classics were interviewed over the course of the two competition weekends and one additional non-competition weekend. Interviews were voluntary and responses were recorded anonymously in accordance with ethics approval (Proposal number: DESC_Barrow2013). General questions asked included anglers' year of birth, income, household size and annual expenditure on angling related items. These were used to generally describe who is angling for smallmouth bass in Clanwilliam.

The questionnaire used was an adaption of that used by Kinghorn (2013) on Wriggleswade Dam (Appendix 2 and 3). The primary aim of the interviews was to quantify expenses incurred by anglers in order to get to and take part in the competitions. Each angler was asked how much they spent on different expense categories as well as where the money was spent. They were also asked about the size of their group and the number of non-anglers present within the group. The amount spent per angler per trip was then calculated.

Based on the work of Tyrrell and Johnson (2001), expenses were divided into four categories and two sub categories (Table 3.2). Category 1 refers to expenses spent within the study region by a non-resident of the study area, category 2 refers to expenses outside the study region by a resident of the study area, category 3 refers to expenses within the study area by a resident of the study area and category 4 refers to expenses spent outside the study area by a resident of the study area. Sub-category A refers to expenses spent because of the activity in focus, which in this case is recreational angling for smallmouth bass. Sub-category B refers to expenses spent for a reason other than the activity in focus. In order to be certain that the expenses recorded were definitely an impact of the angling competition and not as a result of another activity the anglers might be taking part in; anglers were asked whether the competition was their main reason for being at Clanwilliam Dam on that weekend. When inferring an estimate of net direct economic impact of the fishing tournament only category 1A expenses were used.

Table 3.2: Summary of different expense categories from Tyrrell and Johnson (2001). Category 1A expenses (description in bold) are the expenses which contribute towards the direct economic impact of the activity.

	Category 1	Category 2	Category 3	Category 4
Sub-category A	**Spent within study region, by non-resident, because of bass angling**	Outside study region, by resident, because of bass angling.	Within study region by resident, because of bass angling.	Outside study region by non-resident, because of bass angling
Sub-category B	Spent within study region, by non-resident for a reason other than bass angling	Outside study region, by resident, for a reason other than bass angling	Within study region by resident, for a reason other than bass angling	Outside study region by non-resident, for a reason other than bass angling

3.2.3 Inferring economic impact of a competition from angler expenditure

In order to estimate economic impact, the sum of the category 1A expenses was divided by the number of anglers interviewed. This amount was taken to represent the average net direct economic impact (NDEI) per angler. The NDEI of the competition is then estimated by multiplying the average NDEI per angler by the number of participants.

This approach does not take into account category 1A expenses incurred by other groups, most notably the organizers of the competition. This amount was obtained through personal communication with the organizers and added to the final estimate. The following formula shows the method used to obtain the total NDEI of the competition (n = number of anglers interviewed and N = number of anglers participating in the tournament):

$$NDEI = \left[\left(\frac{Sum\ of\ Catergory\ 1a}{n}\right) \times N\right] + Category\ 1a\ expenses\ of\ organizers$$

The NDEI does not take into account indirect economic impacts generated by the direct impacts. Indirect impacts refer to the use of the directly injected money a second time. For example, a portion of anglers' money which is spent on food and drinks at restaurants within Clanwilliam would be paid out to the employees of those restaurants. Multipliers are an estimate of the percentage of the direct impact which is spent a second time within the region's economy. Due to the time and scope of this project, a multiplier was not calculated, but rather estimated to be 0.21 based on published studies which were of a similar nature to this study (Antrobus et al. 1997; Chen et al. 2003 and Kinghorn, 2013).

3.2.4 Inferring annual economic impact of bass angling from angler expenditure

The results and entries of the Summer and Winter Classics as well as the divisional competitions held on Clanwilliam Dam twice annually, were obtained online (South African Bass Anglers Association, 2011; Bass Fishing South Africa, 2014). Entrants in these three competitions were compared. Many of the anglers competed in two or all of these competitions. A total of 302 individuals were identified as making up all the competitors of these three angling competitions. This number was taken as a minimum estimate of the total number of anglers who fish at Clanwilliam Dam annually. This number was multiplied by the average number of trips made to the dam annually as reported by interviewed anglers. The resulting figure was estimated to represent the number of angler trips per annum to Clanwilliam Dam. The number of angler trips per annum multiplied by the angler expenditure of a single angler trip gave the estimated annual NDEI of bass anglers on the town of Clanwilliam.

In order to estimate the annual economic impact of bass angling to the town of Clanwilliam, an average category 1A expenses per angler per trip was estimated. This was calculated by adding category 1A expenses from both the Summer and Winter Classics and dividing this by the number of interviews conducted (N =149). This value represents the average amount spent per angler, per trip to Clanwilliam. The mean number of trips made per annum per angler was multiplied by the estimate of the average amount spent per angler, per trip to Clanwilliam. This value was taken as the NDEI of angling for smallmouth bass on Clanwilliam. This was increased by a multiplier in order to account for indirect impacts.

3.3 Results

3.3.1 Descriptive statistics for all interviews

Over the course of the two tournament weekends and a single non-tournament weekend, 160 interviews were conducted. Of these, 68 were at the Winter Classic, 81 at the Summer Classic and 11 on the non-tournament weekend. Of the 81 interviews conducted at the Summer Classic, 14 were anglers who had been interviewed at the Winter Classic. Of the 11 anglers interviewed on the non-tournament weekend, seven had been interviewed before. Therefore, 139 different anglers were interviewed over the three weekends on which interviews were conducted.

A total of 92 (71%) of the respondents (n=128) travelled 200-300 km, one way, to get to the dam (Figure 3.1). Of the individuals that travelled over 1000 km, one way to Clanwilliam Dam (n=5), all indicated that the fishing competition was their primary reason for visiting Clanwilliam.

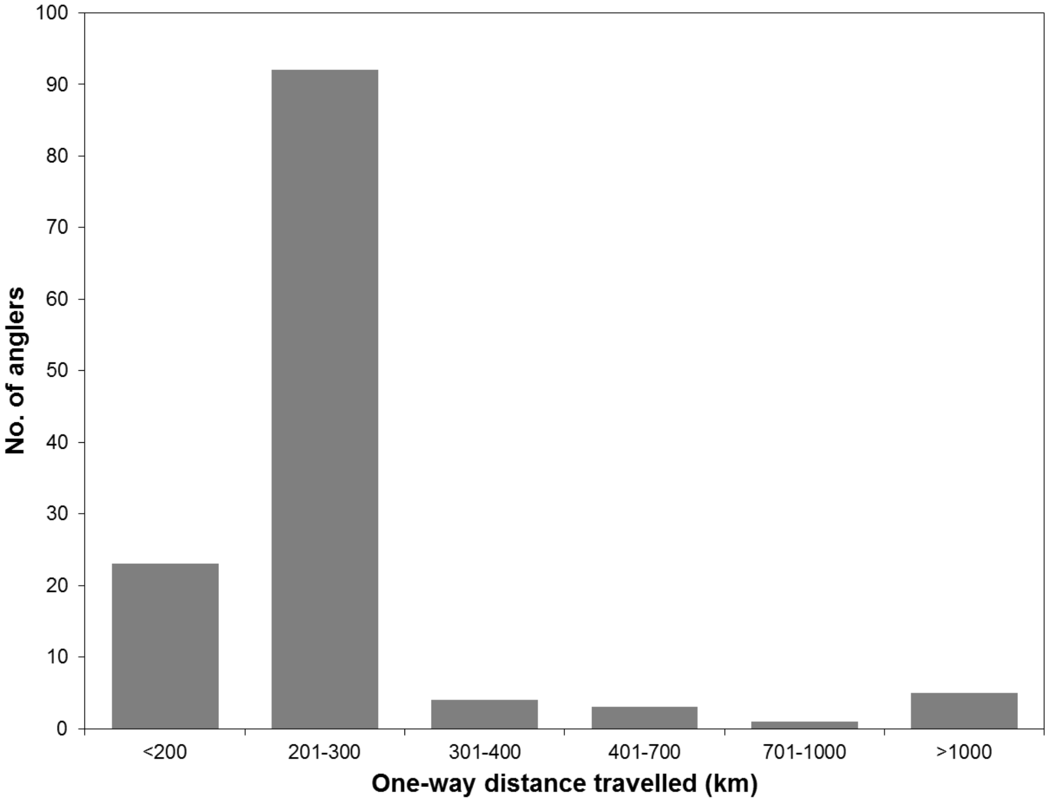

Figure 3.1: The distance travelled to Clanwilliam Dam, Western Cape, South Africa by anglers who competed in the Winter- and Summer Classic angling competitions.

3.3.2 Winter Classic

The Winter Classic had 96 participants, and 68 (71%) were interviewed. Four of the respondents (6%) were locals (individuals from the town of Clanwilliam) and 46 respondents (68%) were from Cape Town. The average distance travelled to the event (one way) was 250 km. Only nine of the respondents (13%) indicated that the Winter Classic was not their main reason for being at Clanwilliam Dam on that weekend.

3.3.3 Summer Classic

The Summer Classic had 243 participants and 81 (33%) of these were interviewed. Of the respondents, one individual was from Clanwilliam and the majority, 51 respondents (63%) were from Cape Town. Only one of the respondents at the Summer Classic travelled over 500km to the competition. Four respondents (5%) indicated that the tournament was not their main reason for visiting Clanwilliam Dam on that weekend. Of these, one indicated that his main reason for coming to Clanwilliam was to fish for bass and not the competition, therefore, his expenditure in Clanwilliam, is an impact of bass angling, but not of the Summer Classic.

3.3.4 General tournament angler profile

Ninety seven percent of the tournament anglers wer male. Anglers were between 28 and 53 years old (average=40.83 years; n=137; standard deviation=12.72). Ninety one of the respondents had some form of tertiary education (68%; n=138) (Figure 3.2). Generally, anglers earn between R20 000 and R30 000 per month (n=126) (Figure 3.3) and have three to four (average=3.27; n=135) people living in their household. In order to fish at Clanwilliam angers travel 280.89 km (n=128) (Figure 3.1) one way and they makes the trip on average, six times a year (average=5.86; n=130).

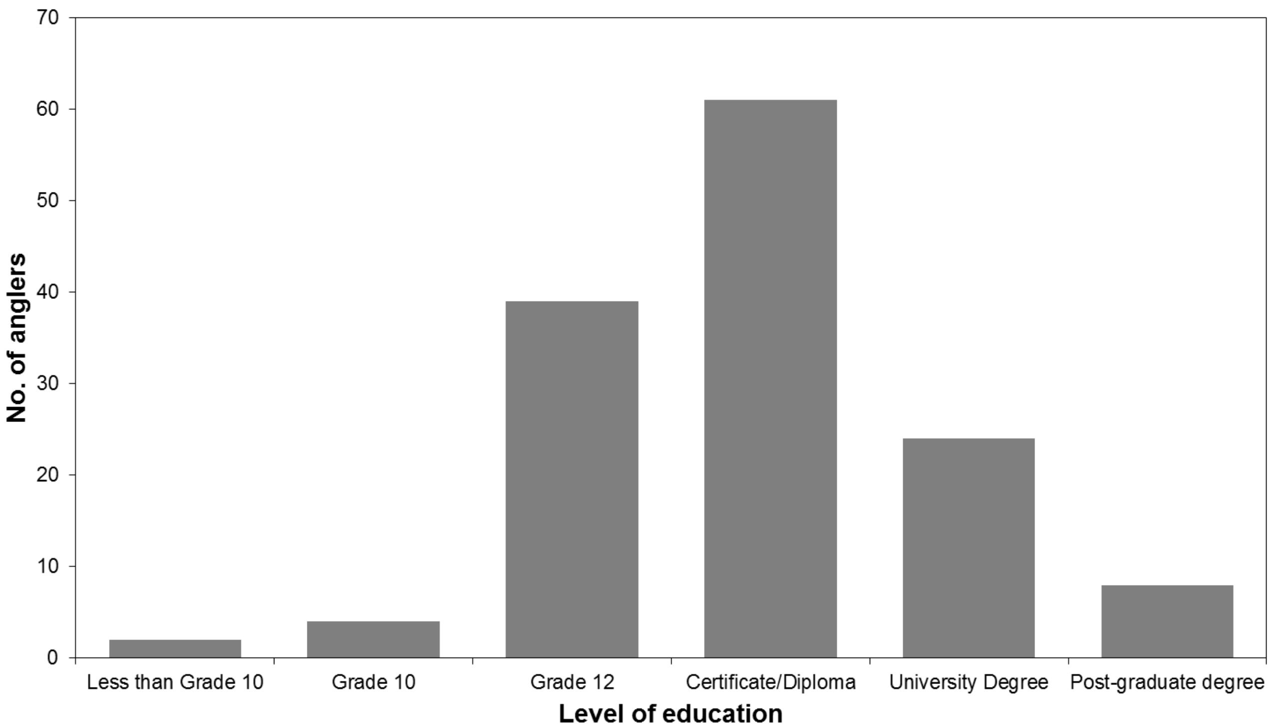

Figure 3.2: The level of education of anglers who were interviewed at the Winter and Summer Classic angling competitions held on Clanwilliam Dam, Western Cape, South Africa.

