

**Importance of freshwater systems and eels in the uMngeni and
uThukela catchments, KwaZulu-Natal, South Africa: community
perspectives**

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ABSTRACT

Globally, the conservation status of inland fishery resources and freshwater systems is vulnerable, threatening communities' livelihoods dependent on freshwater harvested species. Few studies have reported on the economic and cultural contributions of catadromous eels (*Anguilla* spp.) in southern Africa, particularly in South Africa. Beyond using freshwater systems for domestic purposes and meeting basic needs, people use rivers for socio-cultural purposes such as; cultural (cleansing), spirituality (healing), and religion (baptism). This study was undertaken to determine if human activities impact the African anguillids eel populations in the local communities of uThukela and uMngeni catchments and management areas in KwaZulu-Natal.

A systematic review was conducted on global studies, with an emphasis on southern Africa, that report on the human perspective on the value of anguillid eels when in freshwater systems. In the southern African region, the available literature focused on the distribution of anguillid eels, habitat loss, and a report on the drastic decline of anguillid eels in KwaZulu-Natal's freshwaters where the *Anguilla marmorata*, *A. mossambica*, *A. bengalensis*, and *A. bicolor* occur. The studies from the northern hemisphere were rich in reports of eel harvesting (wild catches) and export, which was lacking in the southern African region. The systematic review showed a scarcity of knowledge regarding anguillid eels' association with spirituality, spirituality, culture, and subsistence in South Africa.

Secondly, people's perceptions of the importance of eel species in freshwater fisheries were assessed using a questionnaire along water courses in the uMngeni and uThukela catchments and ecological management areas, KwaZulu-Natal. A total of 154 people were interviewed (66% males, 34% females); the majority of these participants were *isiZulu*-speaking, which contextualises the findings to the area of KwaZulu-Natal, uThukela and uMngeni management

areas in particular. The fishing of eels was found in both catchments, with 74% (of the n = 102) being subsistence fishers (with only one female fisher), and 41% of these subsistence fishers specifically targeted eels. All the fishers that targeted eels depended on freshwater eel catches for income because of the relatively high demand and value. Some fishers caught and sold eels to traditional healers who used their products of medicinal products for different uses.

Thirdly, the use of freshwater eels (*Anguilla* spp.) was assessed beyond harvesting them to sell or consume. In particular, using a questionnaire, the spiritual and cultural values of African freshwater eels and their associated freshwater environment in the uMngeni and uThukela catchments were investigated. A total of 154 people from different communities were interviewed along these river systems during 2021 and 2022. In the different communities within catchments, participants reported a number of different beliefs associated with eels and rivers. The responses showed that people valued clean rivers for various cultural, religious, and recreational activities. Some valued eels as they were associated with their beliefs. People who use freshwater for their respective cultural and spiritual, fishing, and domestic purposes voiced a considerable challenge in using freshwater systems, water pollution and water contamination from industrial waste or eutrophication from agricultural waste. Without community participation, there is no guaranteed sustainability of the water resources for the spiritual and cultural values of freshwater eels and freshwater systems.

Community leaders and water management bodies must engage with communities in identifying important river uses (domestic, fisheries), and their contribution to spiritual and cultural practices. This will ensure long-term sustainable use and protection of inland water and fisheries resources associated with cultural and spiritual beliefs in KwaZulu-Natal. Freshwater eels hold a crucial aspect in the lives of traditional healers, some local fishers, and the general public,

those that have knowledge of the use of these species. The study has shown that these species are still under-studied in KwaZulu-Natal, and most people have little understanding of the economic and cultural values, leading to less appreciation of these species by most people, mostly non-fishers.

PREFACE

The data described in this thesis were collected in uMngeni and uThukela management areas, KwaZulu-Natal, Republic of South Africa, from March 2021 to October 2022. Experimental work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Prof Colleen T. Downs, Dr Céline C. Hanzen and Dr Matthew J. Burnett.

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, School of Life Sciences, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it is duly acknowledged in the text.



.....
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February 2023

I certify that the above statement is correct, and as the candidate's supervisor, I have approved this thesis for submission.



.....
Prof Colleen T. Downs

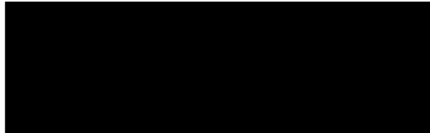
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DECLARATION 1 - PLAGIARISM

I, Mxolisi Nhlakanipho Nkomo, declare that

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DECLARATION 2 - PUBLICATIONS**

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis.

PUBLICATION 1 – not submitted

Economic, social and cultural values of freshwater eels and their associated river systems in southern Africa: A systematic review

Mxolisi N Nkomo, Céline C. Hanzen, Matthew J. Burnett, and Colleen T. Downs

Author contributions:

MNN conceived paper with CTD, CCH and MJB. CTD, CCH and MJB sought funding. MNN collected and analysed data, and wrote the paper. CTD, CCH and MJB contributed valuable comments to the manuscript.

PUBLICATION 2 – not submitted

The importance of eels (*Anguilla* spp.) for inland small-scale fisheries in local communities of the uMngeni and uThukela catchments, KwaZulu-Natal, South Africa

Mxolisi N Nkomo, Céline C. Hanzen, Matthew J. Burnett, and Colleen T. Downs

Author contributions:

MNN conceived paper with CTD, CCH and MJB. CTD, CCH and MJB sought funding. MNN collected and analysed data, and wrote the paper. CTD, CCH and MJB contributed valuable comments to the manuscript.

PUBLICATION 3 – not submitted

Cultural and spiritual values of rivers and freshwater eels in the uMngeni and uThukela catchments, KwaZulu-Natal, South Africa

Mxolisi N Nkomo, Céline C. Hanzen, Matthew J. Burnett, and Colleen T. Downs

Author contributions:

MNN conceived paper with CTD, CCH and MJB. CTD, CCH and MJB sought funding. MNN collected and analysed data, and wrote the paper. CTD, CCH and MJB contributed valuable comments to the manuscript.



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February 2023

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A freshwater eel captured by a fisherman in the present study (Source: M.N. Nkomo)

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CHAPTER 1

INTRODUCTION

1.1 Background

Presently developed countries recognise recreational fisheries' economic and commercial value and impact more than developing countries (Mann, 2013; Potts et al., 2020). Globally, this activity involves 220 – 700 million people and captures approximately 40 billion fish valued at US\$190 billion per annum (Embke et al., 2022), including other freshwater fish. A South African study showed recreational angling generated approximately ZAR32.6 billion with 1,327,633 participants per annum and sustained 94,070 full-time jobs (Potts et al., 2022). However, in this account, Potte et al. (2022) allude to recreational fishing competing with commercial and small-scale subsistence fishing. Despite those remarks, records report about anguillid eels in recreational fishing (Mann, 2013). In South Africa, there is little information on the harvest and consumption of freshwater fish, which is generally reported in detail in developed countries (Britz et al., 2015). The value of fishing reported in South Africa does not include the extent of fishing or artificial reproduction (aquaculture) of anguillid eels for consumption or any other use. Hanzen et al. (2022) emphasised the drastic decline of anguillid eels in the rivers of KwaZulu-Natal Province, South Africa.