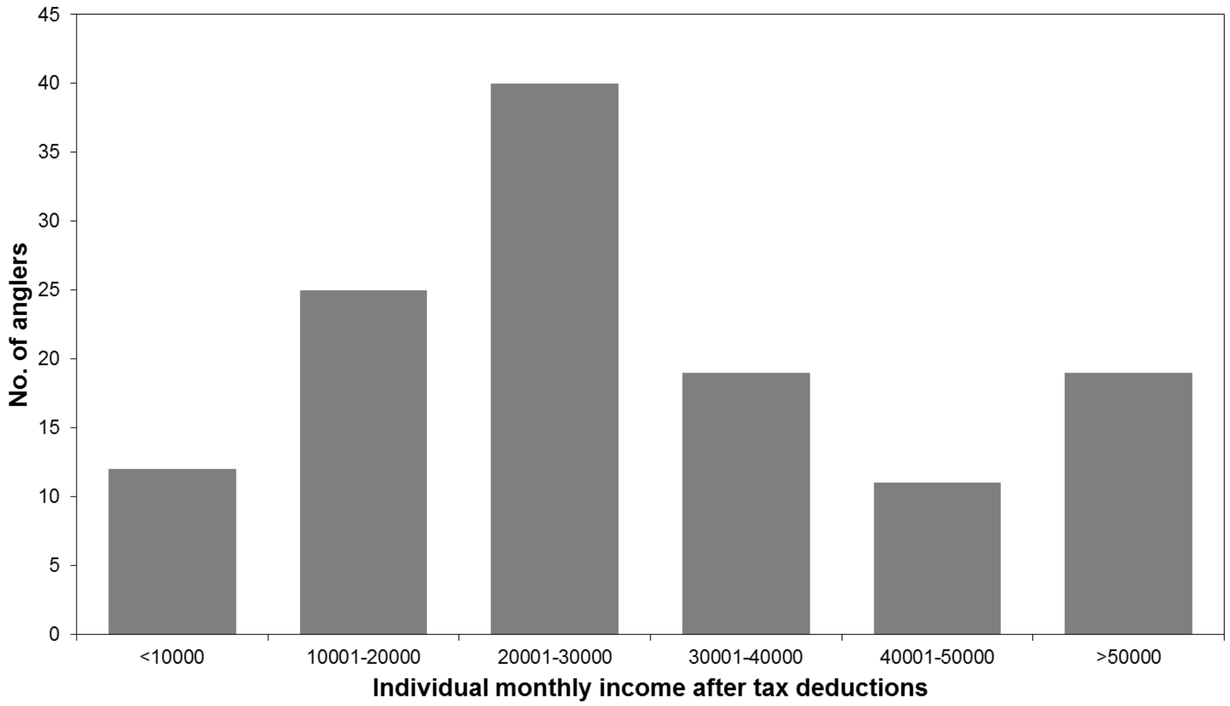

Figure 3.3: The individual monthly income after tax of anglers competing in the Winter- and Summer Classic angling competitions held on Clanwilliam Dam, Western Cape, South Africa.

Anglers own on average 14 rods (average= 14.39; n=91; SD=16.42) with an average price of R1 341 (n=91; SD=R2 047) and buy a new rod every 2.36 years (n=91; SD=1.98). Anglers generally own 14 reels (average= 13.77; n=91; SD=17.27) with an average price of R1 333 (n=91; SD=R1 152) and buy a new reel every 3.19 years (n=91; SD=2.24). Average annual angler expenditure in terms of rods, reels, terminal tackle, boat insurance, boat and motor servicing and licensing was R22 699 (Figure 3.4). On average, anglers spent R2 132 per annum on rods and reels, R6 233 (n=122; SD=R12 369) on terminal tackle per annum, R6 387 (n=87; SD=R9 586) on boat and motor services per annum, R7 266 (n=70; SD=R28 401) on boat insurance per annum and R680 (n=80; SD=R1 217) on boat licensing per annum.

Clanwilliam Dam was rated by 85% (n=104) of the anglers as the best bass fishing experience of all the sites that they fish. Furthermore, the bass fishing experience which Clanwilliam Dam offered was given an average rating of 8.02 (n=148; SD=1.74) out of 10; where 1= poor; 10=excellent.

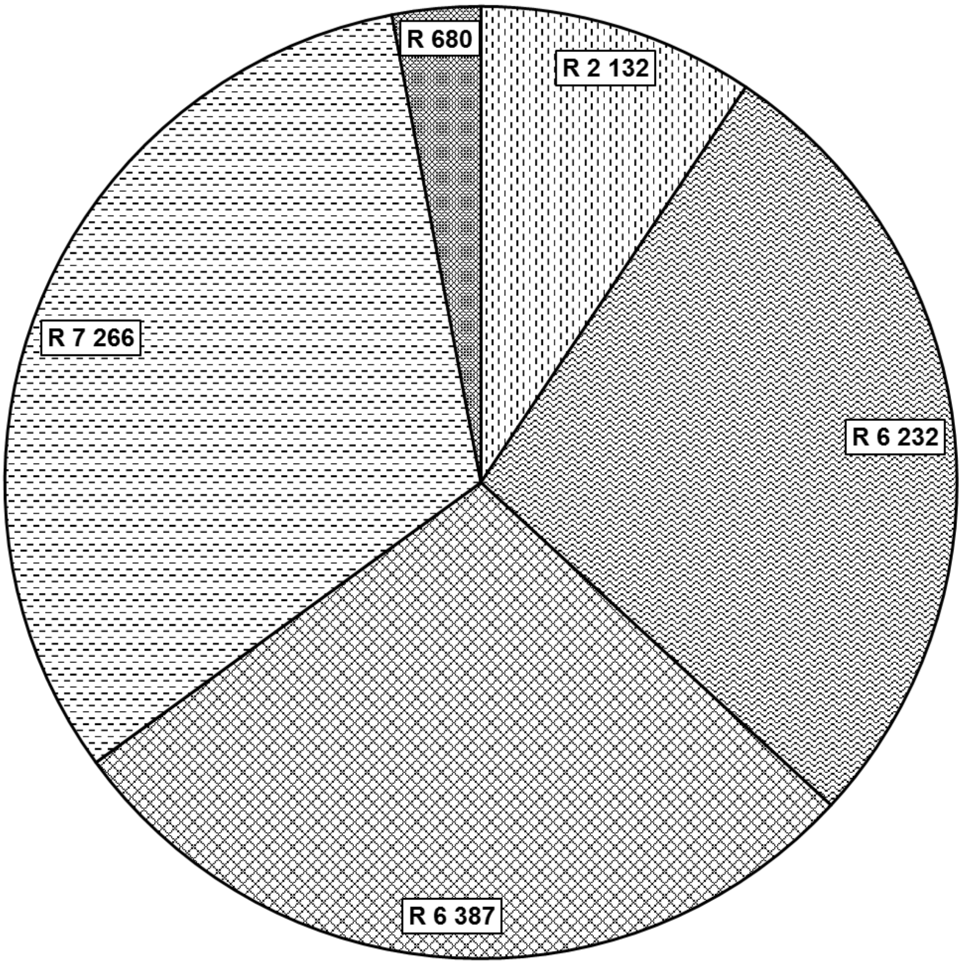

Figure 3.4: The annual angling related expenditure of anglers competing in the Winter- and Summer Classic angling competitions held on Clanwilliam Dam, Western Cape, South Africa. : rods and reels; : terminal tackle; : boat and motor servicing; : insurance and : licensing.

3.3.5 Expenditure in Clanwilliam

Winter Classic

Anglers at the Winter Classic reported that they spent an average of R3 236.25 (n=68) in order to be at the dam and take part in the competition on the weekend. Of this, category 1A expenses made-up an average of R1 398.66 per angler (Figure 3.5). The expenses reported by the organisers come to a total of R46 300.00 within Clanwilliam (Fraser C. 2014, written communication, May 27, 2014). From this it is inferred that the NDEI inferred from angler expenditure of the Winter Classic on the town of Clanwilliam comes to a total of R180 571.53

(Figure 3.6). Accommodation makes up 22% of category 1A expenditures and for the Winter Classic; whilst food and drinks made up 36% (Figure 3.5). These industries would generate higher indirect impacts than fuel as a larger portion would go towards paying local labour, especially within the accommodation sector. Using a multiplier of 0.21, the indirect economic impact of the Winter Classic is estimated as R37 920.02 and the total economic impact of this competition is estimated to be R218 491.55 (Figure 3.6).

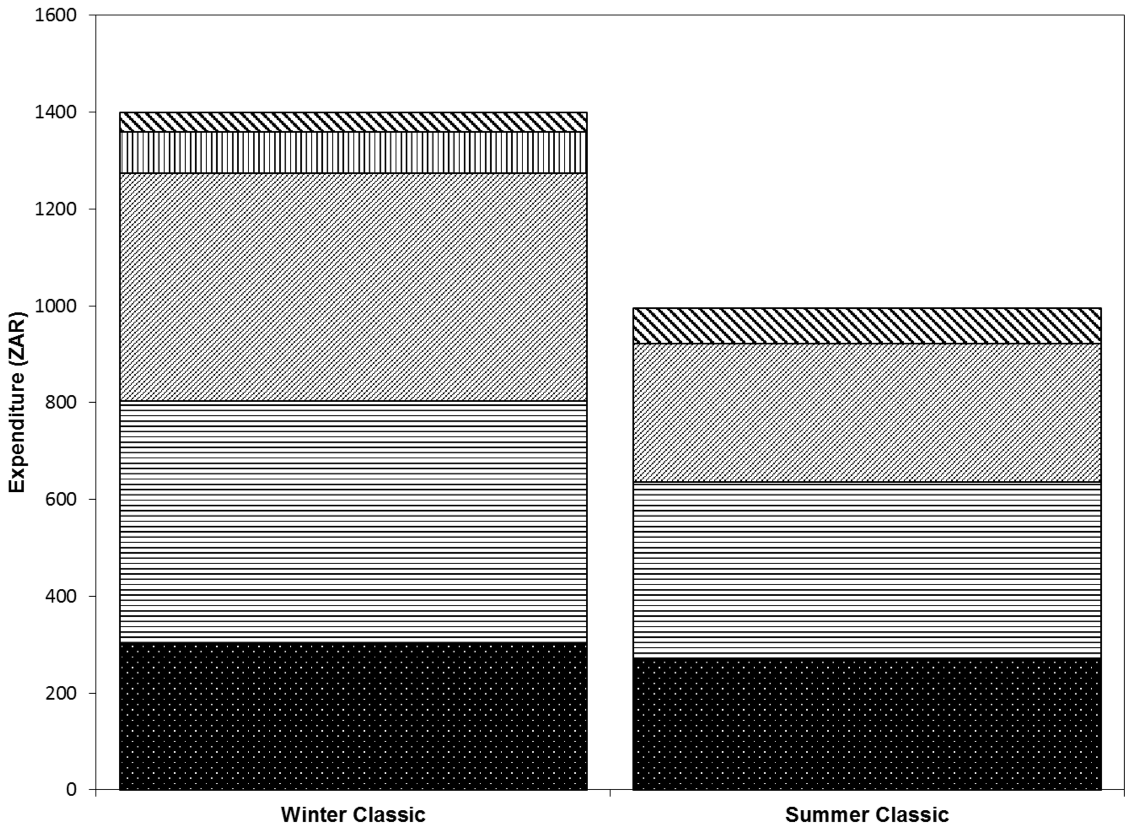

Figure 3.5: The category 1A expenses of the average angler taking part in the Winter and Summer Classic angling competitions held on Clanwilliam Dam, Western Cape, South Africa. : accommodation; : food and drinks; : fuel; : tackle and : other.

Summer Classic

The Summer Classic had 243 participants and 82 of these were interviewed. Anglers at the Summer Classic reported that they spent an average of R2 822.82 (n=82) in order to be at the dam and take part in the competition on the weekend. Of this, category 1A expenses made-up an average of R995.12 per angler (Figure 3.5). The total category 1A expenditure of the 243 anglers taking part in the Summer Classic is therefore estimated as R241 815.00 (Figure 3.6). The expenses reported by the organisers comes to a total of R30 000. Of this, R25 000 was spent at Clanwilliam. (Greenway D. 2014, written communication, May 26). The NDEI inferred from angler expenditure of the Summer Classic on the town of Clanwilliam was R263 866.03 (Figure 3.6). Indirect economic impacts of the competition come to R56 031.15 and the total economic impact of the Summer Classic is estimated as R322 846.15 (Figure 3.6).

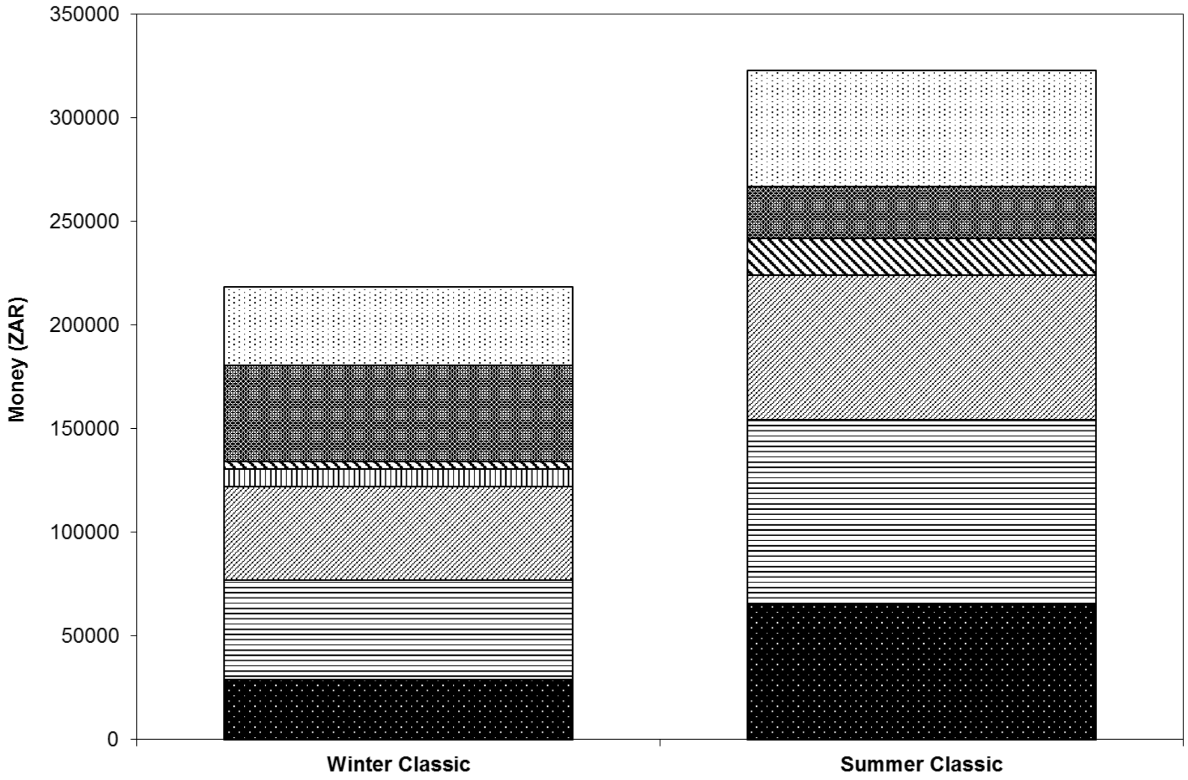

Figure 3.6: The category 1A expenditure and estimated indirect impacts of the Winter and Summer bass classic competitions at the town of Clanwilliam, Western Cape, South Africa. : accommodation; : food and drinks; : fuel; : tackle; : other; : expenditure of organisers and indirect economic impact.