Economic development, fishing job opportunities, climate, cultural importance, and societal leisure are some of the drivers of fishing activities and changes in fish populations in freshwater systems (Arlinghaus et al., 2017; Jacoby et al., 2015). In the management of rivers for species survival, the economic value of recreational fishing supports its sustainability (Cooke and Cowx, 2006), enhancing the management of freshwater systems (dams, lakes, rivers) from factors affecting freshwater species, including freshwater eels (Arlinghaus et al., 2017). In Africa, few studies report on the sustainability of freshwater systems for the sustainability of freshwater

species (Arlinghaus et al., 2017). The inadequate measure of the economic value of fishing thus undermines the need to carefully use and manage river water sustainably (Southwick and Bouaziz, 2016; Potts et al., 2022). Developed countries use freshwater fish extensively (including eels) to generate income and sustain their biodiversity by maintaining populations (that of eels in particular) of species through aquaculture and enforcing regulations in inland fisheries (Jacoby et al., 2015). In developing countries, the inadequacy of reports on the value of small-scale and sustainable fishing, and the socio-ecological value of freshwater species, anguillid eels in particular, overlook the sustainability of freshwater systems and resources (Sowman et al., 2014). This thesis explores and reports on the community's perspectives on the value of eels and their associated rivers. Further, it interrogates the human perspective on the possible causes of the observed decline of anguillid eel species in the KwaZulu-Natal's freshwater systems, particularly the uThukela and uMngeni catchments. Lastly, the study reports and tries to unpack the socio-cultural, spiritual, and religious value of rivers and anguillid eels.

1.2 South African freshwater eels

African freshwater eels (*Anguilla* spp.) are facultative catadromous fish species (Arai et al., 2012) which occur in the western Indian Ocean and recruit into the east-flowing rivers of Africa, including the east-flowing South African river systems (Hanzen et al., 2019). There are four African species; all occur in KwaZulu-Natal. These are the African longfin *Anguilla mossambica* (endemic to Africa), the giant mottled eel *A. marmorata*; the Indian mottled eel *A. bengalensis*; and the shortfin eel *A. bicolor* (Hanzen et al., 2019, 2022). These eels' spawning grounds are thought to be in the west Mascarene Ridge in the Indian Ocean (Réveillac et al., 2009).

The leptocephalus, eel larvae, are carried by oceanic currents towards the coast and metamorphose into transparent glass eels (Tesch and Thorpe, 2003). The glass eels gain pigmentation as they recruit to rivers, where they then grow to the elver stage (Tesch and Thorpe, 2003). In the elver life stage, the body weight and length of these species allow them to climb up wetted surfaces as they migrate towards the river's headwaters (Tesch and Thorpe, 2003). Their ability to climb has seen them penetrate far upstream, including large dams/ impoundments' walls, for example, Lake Kariba Dam, in Zimbabwe, with a height of 12 m (Balon and Coche, 1974) and over natural vertical waterfalls, for instance, the Howick Falls, South Africa (Hanzen et al., 2022). Elvers later mature to yellow eels, the riverine resident stage. They can stay between five and seven years in rivers, depending on the species, location (biological and environmental factors), and sex (McEwan and Hecht, 1984; Tesch and Thorpe, 2003). Yellow eels can inhabit all types of freshwater environments, from river sources to lower reaches of the river (Lin et al., 2015). After their yellow eel stage, they morph into a silver eel stage, their eyes increase in size and appear dilated, and the body's colour pigmentation changes to almost white, giving the appearance of looking silver (Tesch and Thorpe, 2003). During this stage, they migrate back to their spawning grounds, breed, and die (Tesch and Thorpe, 2003).

The migratory requirements of the African anguillids make them susceptible to physical environmental (e.g., water levels change with seasons, predators, habitat) and anthropogenic (e.g., water abstraction, fragmentation, fishing) stressors in both freshwater and marine environments. This is of concern as declines in their distribution ranges have been observed in the region (Hanzen et al., 2022).