Annual

The average expense incurred by an angler to get to and fish at Clanwilliam Dam for a weekend was R2 617.60 (n=149). Category 1A expenses of one angler trip to Clanwilliam make up R1 138.80 of this amount. It is estimated that a minimum of 302 anglers fish Clanwilliam Dam annually. Of these, 139 were interviewed (46%), representing an accurate sample size of the group. Interviewed anglers reported visiting Clanwilliam Dam to fish for bass 5.86 times per annum. This means that 1757.64 angler trips are made to Clanwilliam Dam annually. Therefore the estimated annual category 1A expenditure of bass anglers to the town of Clanwilliam is R2 000 721.61 (Figure 3.6). If the multiplier of 0.21 is used again, annual indirect economic impact of bass anglers on the town of Clanwilliam comes to R 420 151.54 (Figure 3.7). Therefore the annual total economic impact is estimated as R 2 420 873.15 (Figure 3.7).

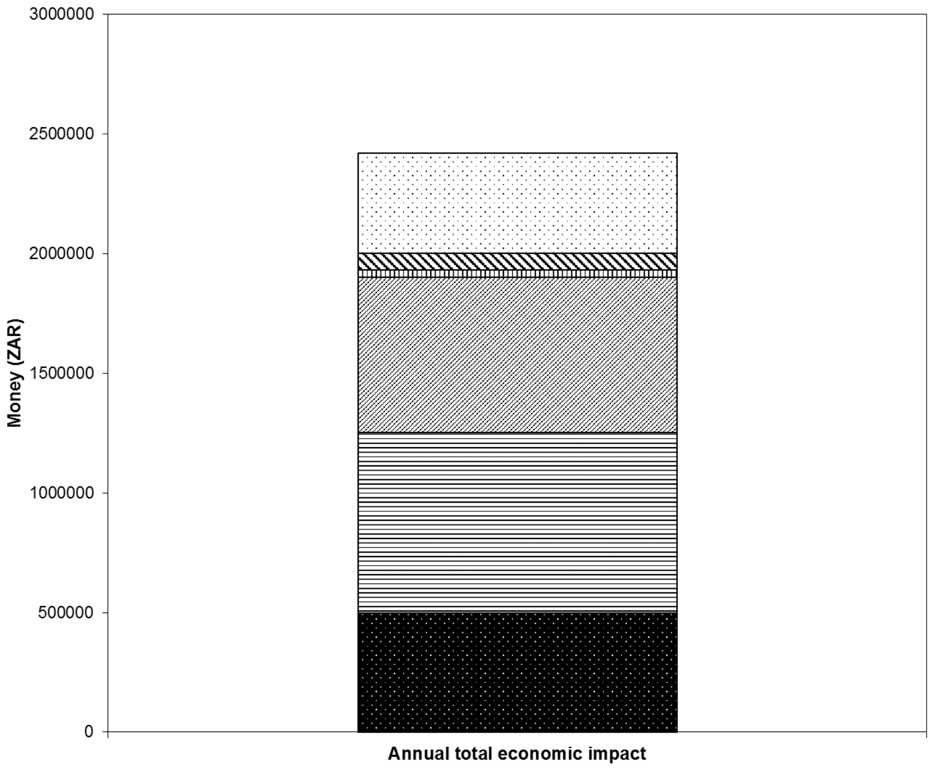

Figure 3.7: A breakdown of the annual expenditure of black bass anglers in Clanwilliam town, Western Cape, South Africa. : accommodation; : food and drinks; : fuel; : tackle; : other and indirect economic impact.

3.4 Discussion

The Clanwilliam Dam recreational bass fishery is one of South Africa's premier smallmouth bass fishing destinations. This study found that it contributes significantly to the economy of the town on its shores. The fishery should be maintained and developed. Collectively the evidence provides a justification for local, contained management of smallmouth bass recreational fisheries in dams, especially those that are not considered areas of high conservation priority.

The estimated R2 million brought into Clanwilliam by bass anglers is a comparatively high value considering that the town only had a population of 7674 in 2011 (Frith, 2014). Furthermore, 62% of the direct expenditure by anglers was spent on food, drinks and accommodation. This money would therefore directly contribute to the employment of those who own or work in shops, restaurants and accommodation facilities.

This estimate is also significant in comparison with other studies which have attempted to quantify the economic impact of environmental attractions. In a study of tourists travelling to view flowers on the Bokkeveld Plateau, an estimated R2.7 million was brought into the Hantam district's economy in 2001 (direct economic impact) (Turpie and Joubert, 2004). If one accounts for inflation, this is the equivalent of approximately R5.5 million in October 2013 when interviews were conducted at the Summer Classic. The estimated NDEI of bass anglers on Clanwilliam, a single dam, in 2013 is already 37% of this amount. The Hantam district's population was 21 578 in 2011 (Frith, 2014) and therefore the impact of this amount would be more diluted in the population than the impact of bass angling on the approximately 7700 individuals in Clanwilliam. There are admittedly difficulties with comparing the present study with that of Turpie and Joubert (2004) because one is comparing the impact of a native species versus an alien species and the regions are different geographically and demographically. However, it is helpful in illustrating that in terms of direct monetary impact, smallmouth bass are similar to a natural resource which in the conservationists' conceptual framework is of infinite value.

Clanwilliam offers bass anglers a unique angling experience. In 2009 the South African record smallmouth bass was caught on the dam. It was recognized by anglers as one of South Africa's premier bass angling destinations (see results) and it is therefore likely that Clanwilliam Dam would have a greater local economic impact than other major dams such as Kwaggaskloof and Theewaterskloof Dams. The economic impact of bass angling on Lake Fork, a man-made impoundment in Texas, United States of America, was estimated by Chen et al. (2003). From the time of the dam's construction it was managed to be a trophy largemouth bass fishery. The study found that Lake Fork generated a higher economic impact than other largemouth bass fisheries. Chen et al. (2003) argue that this was because it had been managed as a trophy fishery (thus offering a unique fishing experience) and therefore attracted more out-of-state anglers than the other fisheries and in turn increased the amount of money it brought into the regional economy. This is most likely the case with Clanwilliam Dam. However, with no management of the fishery it is possible that the quality of the fishing experience could deteriorate, especially with the recent illegal introductions of species such as common carp and sharptooth catfish *Clarias gariepinus* (Burchell). If the dam offered only an equivalent fishing experience to that of Theewaterskloof or Kwaggaskloof, anglers residing in Cape Town would potentially lack the incentive to make the longer journey. If this were the case, there would be a significant economic impact on the town of Clanwilliam from a loss of revenue.

The estimated amount of money spent within Clanwilliam annually by bass anglers of R2 000 722 (which would not be spent in the town if Clanwilliam if the recreational bass fishery did not exist) is a minimum estimate for the following two reasons. Firstly, the 302 anglers who were participants in four competitions are used as the total number of anglers who fish Clanwilliam Dam annually. This figure represents the minimum number of anglers who fish the dam; as many anglers may have motivations other than the competition. Secondly, the estimate represents the impact of anglers only and not of the organizers of the competitions. The organizers of the Classics reported combined expenses within the town of Clanwilliam of R 71 300, an amount excluded from the estimate of annual economic impact. The organisers of the divisional competitions and the Bass Fishing South Africa Money Trail competitions are also likely to have an economic impact on the town. However, as these competitions have far fewer participants, it is likely that their organisers have less of an economic impact than the Winter and Summer Classic organisers. Therefore this estimate represents the formalized bass angling sector and is a minimum estimate of the contribution which bass angling makes to the economy of Clanwilliam town.

The estimates of annual angler expenditure are also minimum estimates. They exclude the following expenditures: angling related clothing, angling related fees and the less frequent purchase of valuable equipment such as boats and boating equipment. This would mean that the estimated annual expenditure would be similar to and potentially greater than that which was reported by Kinghorn (2013). It is most likely that the annual expenditure is spent mostly in the angler's places of residence. At the Summer Classic, 63% were from Cape Town. These anglers are spending approximately R22 700 per year on angling related expense in Cape Town. This suggests that bass angling has a sizeable economic impact there as it contributes towards the income of insurance companies and boat and motor suppliers. Certain industries have also developed around bass angling such as suppliers of lures and the publishing of bass angling magazines.

The estimated multiplier (estimate of how much of the original direct expenditure has a secondary indirect impact within the town) of 0.21 was based upon other similar published studies. Antrobus et al. (1997) calculated a multiplier of 0.18 for the city of Grahamstown for the annual Arts Festival while Chen et al. (2003) studied impact in the Lake Fork region, Texas and reported an estimated multiplier of 0.28. Based on these two studies, Kinghorn (2013) chose a multiplier of 0.23, as his study focused on the impact of angling in the Amathole region and expected a similar multiplier as Chen et al. (2003). However, as most expenses reported in Kinghorn (2013) were towards fuel for boats and vehicles, the indirect impacts of such expenditure would be relatively low within the region of expenditure. For this reason the author estimated a multiplier of 0.23, mid-way between that estimated by Chen et al. (2003) and Antrobus et al. (1997). As the present study is estimating impact on a town, the multiplier of 0.18 estimated by Antrobus et al. (1997) for the city of Grahamstown is very informative. However, due to the fact that a large portion of angling impact is upon the accommodation and food and drinks sectors, the multiplier was estimated to be between that which was used by Kinghorn (2013) and Antrobus et al. (1997).

The present study reports the economic impact of bass angling in Clanwilliam only, but the provincial economic impact of bass angling would exceed this estimate. There are black bass competitions on two other major dams in the Western Cape (Theewaterskloof and Kwaggaskloof) and at numerous other smaller dams and rivers within the province (Figure 3.8). Although competitions at each of these venues would have a localised economic impact, the combined and broadly dispersed nature of these would be significant for the region as a whole. This economic impact therefore provides some justification for the management of black bass fisheries in Western Cape dams, so that their economic benefits are maintained and possibly even enhanced. The economic impacts reported by both Chen et al. (2003) and Fedler (2009) are vastly greater than those reported in this and other local studies. However, the average expenditure per angler per trip reported by Chen et al. (2003) and Fedler (2009) is similar to those reported in this study. Therefore, the per capita expenditure of anglers does not explain the difference in the magnitude of the economic impact. Rather it is the number of anglers who make use of these fisheries which mean that they have a larger economic impact than local fisheries. This could be attributed to cultural differences, or the fact that the water bodies in the United States of America are much larger and can therefore accommodate more anglers.

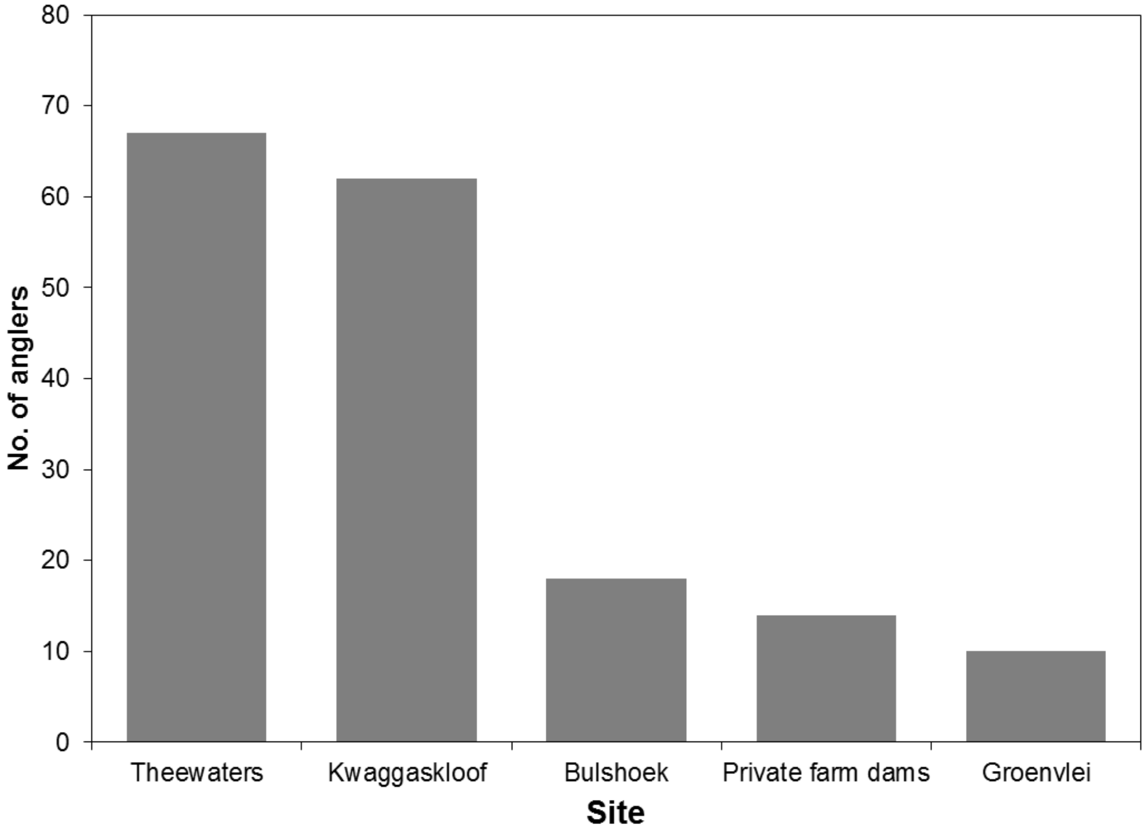

Figure 3.8: Alternate angling destinations within the Western Cape, South Africa and the number of interviewed anglers, who fish at Clanwilliam Dam, Western Cape, South Africa, who reported that they fish them.

To develop and exploit South Africa's inland fisheries, better policy is required (Weyl et al. 2007). Informatiuon such as that gathered during this study would be useful for the development of this policy. The findings of this research suggest that black bass angling has a significant positive impact throughout the Cape Floristic Region (CFR). A challenge facing policy makers is to reconcile the interests of those who benefit from recreation fisheries which have developed around black bass with the goals of conservation authorities. By setting clear and appropriate management objectives for fisheries and water bodies in the CFR and nationally it may be possible to develop recreational fisheries while not obstructing conservation goals (Cowx et al. 2010). Further research on other recreational fisheries in South Africa is required so that appropriate management objectives can be set.

3.5 References

Antrobus G, Williams V, Fryer D, Khumalo B, Streak J, Webb A (1997) The economic impact of the 1996 Standard Bank National Arts Festival. Rhodes University, Grahamstown.

Bass Fishing South Africa. Bassfishing.co.za [homepage on the internet]. Cape Town: Saartchi andSaartchi Synergize; no date [cited 27 May 2014] Available from: www.bassfishing.co.za.

Bradford DF, Cooper SC, Jenkins TM, Kratz K, Sarnelle O, Brown AD (1998) Influences of natural acidity and introduced fish on faunal assemblages in California alpine lakes. Canadian Journal of Fisheries and Aquatic Science. 55: 2457-2491.

Buria L, Albariño R, Villanueva VD, Modenutti B, Balseiro E (2007) Impact of exotic rainbow trout on the benthic macro-invertebrate community from Andean-Patagonian headwater streams. Fundamental and Applied Limnology. 168: 145-154.

Cambray JA (2003) Impact on indigenous species biodiversity caused by the globalisation of alien recreational freshwater fisheries. Hydrobiologia. 500: 217-230.

Chen RJ, Hunt KM, Ditton RB (2003) Estimating the economic impacts of a trophy largemouth bass fishery: issues and applications. North American Journal of Fisheries Management. 23: 835-844.

Cowx IG (1994) Stocking strategies. Fisheries Management and Ecology. 1: 15-31.

Cowx IG, Arlinghaus R, Crooke SJ (2010) Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters. Journal of Fish Biology. 76: 2194-2215.

De Moor IJ, Bruton MN (1988) Atlas of alien and translocated indigenous aquatic animals in southern Africa. South African National Scientific Programmes Report No. 144. Council for Scientific and Industrial Research, Pretoria.

Du Preez M, Lee DE (2010) The contribution of trout fly fishing to the economy of Rhodes, North Eastern Cape, South Africa. Development Southern Africa. 27: 241-253.

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

Fedler T (2009) The economic impact of recreational angling in the Everglades Region. Tarpon and Bonefish Trust, Key Largo.

Flecker AS, Townsend CR (1994) Community wide consequences of trout introduction in New Zealand streams. Ecological Applications. 4: 798-807.

Frith A. Census 2011 [homepage on internet]. Cape Town: Adrian Frith; no date [cited on 1 July 2014]. Available from: census2011.adrianfrith.com

Goldschmidt T, Witte F, Wanink J (1993) Cascading effects of the introduced Nile perch on the detritivorous phytoplanktivorous species in the sublittoral areas of Lake Victoria. Conservation Biology. 7: 686-700.

Government Gazette (2014) National Environmental Management: Biodiversity Act (10/2004): Draft Alien and Invasive Species Lists. Pretoria.

Gozlan RE (2008) Introduction of non-native freshwater fish: is it all bad? Fish and Fisheries Management. 10: 109-110.

Khan TA, Wilson ME, Khan MI (2003) Evidence for invasive carp mediated trophic cascade in shallow lakes of western Victoria, Australia. Hydrobiologia. 506: 465-472

Kinghorn J (2013) The value of non-native fish species: a study of recreational angling in the Amathole district. Unpublished Msc Thesis Rhodes University, Grahamstown.

Leibold ML, van Zyl CJ (2008) The economic impact of sport and recreational angling in the Republic of South Africa, 2007. Unpublished report. Development Strategies International (Pty) LTD, Cape Town.

MacRae PSD, Jackson DA (2001) The influence of smallmouth bass (*Micropterus dolomieu*) and habitat complexity on the structure of littoral zone fish assemblages. Canadian Journal of Fisheries and Aquatic Science. 58: 342-351.

Maezono Y, Kobayashi R, Kusahara M, Miyashita T (2005) Direct and indirect effects of exotic bass and bluegill on exotic and native organisms in farm ponds. Ecological Applications. 15: 638-650.

Marr SM, Marchetti MP, Olden JD, García-Berthou E, Morgan DL, Arismendi I, Day JA, Griffiths CL, Skelton PH (2010) Freshwater fish introduction in Mediterranean-climate regions: are there commonalities in the conservation problem. Diversity and Distributions. 16: 606-619.

Mccafferty JR, Ellender BR, Weyl OLF, Britz PJ (2012) The use of water resources for inland fisheries in South Africa. Water SA. 38: 327-344.

McIntosh AR, Townsend CR (1996) Interactions between fish, grazing invertebrates and algae in a New Zealand stream: a trophic cascade mediated by fish-induced changes to grazer behaviour? Oecologia. 108: 174-181.

Myles AE, Swaim J (2010) Economic impact of collegiate bass tournaments: experiences from Auburn University. Southern Agricultural Economics Association, Orlando.

Pascuel MA, Lancelotti JL, Ernst B, Ciancio JE, Aedo E, García-Asorey M (2009) Scale connectivity, and incentives in the introduction and management of non-native species: the case of exotic salmonids in Patagonia. Frontiers in Ecology and the Environment. 7: 533-540.

South African Bass Anglers Asscociation. S.A.B.A.A. Durban: Always Active Technologies; 2011 [cited on: 2014 May 28]. Available from: www.sabaa.co.za

Townsend CR (1996) Invasion biology and ecological impacts of brown trout, *Salmo trutta*, in New Zealand. Biological Conservation. 78: 13–22.

Turpie J, Joubert A (2004) The value of flower tourism on the Bokkeveld Plateau- a botanical hotspot. Development Southern Africa. 21: 645-662.

Tweddle D, Bills R, Swartz E, Coetzer W, Da Costa L, Engelbrecht J, Cambray J, Marshall B, Impson D, Skelton P, Darwall WRT, Smith KG (2009) The status and distribution of freshwater fishes. In Darwall WRT, Smith KG, Tweddle D, Skelton P (Eds.). The status and distribution of freshwater biodiversity in southern Africa. Internation Union for

Conservation of Nature, Gland, Switzerland and South African Institute for Aquatic Biodiversity, Grahamstown, South Africa.

Tyrrell TJ, Johnson RJ (2001) A framework for assessing direct economic impacts of tourist events: Distinguishing origins, destinations, and causes of expenditures. Journal of Travel Research. 40: 94-100.

Weyl OLF, Potts W, Rouhani Q, Britz P (2007) The need for an inland fisheries policy in South Africa: A case study of the North West Province. Water SA. 33: 497-504.

Weyl OLF, Finlayson BJ, Impson ND, Woodford DJ, Steinkjer J (2014) Threatened endemic fishes in South Africa's Cape Floristic Region: A new beginning for the Rondegat River. Fisheries. 39: 270-279.

Witte F, Goldschmidt T, Wanink J, Vanoijen M, Goudswaard K, Wittemaas E, Bouton N (1992) The destruction of an endemic species flock – quantitative data on the decline of the haplochromine cichlids of Lake Victoria. Environmental Biology of Fishes. 34: 1-28.

CHAPTER 4: ESTIMATING THE COST OF THE RONDEGAT REHABILITATION PROJECT

4.1 Introduction

Management of invasive alien species is potentially very expensive (Lovell et al. 2006). These costs are important to consider as they guide future management by providing insight into the feasibility of future control efforts (Caffrey et al. 2014). The Rondegat River rotenone treatments were intended to be a pilot study. If the project is to achieve that aim it is important that not only the outcomes of the treatments are documented but also the inputs.

The treatment of the Rondegat River was achieved by a process formally initiated in 2004 and resulted in an initial treatment in February 2012. The planning and implementation of first treatment received a lot of attention in the media (Impson and van der Walt, 2014). Not all of this attention was favourable and so a large amount of effort was placed on stakeholder engagement and public relations (D. Impson, written comm. Sept. 22 2014). This added to the cost of the first treatment, but was crucial in order for the project to proceed and so that the intervention was not influenced by the deliberate reintroduction of alien species by stakeholders. Examples of the public relations efforts are the production of a video documenting the treatment and the presence of senior CapeNature staff during the first treatment. This ensured that any potential disruption on the day of treatment, or unexpected media involvement, could be effectively addressed (D. Impson, pers. comm.). These senior staff did not attend the second treatment, because the first treatment had progressed smoothly. Furthermore, the first treatment was a learning experience for those involved because it was the first of its type in a South African river. It thus required more planning more labour and more procurement of equipment than the second treatment. For example during the first treatment there were seven drip stations each manned by two individuals, while during the second there were only four such treatments and each was manned by only one individual.

The aim of this study is to get an estimate of treatment costs which could inform potential future treatments on other rivers that are conservation priorities. Although an estimate has been made of the cost of the project (Impson et al. 2013), it includes efforts dating back a decade, which involved preliminary planning and was not focused on the Rondegat River but on alien fish eradication in general. The objectives are to determine the cost of money and time incurred by CapeNature in the 2011/12 and 2012/13 financial years that went towards implementing the Rondegat River smallmouth bass removal project.

4.2 Material and Methods

Project costs were divided into four categories, namely cost of labour, major expenses which exceeded R10 000, minor expenses such as stationary and equipment less than R10 000, transport and food and external services provided. Cost estimates for each category was as described below.

4.2.1 Estimating cost of labour

Man hours were determined from personal communication and semi-structured interviews with those responsible for the implementation of the project. Implementers were asked how many hours they spent planning and implementing the treatments. The names of persons responsible for various tasks during the week of the second treatment were obtained from Impson and van der Walt (2013) and through personal communication with Dean Impson (CapeNature Scientist Freshwater Fishes). The cost of the each individual's time per hour was determined by dividing the annual salary for their specific post level by the number of hours worked per year.

4.2.2 Estimating costs of external service providers

A number of tasks were contracted out to different external service providers. These include two environmental impact assessments, one for the treatment itself and one for the adjustments to the in-stream weir. Other tasks contracted out to companies outside of CapeNature included importing the rotenone from the United States of America, the production of an awareness video documenting the efforts of the project, other public relations and promotion material, clearing the channel of vegetation to enable easier access to the river during the second treatment, raising the weir and legal assistance. The cost of all these were acquired from reviewing CapeNature's financial records for these financial years.

4.2.3 Estimating costs for capital costs and travel

The cost of equipment, chemicals and all other items purchased for the project was acquired from financial records maintained by CapeNature. These records were also used to determine the travel and catering costs incurred for both treatments.

4.3 Results and Discussion

The largest expenditure item was labour costs, which was R491 384 for the first treatment and R211 910 for the second treatment (Table 4.1). A total of 5079 hours were dedicated towards the Rondegat River smallmouth bass removal project from 2011-2013 (Appendix 4). The post of each person involved in the project is included in Appendix 4 to give an indication of expertise required for each role. Thirty-three staff members working a total of 3389 hours within the 2011/12 financial year were required to plan and implement the first treatment, while only 20 staff members working a total of 1190 man-hours were required in the planning and execution of the second treatment (Appendix 4). The total cost of the 5079 hours was R703 294. The total cost of all expenses incurred for the first treatment comes to R921 830 and the total cost for the second treatment comes to R495 910 (Table 4.1). As mentioned this does not account for hours spent on the project since its inception, but is a good estimate of the number of man hours that would be required for implementing similar projects elsewhere in the CFR.

Table 4.1: The costs of the Rondegat smallmouth bass removal project implemented on the Rondegat , Western Cape, South Africa in 2012 and 2013.

2011/12	Cost (R)	2012/13	Cost (R)
Labour[a]	**491 384.29**	**Labour [a]**	**211 910.48**
Overall planning	282 608.64	Overall planning	140 846.98
Administration	80 000.80	Administration	6 227.24
Strategic senior staff	15 000.00	Application	64 836.26
Application	113 774.85		
Major puchases (>R10 000)	**99 278.98**	**Major puchases (< R10 000)**	**24 634.05**
Communications equipment	27 268.80	Electronic equipment	10 099.97
Rotenone	34 104.40	Clothing	14 534.08
Clothing (uniforms and safety)	37 905.78		
Minor purchases (<R10 000)	**73 031.87**	**Minor purchases (<R10 000)**	**31 821.19**
Transport and food	**91 461.02**	**Transport and food**	**129 585.16**
External services provided	**166 674.56**	**External services provided**	**112 494.12**
Environmental impact assessment of weir adjustments	62 620.00	Adjustments to weir	100 993.46
Freight charges for rotenone	11 894.56	Clearing of river channel vegetation	11 500.66
Short video of project	82 660.10		
Legal assistence	37 572.00		
Other	34 547.90		
Total	**921 830.72**	**Total**	**510 445.00**
	Total project costs:		**1 432 275.72**
	Cost per kilometer:		**358 068.93**

[a]for a more detailed breakdown of labour refer to Appendix 4

The total cost of the project is estimated to be R 1 432 275.72(Table 4.1). This translates to a cost of R 358 068 per kilometre of river which was treated. There are plans to use rotenone in several streams where invasive fish pose a serious threat to native fauna (Impson and van der Walt, 2014). Each river will have unique challenges and costs, however, the value of R 358 068 per kilometre could potentially inform and guide planning of these projects.