A recognised socio-economic value is associated with eels in Asia, Europe, and North America (Stein et al., 2016), with little data from Africa. The demand for glass eels to raise to adult

for the food market has led to a decline in abundance to meet the production demands in Asia and Europe (Heinsbroek, 1991). European eels, *Anguilla anguilla*, and Japanese eels, *A. japonica*, are expensive food commodities that require a continuous production of glass eels from the environment to meet demand (Heinsbroek, 1991). The demand for glass eels is so high that in some estuaries in Europe, there are illegal harvests of glass eels during the migration season (Neves, 2014), despite the ban on export from the European Union since 2010 (Nijman, 2017). Water temperature affects the mobility of freshwater eels, making them less vulnerable to harvesting; this increases interest in other river sources, particularly to support the Asian eel market demand. A concern is that African anguillid eel resources might be seen as a lucrative source for international investors and growers, and targeted next (Hanzen et al., 2019).

While some African countries have recently entered the trade (Hanzen et al., 2019), the threat to African eel populations is poorly understood. However, local declines have been observed (Hanzen et al., 2022). The island of Réunion (Réveillac et al., 2009) is the only nation in the western Indian Ocean to develop a conservation plan for its anguillid eel populations. In South Africa, a recent study showed a serious decline in their distribution range in KwaZulu-Natal, with between 35% and 82% of the range lost since the 1950s, depending on the species (Hanzen et al., 2022). Reasons reported for the decline included the loss of ecological connectivity, pollution, overexploitation, habitat destruction and climate change (Hanzen et al., 2022). Until 2021, South Africa had no formal policies on inland catches to support and regulate sustainable development and management, including legislative and empowerment of rural communities in equitable access to suitable resources (i-DFFE, 2021). A concern of overharvesting of freshwater species may have been overlooked in sustainable management to support small-scale fishing and cultural uses. In particular African freshwater eels' importance for sustainable fisheries and people's cultural values

and livelihoods remains largely unknown (Hanzen et al., 2019). A drastic decline in freshwater eels in the management areas of uThukela and uMngeni was highlighted when studying the dynamics of these catadromous species (Hanzen et al., 2021).

The sub-tropics of eastern South Africa have distinct wet and dry seasons, summer and winter, respectively (Crétat et al., 2012; van Wilgen et al., 2016), resulting in high rainfall in this region when compared with the rest of the country (van Wilgen et al., 2016). This affects the rivers' water flow and levels seasonally, and climate change impacts this further (Verdonschot et al., 2010). Water flow in the east-flowing rivers in KwaZulu-Natal has been altered immensely because of human demand for clean water (Thabethe, 2011). This is through-made dam construction and abstraction of water for hydro-power, and inter-basin transfer schemes (Thabethe, 2011), negatively impacting freshwater fish species in these freshwater rivers (Evans et al., 2022).

Human speech, tradition, culture, and habits, form a context (a preferred context) (Minow and Spelman, 1989). How people interact with the environment and resources in their daily lives emanates from their formulated context. According to Duranti and Goodwin (1992), the social context is what makes up theories in the development of societies (sociology), and language (linguistics), which accords with history and culture.

1.3 Research aim and objectives

The research aim was to assess the economic and cultural contributions and importance of African freshwater eels and their associated freshwater rivers in the uThukela and uMngeni catchments in KwaZulu-Natal, South Africa, considering the people's perspectives through questionnaires and interviews. In this thesis, firstly, understanding the existing socio-economic value of anguillid eels globally, emphasising southern African countries, including Madagascar and the surrounding

islands, was reviewed. Secondly, the degree and impact of small-scale inland fisheries were assessed for African freshwater eels in KwaZulu-Natal. This included the use of these fish species and evaluating the potential over-harvesting of their use in consumption and cultural practice or belief. Lastly, the cultural and spiritual associations with rivers and freshwater eels were assessed, including how the changes in these natural resources shape people's lives and societies.

The fundamentals of this thesis are thus rooted in people's responses regarding the occurrence and use of African anguillid eels in the uMngeni and uThukela catchments, and their use of these rivers for cultural and spiritual activities. The reported findings in the thesis focus on intra-site ambivalence. Included is evaluating how people perceive the extent to which freshwater systems and African anguillid eels shape the daily lives and activities of people and understand their dependence on ecosystem services. The main focus of this thesis is to understand the socio-economic value of *Anguilla* spp. occurring in KwaZulu-Natal based on human perspectives, highlighting the influence of eel harvesting as a potential cause for their decline. In addition, the use of water sources for cultural and spiritual activities was highlighted.