This estimate has limitations. As mentioned, costs are only documented from the 2011/12 and 2012/13 financial years. That is why this estimate is significantly less than the estimate by Impson et al. (2013). An example of the a large cost which is excluded from this analysis is the environmental impact assessment which evaluated the potential use of rotenone to eradicate alien fish from four rivers in the Cape Floristic Region (CFR) and suggested the Rondegat River as pilot project (Enviro-Fish Africa, 2009). This assessment was conducted in 2008 and is excluded from this cost analysis for two reasons. Firstly, the assessment was carried out for four rivers in the CFR, not just the Rondegat River and secondly it was a cost that was not incurred within the 2011/12 or 2012/13 financial years. The final planning phase of the project began to focus on the Rondegat River in July 2010 (Impson and van der Walt, 2014) and therefore this study does include most costs involved.

This study is an example of the costs associated with mitigating the negative ecological impacts of an alien invasive species. As smallmouth bass is an example of a typical conflict species, its value to stakeholder groups who benefit from its occurrence must be acknowledged. This species is a popular sport fish and has a considerable positive socio-economic impact both on a local and national scale. This is evident from the amount of money which smallmouth bass anglers annually contribute to the economy of Clanwilliam town as a direct result of having smallmouth bass in Clanwilliam Dam, as illustrated in Chapter 3. When comparing this value to the cost of the rehabilitation of the Rondegat River, it is evident that the cost of reversing the negative ecological impact of the species by removing it is less than the annual financial benefits derived from having the species present in Clanwilliam Dam. At the same time, these benefits are not diminished in any way by the eradication of smallmouth bass from the Rondegat River. Benefits of smallmouth bass were not diminished because the rotenone did not impact on the smallmouth bass population in the dam and the smallmouth bass population in the Rondegat River was of little or no angling value. This shows that the conservation of native fish is both feasible and beneficial and at a cost of R354 435 per kilometre, it makes economic sense to conserve native fishes and maintain smallmouth bass economic benefits by using rotenone and in-stream barriers. The value of the Rondegat project does not lie only in the actual recovery of the indigenous fish fauna but also in illustrating the successful management of a conflict species within the current legislative framework to the benefit of all stakeholders.

Using this costing, a conventional cost-benefit analysis, like that done by De Wit et al. (2001) can be done. To do this requires quantifying, in monetary terms, the benefit derived from the recovery of native fish in the Rondegat River which can be compared to this cost. This benefit could be quantified using a willingness to pay (WTP) valuation. In chapter 3 anglers at Clanwilliam Dam were asked how much they are willing to pay towards projects such as the Rondegat smallmouth bass removal project. However, they are not the appropriate target group for a WTP valuation of native fish recovery on the Rondegat River. The recovery of the threatened native fish fauna reverses the negative ecological impact of the alien invasive species, but the value of this is perceived by the stakeholder groups who either value the conservation of these species (people you visit the river in holiday periods) or are legally mandated to conserve biodiversity (such as the provincial conservation agency). Therefore a WTP valuation would require interviewing these stakeholders in order to determine how much they would be willing to pay towards projects such as the Rondegat River smallmouth bass removal projects. Such a survey was not conducted in this thesis. There is a need for surveys of this nature in order to express the value of native fish fauna in monetary terms.

The outcomes of the treatments of the Rondegat River were as desired (documented in chapter two). This chapter documents how those outcomes were achieved at a relatively low inputs. Low in comparison to the costs of managing other invasive alien species in South Africa (Van Wilgen et al. 2012); low in comparison to the costs of managing freshwater invasive alien species in the United State of America (Lovell et al. 2006; Nghiem et al. 2013) and more significantly, lower than the annual contribution to the local economy as a consequence of a large smallmouth bass population in the Clanwilliam Dam.

4.4 References

Caffrey JM, Baars JR, Barbour JH, Boets P, Boon P, Davenport K, Dick JTA, Early J, Edsman L. Gallagher C, Gross J, Heinimaa P, Horril C, Hudin S, Hulme PE, Hynes S, MacIsaac HJ, Mcloone P, Millane M, Moen TL, Moore N, Newman J, O'Conchuir R, O'Farrell M, O'Flynn C, Oidtmann B, Renals T, Ricciardi A, Roy H, Shaw R, van Valkenburg JLCH, Weyl OLF, Williams F, Lucy FR (2014) Tackling invasive alien species in Europe : the top 20 issues. Management of Biological Invasions. 5: 1–20.

De Wit MP, Crookes DJ, van Wilgen BW (2001) Conflicts of interest in environmental management : estimating the costs and benefits of a tree invasion. Biological Invasions. 3: 167–178.

Enviro-Fish Africa (2009) Environmental impact assessment of the proposed eradication of invasive alien fishes from four river sections in the Cape Floristic Region. Enviro-Fish Africa (Pty) LTD, Grahamstown.

Finlayson B, Schnick R, Skaar D, Anderson J, Demong L, Duffield D, Horton W, Steinkjer J (2010) Planning and standard operating procedures for the use of rotenone in fish management – rotenone SOP manual. American Fisheries Society, Bethesda, Maryland.

Impson ND, van Wilgen BW, Weyl OLF (2013) Coordinated approaches to rehabilitating a river ecosystem invaded by alien plants and fish. South African Journal of Science. 109: 3-6.

Impson ND, van der Walt R (2013) Rondegat River rehabilitation operational plan for the second rotenone treatment. Unpublished CapeNature internal report.

Impson ND, van der Walt R (2014) Rehabilitation of the Rondegat River in the Cederberg, Western Cape: lessons learnt in a project to eradicate alien smallmouth bass using the piscicide rotenone. Unpublished CapeNature internal report.

Lovell SJ, Stone SF, Fernandez L (2006) The economic impacts of aquatic invasive species: a review of the literature. Agricultural and Resource Economics Review. 35: 195–208.

Jordaan MS, Weyl OLF (2013) Determining the minimum effective dose of rotenone for eradication of alien smallmouth bass *Micropterus dolomieu* from a South African river. African Journal of Aquatic Science. 38: 91-95.

Magadlela D, Mdzeke N (2004) Social benefits in the Woking for Water programme as a public works initiative. South African Journal of Science. 100: 94-96.

Nghiem LTP, Soliman T, Yeo DCJ, Tan HTW, Evans TA, Mumford JD, Keller RP, Baker RHA, Corlett RT, Carrasco LR (2013) Economic and environmental impacts of non-indigenous species in Southeast Asia. PloS One. 8: e71255.doi:10.1371/journal.pone. 0071255

Slabbert E, Jordaan MS, Weyl OLF (2014) Analysis of active rotenone concentration during treatment of the Rondegat River, Cape Floristic Region, South Africa. African Journal of Aquatic Science. In press.

CHAPTER 5: FINAL DISCUSSION

A wide variety of impacts are associated with invasive alien species. Environmental impacts refer to ‘measurable changes to the properties of an ecosystem caused by an alien species’ (Ricciardi et al. 2013; Blackburn et al. 2014). As this study also includes socio-economic aspects, impact is more complex. The ecological and economic impacts of invasions are seldom compared and discussed in published literature (Vilà et al. 2010). Furthermore although the socio-economic impacts of invasions are documented, socio-economic impacts are seldom clearly defined (Born et al. 2005, Lovell et al. 2006). Impacts in this study are extended to include to measurable economic changes (Jeschke et al. 2014). It is important to consider that impacts are often bidirectional (can be negative and positive), an alien species often has as many socio-economic impacts as ecological ones, and impact can vary greatly on a spatial scale (Ricciardi et al. 2013; Jeschke et al. 2014). Impact is an effect of an action. That is why impacts of a deliberately introduced species are essentially anthropogenic (Blackburn et al. 2014). This thesis focuses on the impacts which the introduction of smallmouth bass has had on the Rondegat River in the Cape Floristic Region (CFR).

Value and positive impact are not the same concept. This study has largely avoided terminology referring to value as it is a difficult term to measure and describe and it means different things to different people (Estévez et al. 2014). For example, the estimates of positive economic impact documented in this study are estimates of actual amounts of money coming into the balance sheets of businesses in Clanwilliam town. What that money means to the owners and employees of the impacted businesses is a question of value. Similarly, the death of any species, invasive or native, is often not popular with members of the public. Thus there are often objections to alien eradication projects and these stem from individual values. Therefore the present study has rather referred to impact measured as actual amounts of money spent or as actual number of native fish recovering. To avoid difficulties arising from differences in value, this thesis does not aim to document the value of smallmouth bass or of native fishes.

The impacts described in this thesis are not surprising given the traits of the alien species i.e. aggressive predator making it an excellent sports fish (MacRae and Jackson, 2001) as well as the traits of the CFR rivers and streams which it has invaded i.e. lacking biotic resistance (Marr et al. 2010; Weyl et al. 2014). The negative ecological impacts could have been predicted had the introduction of black bass been more recent (Baltz and Moyle 1993; Clavero and García-Berthou 2005; Marr et al. 2010; Dick et al. 2013). This reinforces the value of research into predicting impacts of alien species and applying this knowledge before species are introduced. However predictable these impacts are, the impacts differ greatly within a small geographical area. Even though the impacts are measured in different units and therefore cannot be compared, it is useful to consider the invaded system and to describe these impacts.

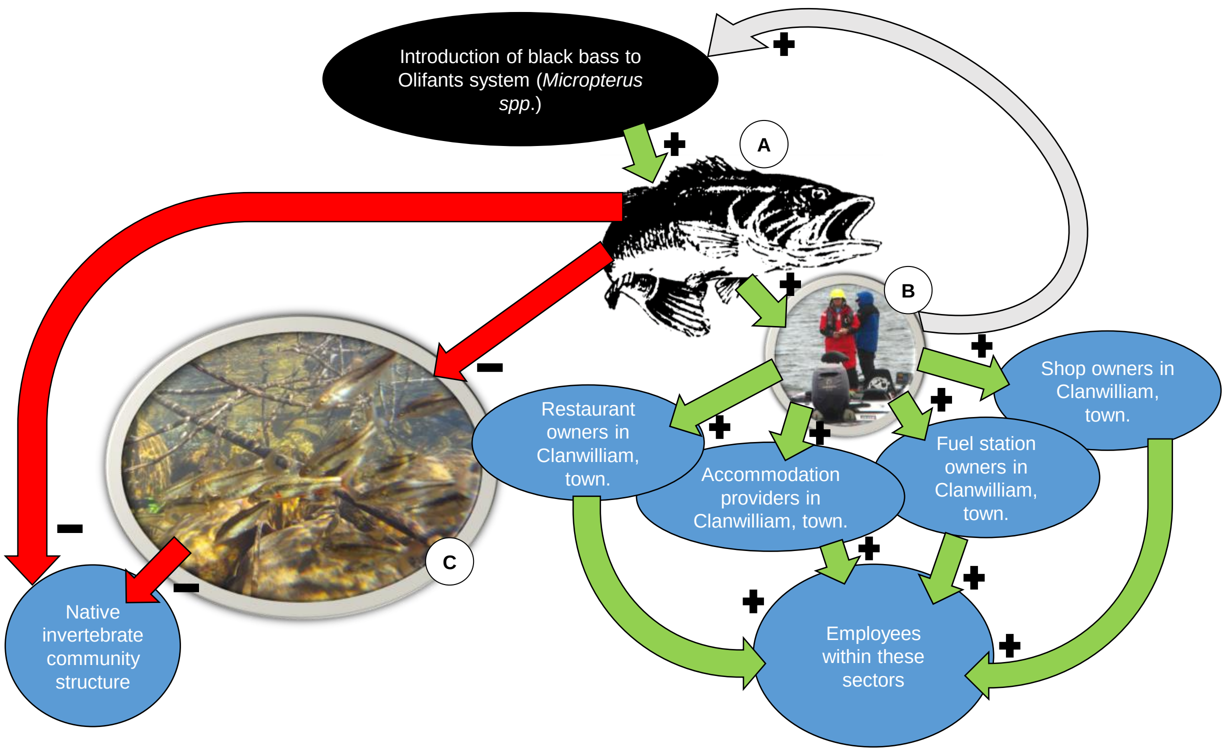

Figure 5.1: The flow of impacts following the introduction of smallmouth bass to the Olifants River system, Western Cape, South Africa. Black shapes indicate the anthropogenic action which drove the flow of impacts. Blue shapes or pictures are impacted groups. Arrows indicate flow of impact; red arrows and – indicate negative impacts, while green arrows and + indicate positive; the grey arrow represents the potential for anglers to reintroduce/stock the system with smallmouth bass. **A.** The smallmouth bass population established in the Olifants system. **B.** Recreational anglers who target smallmouth bass in Clanwilliam Dam. **C.** Native fishes in headwater streams of the Olifants system.

The conceptual flow of the impacts of the introduction of smallmouth bass is shown in Figure 5.1. The introduction of smallmouth bass to the Olifants River (and therefore Clanwilliam Dam) directly impacted the Rondegat River as well, since these systems are within the same catchment and therefore directly connected. Following the introduction of smallmouth bass to the Olifants system, a population established which was large enough to sustain a recreational fishery in Clanwilliam Dam. Most competition anglers do not reside in Clanwilliam town and when they come to fish in the Clanwilliam Dam, they spend money in the town. This study has estimated that approximately R 2 million is spent in Clanwilliam town annually by smallmouth bass anglers which would otherwise not be spent there (Chapter 3). The owners of fuel stations, shops, restaurants and accommodation in Clanwilliam town benefit directly as angler's money is spent in exchange for their products and services. This indirectly contributes to employment within these sectors and thus improves the lives of the population of Clanwilliam town. This illustrates that the introduction of smallmouth bass to the Olifants' system has had a positive socio-economic impact.

The introduction of smallmouth bass to the Olifant's system has, however, also resulted in negative ecological impacts as can be seen in Figure 5.1. Native fish communities of the Olifants River system were not well studied before smallmouth bass were introduced in the 1940's (Harrison, 1953) and there is a lack of quantitative pre-invasion data. However, the survey data of the control reach provided an indication of the pre-invasion state of the river. Although the data collection for the study was completed only 12 months after the final treatment, the results already indicate that the native fish have recovered significantly within the treatment reach. The difference between the invaded and the recovered state is a good measure of the minimum impact of smallmouth bass on the native fish community and future monitoring will provide better insights into what the pre-invasion state of the river was. A year of monitoring following eradication, as presented in Chapter 2, show that smallmouth bass prevented the existence of three native fish populations in the Rondegat River where it had invaded. Smallmouth bass also indirectly impacted invertebrates in the Rondegat River (Lowe et al. 2008). Based on the results of earlier studies (Woodford et al. 2005; Weyl et al. 2013) and the results of Chapter 2, it can be concluded that smallmouth bass has had significant negative ecological impacts in the Olifant's River and associated systems.

If one considers the system according to Figure 5.1 there appears to be a conflict between resolving the negative impacts and maintaining the positive impacts of smallmouth bass in the Olifants system. When the affect of the Rondegat River rehabilitation project is added to the conceptual diagram (Figure 5.2) and the smallmouth bass population in Clanwilliam Dam and in the Rondegat River are split it is clear that the negative impacts of smallmouth bass in the headwater streams can be mitigated whilst the positive impacts in the mainstream system can be maintained. This distinction is made possible by the presence of and adjustments to an in-stream weir which acts as a barrier separating the smallmouth bass populations. This distinction is also possible, or rather feasible because areas of high conservation priority overlap with areas of low or no bass angling value, whilst areas with low conservation value have high angling value. Because this spatial distinction can be made, smallmouth bass can be managed to meet the priorities of all interested parties.

The NEM: BA Invasive Alien Species Regulations (2014) categorize and provide a mandate to appropriate organs of state to develop management plans for the monitoring, control or eradication of invasive alien species. Smallmouth bass are currently category 1B species within protected areas but category 2 outside these areas (Government Gazette, 2014). Any transfer of a category 1B species is restricted, while a category 2 species can, with a permit, be stocked and translocated within their current distribution range. Effectively smallmouth bass can be managed differently in different geographic localities, depending on the ecological threat posed. For example, a dam, which is not necessarily considered a conservation priority ecosystem, can be managed as a recreational fishery, whilst smallmouth bass in a stream with an endangered native fish can be removed. This is in-line with suggested strategies for evaluating a stocking programme to maximise socio-economic benefit while mitigating against environmental harm, thereby avoiding conflict (Cowx, 1994; Richardson and Wilgen 2004). The first step in such a strategy would be to set appropriate objectives for South Africa's various inland fisheries and water bodies (Cowx, 1994). Figure 5.2 shows how the NEM: BA categorization of smallmouth bass contributes towards making the distinction between useful and unwanted populations of smallmouth bass.

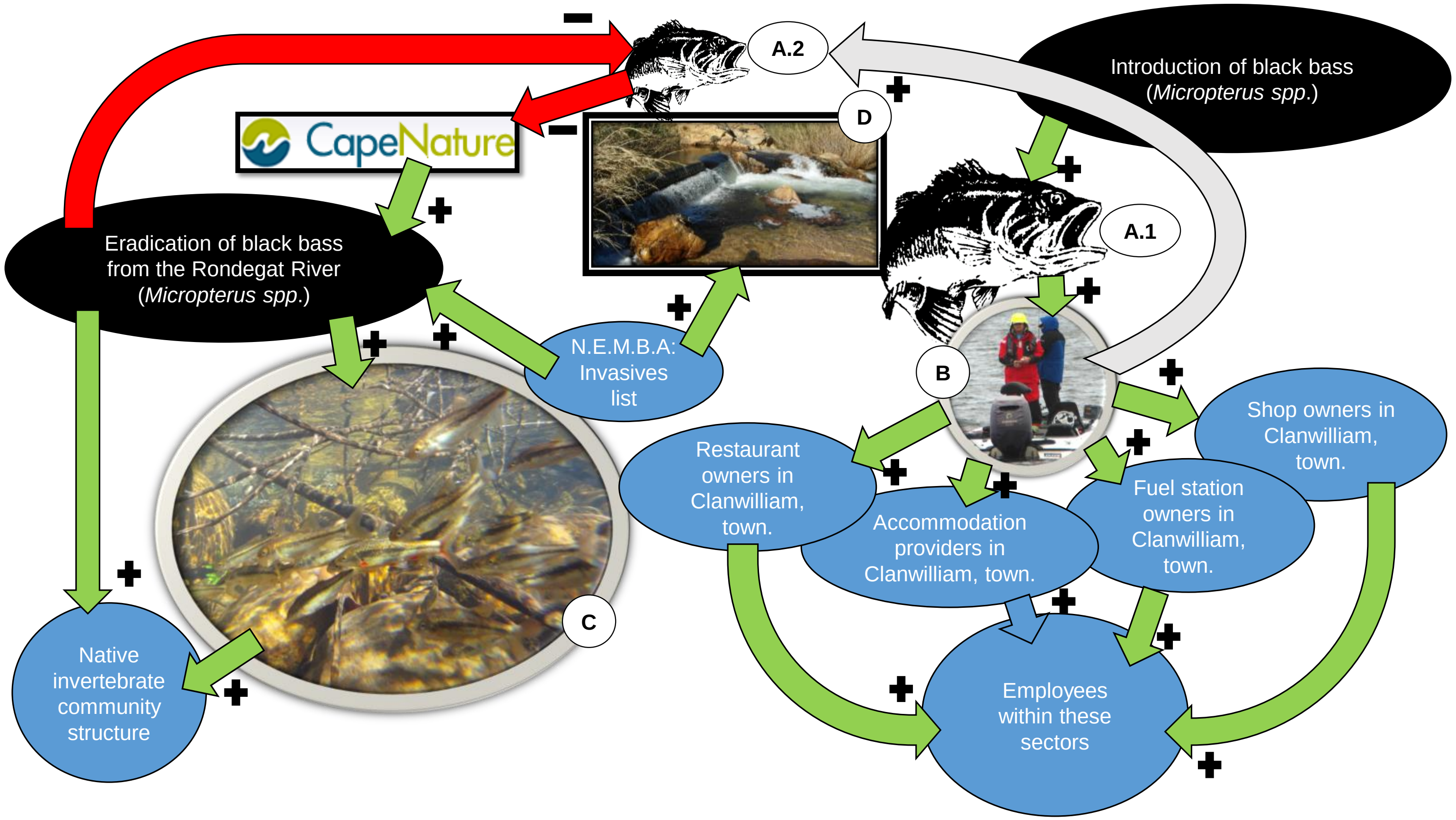

Figure 5.2: The effect of the intervention by CapeNature in the Rondegat Rive on the flow of impacts of smallmouth bass within the Olifant's River system, Western Cape, South Africa. Black shapes indicate the anthropogenic action which drives the flow of impacts. Blue shapes or pictures are impacted groups. Arrows indicate flow of impact; red arrows and – indicate negative impacts, while green arrows and + indicate positive; the grey arrow represents the potential stocking of the Rondegat River with smallmouth bass. **A.1.** The smallmouth bass population established in the Olifants system. **A.2.** The smallmouth bass population established in the Rondegat River. **B.** Recreational anglers who target smallmouth bass in Clanwilliam Dam. **C.** Native fishes in the Rondegat River. **D.** The adjustments to the in-stream weir in the Rondegat River which created a barrier to smallmouth bass moving upsteam.

The costs of controlling an alien species is an important consideration for making management decisions (Caffrey et al. 2014). As has been done in numerous cases of management and control of alien species in the USA (Leigh, 1998; Pimental, 2000; Lupi et al. 2003), the cost of removing smallmouth bass from the Rondegat River can be taken as a further impact of smallmouth bass (Lovell et al. 2006). Knowing the cost of the project is also helpful to plan for the future use of rotenone for the management of alien fish populations in the CFR. If the costs of removing undesirable populations of smallmouth bass and constructing in-stream barriers are excessively high, then a scenario exists where it would not be financially viable to balance conservation and angling goals. The cost of the Rondegat River Rehabilitation Project at R1.4 million was less than the annual contribution which smallmouth bass anglers make to the Clanwilliam economy annually (Chapter 3). The costs of control therefore do not outweigh the benefits associated with this angling species.

Under the Convention of Biological Diversity (CBD), Aichi biodiversity Target number 9 aims to have eradicated or controlled all priority invasive alien species by 2020. This target is under the strategic goal that aims to ‘Reduce the direct pressures on biodiversity and promote sustainable use’ (Convention of Biological Diversity, 2014). In this case, the invasive species needs to be used sustainably. The Rondegat River Rehabilitation Project is an example of how South Africa is moving towards that target whilst maintaining sustainable use of the alien species. Following the final treatment of the Rondegat River, a workshop was held by CapeNature which involved various angling stakeholders, including members of South African Bass Anglers Association (SABAA) and the Cape Piscatorial Society as well as the South African Institute for Aquatic Biodiversity (SAIAB). The aim of the workshop was to evaluate additional rivers of high conservation priority where alien fish eradication was considered feasible by CapeNature (Van der Walt et al. 2013). Thirteen rivers were evaluated and with the exception of one, it was agreed that these rivers did not have angling value. The success of the Rondegat River eradication project highlights the fact that there is the potential to reclaim a large amount of invaded habitat without causing conflict with anglers. A minimum cost of R 358 068 per kilometre estimated for the Rondegat River removal project should be budgeted for future alien fish removal projects.

NEM:BA categorization of freshwater fish enabled the distinction to be made between desirable and undesirable populations of smallmouth bass. Therefore, in as much as it allowed for the eradication of the smallmouth bass population in the Rondegat, it allows for proactive zoning of existing smallmouth bass fisheries following stakeholder engagement. NEM:BA regulations are not restrictive on recreational fisheries and the recent opposition to the categorization of rainbow trout in particular is very unfortunate (Ellender et al. 2014). Even though rainbow trout fisheries are not restricted to impoundments, priority angling rivers seldom overlap with priority conservation waters (Van der Walt et al. 2013). Therefore, rather than resulting in the loss of recreational fisheries, categorization of rainbow trout in a similar fashion to smallmouth bass would provide a legal basis to maintain current recreational fisheries while still enabling the mitigation of negative ecological impacts (Ellender et al. 2014). Challenging as it has been, policy-makers and stakeholders need to continue working together to overcome their difference in values (Estévez et al. 2014). The same can be said regarding any future alien fish eradication projects planned for the CFR; an inclusive stakeholder engagement process is critical and anglers need to be kept informed and involved in the process.

Freshwater ecosystems experience higher extinction rates and a greater proportion of threatened species than marine and terrestrial ecosystems (Ricciardi and Rasmussen 1999; Dudgeon et al. 2006). While artificial impoundments are necessary to keep up with demands for water, they are known to facilitate freshwater invasions (Havel et al. 2005; Johnson et al. 2008). This is an important consideration in management of water resources. When it is necessary to build an impoundment, the construction of in-stream weirs in all inflowing rivers and streams which are not invaded by smallmouth bass (or any other potential invasive species) should be considered before the impoundment is built. Weirs should be high enough to act as a barrier to smallmouth bass upstream movements, but not have such a great impact on the river flow so as to facilitate invasion themselves. This could prevent the impoundment from facilitating the invasion of headwater streams. There are numerous large impoundments already built in the CFR and many of these support recreational black bass fisheries. The most notable of these are the Brandvlei/Kwaggaskloof Dam and the Theewaterskloof Dam. The ichthyofauna of the rivers and streams flowing into these two dams should be monitored in order to determine the feasibility of conducting alien eradication projects similar to the Rondegat project.

Smallmouth bass have a widespread distribution throughout the CFR. Most mainstream rivers have been invaded (Weyl et al. 2014) whilst headwater streams offer a last refuge for native fish species. Predictive models suggest that in Canada, climate change will facilitate invasion by smallmouth bass (Sharma and Jackson, 2008). There is therefore a need to research and predict the impact which climate change will have on alien fish distributions in South Africa. Headwater streams in which smallmouth bass invasion has been halted by edaphic characteristics, such as, temperature as opposed to physical barriers need to be identified as systems vulnerable to climate change facilitated invasion. The possibility of inserting physical barriers in such systems should be considered.

There have also been concerns that major alien clearing efforts have not been effective (McConnachie et al. 2012). The use of rotenone in conservation is potentially very controversial (Impson and van der Walt, 2014; Weyl et al. 2014). If the removal of smallmouth bass from the Rondegat River using rotenone is to fulfil its original purpose as a pilot study, its efficacy must act as evidence, either for or against the future use of rotenone for alien fish eradication attempts in the CFR. The removal of smallmouth bass from the Rondegat River is in many ways an attempt to restore a natural ecosystem. Restoration in the South Africa needs to be evidence based, however in most South African restoration attempts, the inputs (time and money) are better documented than the outcomes of these attempts (how effective they were at achieving their goals) (Ntshotsho et al. 2011). This study documents inputs (effort and expenditure) and outcomes (smallmouth bass eradication and native fish recovery) of the project and both are evidence that rotenone is an effective restoration tool for invaded freshwater ecosystems.

Rotenone has been used to reclaim invaded water bodies for native fish in many parts of the world (Lintermans 2000; Britton and Brazier 2006; Pham et al. 2013). The Rondegat River project is, however, the first time that it has been officially used to eradicate an alien fish in a South African stream and the present study illustrates the successful recolonization of the native fish community post-treatment. With the success of this pilot study, rotenone has been shown to be a valuable tool for managing alien species in South Africa to ensure survival of native fish communities. This is especially relevant given the on-going discovery of new fish species and many new lineages within currently described species (Skelton and Swartz, 2011; Chakona and Swartz 2013). The majority of these lineages are expected to be highly threatened and range-restricted, which highlights the need for urgent and effective conservation interventions, many of which will relate to the management of invasive alien species. With appropriate research and monitoring, rotenone should be used to successfully manage alien fish invasions to increase habitat availability to other native species.

The success of the Rondegat River smallmouth removal and rehabilitation can be undone by disgruntled stakeholders (Figure 5.2). Any group (business owners as well as anglers) which benefits from the presence of smallmouth bass might have an incentive to reintroduce smallmouth bass above the weir in the Rondegat River. This is however, an unlikely scenario. Firstly, the Rondegat River was never an important priority recreational fishery and the smallmouth bass which were removed were not large individuals (Weyl et al. 2013). Secondly, CapeNature engaged with stakeholders and bass anglers volunteered to participate during the first treatment (Impson and van der Walt (2014). Although a reintroduction scenario is unlikely, it highlights the need for stakeholder engagement during management of invasive alien species which have positive impacts.

There is clearly a potential conflict of interest in managing smallmouth bass, but this study documents a management effort which was able to mitigate negative without negating the positive impacts. This approach, which considered all stakeholders, is made possible through well thought-out legislation. There is a need, however, to set appropriate objectives for freshwater bodies of low conservation priority. This would empower the development of inland recreational smallmouth bass fisheries and dams so that positive impacts of recreational fisheries can be enhanced while simultaneously mitigating the negative impacts of the species especially in headwater streams where it is geographically possible to apply control measures. .

5.1 References

Baltz DM, Moyle PB (1993) Invasion resistance to introduced species by a native assemblage of California stream fishes. Ecological Applications. 3: 246–255.

Blackburn TM, Essl F, Evans T, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Marková Z, Mrugala A, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Ricciardi A, Richardson DM, Sendek A, Vilà M, Wilson JRU, Winter M, Genovesi P, Bacher S (2014) A unified classification of alien species based on the magnitude of their environmental impacts. PLoS Biology. 12: e1001850. doi:10.1371/journal.pbio.1001850

Born W, Rauschmayer F, Bräuer I (2005) Economic evaluation of biological invasions – a survey. Ecological Economics. 55: 321-336.

Britton JR, Brazier M (2006) Eradicating the invasive topmouth gudgeon, *Pseudorasbora parva*, from a recreational fishery in Northern England. Fisheries Management and Ecology. 13: 329-335.

Caffrey JM, Baars JR, Barbour JH, Boets P, Boon P, Davenport K, Dick JTA, Early J, Edsman L. Gallagher C, Gross J, Heinimaa P, Horril C, Hudin S, Hulme PE, Hynes S, MacIsaac HJ, Mcloone P, Millane M, Moen TL, Moore N, Newman J, O'Conchuir R, O'Farrell M, O'Flynn C, Oidtmann B, Renals T, Ricciardi A, Roy H, Shaw R, van Valkenburg JLCH, Weyl OLF, Williams F, Lucy FR (2014) Tackling invasive alien species in Europe : the top 20 issues. Management of Biological Invasions. 5: 1–20.

Chakona A, Swartz ER (2013) A new redfin species, *Pseudobarbus skeltoni* (Cyprinidae, Teleostei), from the Cape Floristic Region, South Africa. Zootaxa. 3686: 565-577.

Clavero M, García-Berthou E (2005) Invasive species are a leading cause of animal extinctions. Trends in Ecology and Evolution. 20: 110.

Conservation of Biological Diversity. Cbd.int. [homepage on the internet]. No date [cited 2014 September 9] Available from www.cbd.int/sp/targets.

Cowx IG (1994) Stocking strategies. Fisheries Management and Ecology. 1: 15-31.

Dick JTA, Gallagher K, Avlijas S, Clarke HC, Lewis SE, Leung S, Minchin D, Caffrey J, Alexander ME, Maguire C, Harrod C, Reid N, Haddaway NR, Farnsworth KD, Penk M, Ricciardi A (2013) Ecological impacts of an invasive predator explained and predicted by comparative functional responses. Biological Invasions.15: 837–846.

Dudgeon D, Arthington AH, Gessner MO, Kawabata ZI, Knowler DJ, Lévêque C, Naiman RJ, Prieur-Richard AH, Soto D, Stiassny MLJ, Sullivan CA (2006) Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews of the Cambridge Philosophical Society. 81: 163–182.

Ellender BR, Woodford DJ, Weyl OLF, Cowx IG (2014) Managing conflicts arising from fisheries enhancements based on non-native fishes in southern Africa. Journal of Fish Biology. In press.

Estévez RA, Anderson CB, Pizarro JC, Burgman MA (2014) Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. Conservation Biology. 00: 1-12.

Harrison AC (1953) The acclimatisation of smallmouth bass. Piscator. 27: 89-97.

Havel JE, Lee CE, vander Zanden MJ (2005) Do reservoirs facilitate invasions into landscapes? BioScience. 55: 518–525.

Impson ND, van der Walt R (2014) Rehabilitation of the Rondegat River in the Cederberg, Western Cape: lessons learnt in a project to eradicate alien smallmouth bass using the piscicide rotenone. Unpublished CapeNature internal report.

Jeschke JM, Bacher S, Blackburn TM, Dick JTA, Essl F, Evans T, Gaertner M, Hulme PE, Kühn I, Mrugała A, Pergl J, Pyšek P, Rabitsch W, Ricciardi A, Richardson DM, Sendek A, Vilà M, Winter M, Kumschick S (2014) Defining the impact of non-native species. Conservation Biology. 28: 1188–1194.

Johnson PT, Olden JD, vander Zanden MJ (2008) Dam invaders: impoundments facilitate biological invasions into freshwaters. Frontiers in Ecology and the Environment. 6: 357–363.

Lintermans M (2000) Recolonization by the mountain galaxias *Galaxias olidus* of a montane stream after the eradication of rainbow trout *Oncorhynchus mykiss*. Marine and Freshwater Research. 51: 799-804.

Lovell SJ, Stone SF, Fernandez L (2006) The economic impacts of aquatic invasive species: a review of the literature. Agricultural and Resource Economics Review. 35: 195–208.

Lowe SR, Woodford DJ, Impson DN, Day JA (2008) The impact of invasive fish and invasive riparian vegetation on the invertebrate fauna of the Rondegat River, Cape Florisitic Region, South Africa. African Journal of Aquatic Science. 33: 51-62.

MacRae PSD, Jackson DA (2001) The influence of smallmouth bass (*Micropterus dolomieu*) and habitat complexity on the structure of littoral zone fish assemblages. Canadian Journal of Fisheries and Aquatic Science. 58: 342-351.

Marr SM, Marchetti MP, Olden JD, García-Berthou E, Morgan DL, Arismendi I, Day JA, Griffiths CL, Skelton PH (2010) Freshwater fish introduction in Mediterranean-climate regions: are there commonalities in the conservation problem. Diversity and Distributions. 16: 606-619.

McConnachie MM, Cowling RM, van Wilgen BW, McConnachie DA (2012) Evaluating the cost effictiveness of invasive alien plant clearing: a case study from South Africa. Biological Conservation. 155: 128-135.

Ntshotsho P, Reyers B, Esler KJ (2011) Assessing the evidence base for restoration in South Africa. Restoration Ecology. 19: 578-586.

Pham L, West D, Closs GP (2013) Reintroduction of a native galaxiid (*Galaxias faciatus*) following piscicide treatment in two streams: response and recovery of the fish population. Ecology of Freshwater Fish. 22: 361-373.

Ricciardi A, Rasmussen JB (1999) Extinction rates of North American freshwater fauna. Conservation Biology. 13: 1220–1222.

Ricciardi A, Hoopes MF, Marchetti MP, Lockwood JL (2013) Progress toward understanding the ecological impacts of nonnative species. Ecological Monographs. 83: 263–282.

Richardson DM, van Wilgen BW (2004) Invasive alien plants in South Africa : how well do we understand the ecological impacts ? South African Journal of Science. 100: 45–52.

Sharma S, Jackson DA (2008) Predicting smallmouth bass (*Micropterus dolomieu*) occurrence across North America under climate change: a comparison of statistical approaches. Canadian Journal of Fisheries and Aquatic Science. 65: 471-481.

Skelton PH, Swartz ER (2011) Walking the tightrope: trends in African freshwater systematic ichthyology. Journal of Fish Biology. 79: 1413-1435.

Van der Walt R (2013). Priority rivers for alien eradication. Workshop proceedings, CapeNature: Cape Town.

Vilà M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE, DAISIE partners (2010) How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross taxa assessment. Frontiers in Ecology and the Environment. 8: 135-144.

Weyl OLF, Ellender BR, Woodford DJ, Jordaan MS (2013) Fish distributions in the Rondegat River, Cape Floristic Region, South Africa, and the immediate impact of rotenone treatment in an invaded reach. African Journal of Aquatic Science. 28: 201-209.

Weyl OLF, Finlayson BJ, Impson ND, Woodford DJ, Steinkjer J (2014) Threatened endemic fishes in South Africa's Cape Floristic Region: A new beginning for the Rondegat River. Fisheries. 39: 270-279.

Woodford DJ, Impson ND, Day JA, Bills IR (2005) The predatory impact of invasive alien smallmouth bass, *Micropterus dolomieu* (Teleostei: Centrarchidae), on indigenous fishes in a Cape Floristic Kingdom mountain stream. African Journal of Aquatic Science. 30: 167-173.

APPENDICES

Appendix 1: The 42 monitoring sites in the Rondegat River and their location.

Site no.	River reach	Co-ordinates
1	Invaded, below treatment	32°15.516' S 18°56.886' E
2	Invaded, below treatment	32°15.461' S 18°57.010' E
3	Treatment	32°15.357' S 18°57.150' E
4	Treatment	32°15.369' S 18°57.116' E
5	Treatment	32°15.353' S 18°57.161' E
6	Treatment	32°15.332' S 18°57.194' E
7	Treatment	32°15.327' S 18°57.191' E
8	Treatment	32°15.201' S 18°57.186' E
9	Treatment (weir pool)	32°15.192' S 18°57.203' E
10	Treatment	32°15.147' S 18°57.331' E
11	Treatment	32°15.248' S 18°57.505' E
12	Treatment	32°15.422' S 18°57.687' E
13	Treatment	32°15.536' S 18°57.812' E
14	Treatment	32°15.549' S 18°57.833' E
15	Treatment	32°15.556' S 18°57.843' E
16	Treatment	32°15.615' S 18°57.907' E
17	Treatment	32°15.672' S 18°57.936' E
18	Treatment	32°16.476' S 18°58.427' E
19	Treatment	32°16.507' S 18°58.459' E
20	Treatment	32°16.526' S 18°58.467' E
21	Treatment	32°16.560' S 18°58.475' E
22	Treatment	32°16.567' S 18°58.479' E
23	Treatment	32°16.574' S 18°58.492' E
24	Treatment	32°16.587' S 18°58.505' E
25	Treatment	32°16.587' S 18°58.505' E
26	Treatment	32°16.623' S 18°58.558' E
27	Treatment	32°16.645' S 18°58.580' E
28	Treatment	32°16.645' S 18°58.580' E
29	Non-invaded	32°16.657' S 18°58.596' E
30	Non-invaded	32°17.311' S 18°59.448' E
31	Non-invaded	32°17.316' S 18°59.459' E
32	Non-invaded	32°17.327' S 18°59.470' E
33	Non-invaded	32°17.340' S 18°59.477' E
34	Non-invaded	32°17.628' S 18°59.731' E
35	Non-invaded	32°17.653' S 18°59.749' E
36	Non-invaded	32°22.219' S 19°03.191' E
37	Non-invaded	32°22.237' S 19°03.258' E
38	Non-invaded	32°22.301' S 19°03.411' E
39	Non-invaded	32°22.321' S 19°03.444' E
40	Non-invaded	32°22.525' S 19°03.789' E
41	Non-invaded	32°22.534' S 19°03.842' E
42	Non-invaded	32°22.536' S 19°03.890' E

Appendix 2: Questionnaire used to survey anglers taking part in the Winter Classic competition.

(*Italics- instructions for interviewer)*

1) Personal information:

1.1) *Sex (don't ask, just record)* __________
1.2) What is your year of birth? __________
1.3) Where do you currently live? ___________________________________
1.4) How many people live in your household? __________
1.5) What is the highest level of education you have received? *(show card)*________

1.6) How many times do you visit Clanwilliam per year?
____

1.7) How many times have you competed in the Winter Classic?
____

1.8) If yes…
Did you take part in a similar interview there?

Yes No

2) Transport

2.1) How many km do you travel to get to Clanwilliam for this competition?

____

2.2) How many people travelled in your vehicle with you? (including yourself)

____

2.3) What car do you drive?

____

(make sure you get model, year and engine size)

2.3.1) Is your car diesel or petrol?

Diesel Petrol

2.3.2) Did you drive up to Clanwilliam in this vehicle?

____

2.4) If you had not come to this competition, would you have gone to fish elsewhere this weekend?

Yes No

2.4.1)If yes, where?

____

2.5) Is this fishing tournament your main reason for your visit to Clanwilliam this weekend?

Yes No

2.5.1) If not then what is your main reason for this trip?

____

3) Expenditure related to the competition

3.1) If possible, I'd like to ask about the money which you've spent in order to participate in the Classic. Are you sharing costs with others or are you paying for everything as an individual?

Individual As group

3.2) *If 'as a group' to 3.1…* How many people are you sharing costs with? _________

3.3) Please indicate below how much you spent in order to come and fish here today as well as where you spent it:

Category	**Location**	**Amount**
Accommodation	1)__________________ 2)__________________	1)__________________ 2)__________________
Food and drinks	1)__________________ 2)__________________ 3)__________________	1)__________________ 2)__________________ 3)__________________
Fuel (for vehicle)	1)__________________ 2)__________________ 3)__________________	1)__________________ 2)__________________ 3)__________________
Tackle	1)__________________ 2)__________________	1)__________________ 2)__________________
Other (please specify): ____________________	1)__________________ 2)__________________ 3)__________________ 4)__________________	1)__________________ 2)__________________ 3)__________________ 4)__________________

3.4) How many people are with you this weekend that are not fishing?

1 2 3 4 5 other:______

3.5) On what date did you arrive in Clanwilliam?

____

3.6) What date do you plan to leave?

____

3.7) What is the average length of your fishing trips to Clanwilliam?

____

4) Site characteristics

4.1) Would you please rate the quality of your bass fishing experience at Clanwilliam on a scale of 1-10:

1------2-----3-----4-----5-----6-----7-----8-----9-----10

Poor to Excellent

4.2) Do fish for bass at any other sites other than Clanwilliam?

Yes No

4.2.1) If so where?

____

4.3) Do any of the other sites you fish at (mentioned above) give you a better bass fishing experience than Clanwilliam? If so which ones and please rate them.

Yes No

If yes:

Site:____

1------2-----3-----4-----5-----6-----7-----8-----9-----10

Poor to Excellent

Site:____

1------2-----3-----4-----5-----6-----7-----8-----9-----10

Poor to Excellent

5) General expenditure

5.1) Would you indicate your individual monthly income category* after tax deductions? *(show card)*

____

5.2) What is your household monthly income category* after tax deductions? *(show card)*

____

5.3) Do you own a boat?

Yes No

5.3.1) If yes, please could you provide the following information about your boat:

Make: ____________________

Year bought: ____________________

Make of outboard: ____________________________________

Horsepower of outboard____________________

Year outboard was bought: ____________________

Make of trolling motor: ________________________________

Thrust of trolling motor: ____________________

Year trolling motor was bought: ____________________

5.4) Do you have electronics on your boat?

Yes No

5.4.1) If yes, please could you provide the following information about your electronics:

Make	Model	Year
1)		
2)		
3)		
4)		

5.5)How many rods do you own?

____

5.5.1)What was their average price?

____

5.5.2) How often do you replace/buy a new rod?

____

5.6) How many reels do you own?

____

5.6.1)What was their average price?

____

5.6.2) How often do you replace/buy a new one of your reels?

____

5.7) How much do you spend on the following per year?

Category	**Amount**
1)Terminal tackle	
2)Boat (incl. service and repairs)	
3)Motor	
5) Insurance	
6) Licensing of boat	

6) Environmental

6.1) Are you aware of the Rondegat River Rehabilitation Project?

Yes No

If yes, go to 6.2, if no, go to 6.3

6.2) Would you be willing to provide financial support for similar projects in other headwater streams in the Western Cape?

Yes No

6.2.1) If yes, how much would you be willing to pay (annually)?

____

Category cards:

Education category card:

Category	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**
Level of education	Less than Grade 10	Grade 10	Grade 12	Certificate/ Diploma	University degree	Post-graduate degree

Individual income category card:

Category	**I1**	**I2**	**I3**	**I4**	**I5**	**I6**
Amount per month	Less than R10 000	R10 000-R20 000	R20 000-R30 000	R30 000-R40 000	R40 000-R50 000	More than R50000

Household income category card:

Category	H1	H2	H3	H4	H5	H6
Amount per month	Less than R30 000	R30 000-R40 000	R40 000-R50 000	R50 000-R60 000	R60 000-R70 000	More than R70000

Appendix 3: Questionnaire used to survey anglers taking part in the Summer Classic competition.

(Italics- instructions for interviewer)

7) Personal information:

1.9) *Sex (don't ask, just record)* __________

1.10) What is your year of birth? __________

1.11) Where do you currently live? ____________________________________

1.12) How many people live in your household? __________

1.13) What is the highest level of education you have received?
(show card)

____

1.14) How many times do you visit Clanwilliam per year?
____

1.15) How many times have you competed in the Summer Classic?
____

1.16) Did you take part in the Winter Classic?
Yes No

1.17) If yes…
Did you take part in a similar interview there?

Yes No

8) Transport

2.1) How many km do you travel to get to Clanwilliam for this competition?

____

2.2) How many people travelled in your vehicle with you? (including yourself)

____

2.3) What car do you drive?

____

(make sure you get model, year and engine size)

2.3.1) Is your car diesel or petrol?

Diesel Petrol

2.3.2) Did you drive up to Clanwilliam in this vehicle?

____

2.4) If you had not come to this competition, would you have gone to fish elsewhere this weekend?

Yes No

2.4.1)If yes, where?

____

2.5) Is this fishing tournament your main reason for your visit to Clanwilliam this weekend?

Yes No

2.5.1) If not then what is your main reason for this trip?

---

9) Expenditure related to the competition

3.1) If possible, I'd like to ask about the money which you've spent in order to participate in the Classic. Are you sharing costs with others or are you paying for everything as an individual?

Individual As group

3.2) *If 'as a group' to 3.1*... How many people are you sharing costs with? _________

3.3) Please indicate below how much you spent in order to come and fish here today as well as where you spent it:

Category	**Location**	**Amount**
Accommodation *(For every figure you get ask whether it is what they spent, or a shared amount and note how much they spent)*	1)_______________ 2)_______________ 3)_______________ 4)_______________	1)_______________ 2)_______________ 3)_______________ 4)_______________
Food and drinks	1)_______________ 2)_______________ 3)_______________ 4)_______________	1)_______________ 2)_______________ 3)_______________ 4)_______________
Fuel (for vehicle)	1)_______________ 2)_______________ 3)_______________ 4)_______________	1)_______________ 2)_______________ 3)_______________ 4)_______________
Tackle	1)_______________ 2)_______________ 3)_______________ 4)_______________	1)_______________ 2)_______________ 3)_______________ 4)_______________
Other (please specify): ____________________	1)_______________ 2)_______________ 3)_______________ 4)_______________	1)_______________ 2)_______________ 3)_______________ 4)_______________

3.4) How many people are with you this weekend that are not fishing?

1 2 3 4 5 other:______

3.5) On what date did you arrive in Clanwilliam?

____

3.6) What date do you plan to leave?

____

3.7) What is the average length of your fishing trips to Clanwilliam?

____

10) Site characteristics

4.1) Would you please rate the quality of your bass fishing experience at Clanwilliam on a scale of 1-10:

1------2-----3-----4-----5-----6-----7-----8-----9-----10

Poor to Excellent

4.2) Do fish for bass at any other sites other than Clanwilliam?

Yes No

4.2.1) If so where?

____

4.3) Do any of the other sites you fish at (mentioned above) give you a better bass fishing experience than Clanwilliam? If so which ones and please rate them.

Yes No

If yes:

Site:____

1------2-----3-----4-----5-----6-----7-----8-----9-----10

Poor to Excellent

Site:____

1------2-----3-----4-----5-----6-----7-----8-----9-----10

Poor to Excellent

11) General expenditure

5.4) Would you indicate your individual monthly income category* after tax deductions? *(show card)*

____

5.5) What is your household monthly income category* after tax deductions? *(show card)*

____

5.6) Do you own a boat?
Yes No

5.3.1) If yes, please could you provide the following information about your boat:

Make: ____________________

Year bought: ____________________

Make of outboard: ____________________________________

Horsepower of outboard____________________

Year outboard was bought: ____________________

Make of trolling motor: ______________________________

Thrust of trolling motor: ___________________

Year trolling motor was bought: ___________________

5.4) Do you have electronics on your boat?

Yes No

5.4.1) If yes, please could you provide the following information about your electronics:

Make	Model	Year
1)		
2)		
3)		
4)		

5.5)How many rods do you own?

____

5.5.1)What was their average price?

____

5.5.2) How often do you replace/buy a new rod?

____

5.6) How many reels do you own?

____

5.6.1)What was their average price?

____

5.6.2) How often do you replace/buy a new one of your reels?

____

5.7) How much do you spend on the following per year?

Category	**Amount**
1)Terminal tackle	
2)Boat (incl. service and repairs)	
3)Motor	
5) Insurance	
6) Licensing of boat	

12) Environmental

6.1) Are you aware of the Rondegat River Rehabilitation Project?

Yes No

If yes, go to 6.2, if no, go to 6.3

6.2) Would you be willing to provide financial support for similar projects in other headwater streams in the Western Cape?

Yes No

6.2.1) If yes, how much would you be willing to pay (annually)?

____

6.3) What management actions would you suggest to improve the quality of the recreational bass fishery on Clanwilliam Dam?

____

____

____

6.3.1) Would you being willing to provide financial support to such management actions?

Yes No

6.3.2)If yes, How much would you be willing to pay annually?

____

Category cards:

Education category card:

Category	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**
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Individual income category card:

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Household income category card:

Category	H1	H2	H3	H4	H5	H6
Amount per month	Less than R30 000	R30 000-R40 000	R40 000-R50 000	R50 000-R60 000	R60 000-R70 000	More than R70000

Appendix 4: The man-hours and labour costs of the two rotenone treatments of the Rondegat River.

Responsibilities	Hours	Level within CapeNature	Hourly rate	Cost for individual
		First treatment (2011/12 financial year)		
Planning and overall command during treatment	1152	Scientist Production B	245.32	282 608.64
Safety officer and communications	32	Programme Manager	296.66	9 493.12
Strategic presence	16	Director	369.32	5 909.12
Strategic presence	16	Regional Manager	312.50	5 000.00
Strategic presence	16	Communication's Manager	255.68	4 090.88
Drip station 1	32	Conservation Manager	204.67	6 549.44
Drip station 1	32	Field ranger	71.96	2 302.72
Drip station 2	32	Project Officer	124.36	3 979.52
Drip station 2	32	Field ranger	71.96	2 302.72
Drip station 3	32	Student Nature Conservator	132.57	4 242.24
Drip station 3	32	Field ranger	71.96	2 302.72
Drip station 4	32	Ecological Co-Ordinator	159.16	5 093.12
Drip station 4	32	Field ranger	71.96	2 302.72
Drip station 5	32	Ecological Co-Ordinator	159.16	5 093.12
Drip station 5	32	Field ranger	71.96	2 302.72
Drip station 6	32	Ecological Co-Ordinator	159.16	5 093.12
Drip station 6	32	Field ranger	71.96	2 302.72
Drip station 7	32	Ecological Co-Ordinator	159.16	5 093.12
Drip station 7	32	Field ranger	71.96	2 302.72
Back pack sprayers	32	Hourly contract labour	25.00	800.00
Back pack sprayers	32	Hourly contract labour	13.75	440.00
Back pack sprayers	32	Student Nature Conservator	132.57	4 242.24
Back pack sprayers	32	Field ranger	71.96	2 302.72
Fish rescue	32	Conservation Manager	198.66	6 357.12
Security officers	32	Field Ranger	71.96	2 302.72
Security officers	32	Field Ranger	71.96	2 302.72
Rotenone deactivation	32	Ecological Co-Ordinator	162.36	5 195.52
Rotenone deactivation, ecotoxicology and bioassay	92	Scientific technician (production) B	154.56	14 219.52
Rotenone deactivation	32	Conservation Manager	217.26	6 952.32
Rotenone deactivation	32	Conservation Trainee	12.69	406.08
Administration	880	Project officer	56.82	50 001.60
Administration	880	Project Officer	34.09	29 999.20
Logistical support and catering	37	Conservation Manager	202.65	7 498.05
Total:	**3889**			**491 384.29**

Second treatment (2012/13 financial year)				
Planning and overall command during treatment	450	Scientist Production B	245.32	110 394.00
Safety officer and communications	21	Programme Manager	296.66	6 229.86
Planning and second in overall command during treatment	206	Technical Co-ordinator	147.83	30 452.98
Drip station 1 and supervised contracted stream clearing	59	Conservation Manager	204.67	12 075.53
Drip station 2 and assit with planning	50	Project Officer	124.36	6 218.00
Drip station 3	21	Student Nature Conservator	132.57	2 783.97
Drip station 4	21	Ecological Co-Ordinator	159.16	3 342.36
Back pack sprayers	21	Hourly contract labour	25.00	525.00
Back pack sprayers	21	Hourly contract labour	13.75	288.75
Back pack sprayers	21	Student Nature Conservator	132.57	2 783.97
Back pack sprayers	21	Field ranger	71.96	1 511.16
Fish rescue	21	Conservation Manager	198.66	4 171.86
Security officers	21	Field Ranger	71.96	1 511.16
Security officers	21	Field Ranger	71.96	1 511.16
Rotenone deactivation	25	Ecological Co-Ordinator	162.36	4 059.00
Rotenone deactivation and ecotoxicology	50	Scientific technician (production) B	154.56	7 728.00
Rotenone deactivation	21	Conservation Manager	217.26	4 562.46
Rotenone deactivation	21	Conservation Trainee	12.69	266.49
Logistical support and catering	61	Finance and Admin Clerk	65.52	3 996.72
Logistical support and catering	37	Conservation Manager	202.65	7 498.05
Total:	**1190**			**211 910.48**