1.4 Structure of the thesis

This thesis is organised with the data chapters prepared as draft manuscripts prepared for submission to peer-reviewed journals. The first chapter (Chapter 1) briefly introduces the study, followed by a systematic review of the economic, social, and cultural value of anguillid eels and rivers in southern Africa (Chapter 2), particularly in South Africa. Following this, there are two questionnaire-based chapters (Chapters 3 and 4), each one covering a specific objective on the human perspective about anguillid eels and rivers in uThukela and uMngeni management areas. Chapter three investigated the importance of African *Anguilla* spp. for inland small-scale fisheries

in local communities of KwaZulu-Natal. Chapter Four reports on the cultural and spiritual values of rivers and freshwater eels in KwaZulu-Natal. The final chapter (Chapter 5) summarises the findings and makes recommendations. Each chapter is formatted according to the journal it is intended to be submitted to. Because of this thesis format, a certain degree of repetition was unavoidable, in particular in the methods section. However, this is deemed to be of little concern as this format allows the reader to read each chapter separately without losing the overall context of the thesis.

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CHAPTER 2

Economic, social and cultural values of freshwater eels and their associated rivers in southern Africa: A systematic review

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Running header: Freshwater eel value in southern Africa

2.1 Abstract

Freshwater eels (*Anguilla* spp.) in Europe, North America, and Asia hold high economic value and are used primarily for consumption as a delicacy. Farming harvested wild-caught eels is important to meet this market demand. Eel farming practices in places such as North America, Taiwan, Japan, Madagascar, Scandinavia, and Norway have been used as a response to the low abundance of these species in the rivers, which would be caught through fishing/wild catches. In South Africa (which is in the southern African region, according to Southern African Development Communities), there has been a drastic decline in the distribution range and population of African freshwater eel species. We undertook a systematic review to understand the use and value of eels globally, but specifically in southern Africa. We searched for studies that have reported on eels to assess any reports on beliefs associated with eels and their economic value in small-scale fisheries. Our main aim was to review the use and economic and social value of freshwater eels in southern Africa and their linkages to cultural practices around rivers. We found that *Anguilla japonica* and *A. anguilla* had the most available literature in terms of studies, mostly their economic value and conservation legislature. Endangered European eels and declining wild catches of Japanese eels enabled eel trade with American eel (*A. rostrata*). In the southern African context, the available literature was mostly on the distribution of freshwater eels, habitat loss, and reported on the decline of freshwater eels, especially in management areas of KwaZulu-Natal freshwater rivers where the *Anguilla marmorata*, *A. mossambica*, *A. bengalensis*, and *A. bicolor* occur, while *A. nebulosa* occurs along the islands of Mauritius and Seychelles. This paucity of knowledge about freshwater eels in South Africa has been observed in the spiritual, cultural, and money or market value of anguillid eels.

Keywords: Anguillids, indigenous knowledge, cultural value, spiritual value, livelihood, inland waters

2.2 Introduction

There are 19 freshwater eel species (*Anguilla* spp.) distributed across the globe (Righton et al., 2021), found in temperate and tropical regions except for the eastern Pacific and southern Atlantic oceans (Feunteun et al., 2003; Righton et al., 2021). These species spawn in temperate and tropical marine areas (Aoyama et al., 2003). From the Mascarene trench, *Anguilla bengalensis*, *A. marmorata*, *A. mossambica*, and *A. bicolor* leptocephalus larvae (Tesch and Thorpe, 2003; Righton et al. 2021) are transported by oceanic currents across the Indian Ocean and recruit in the southern African rivers (Hanzen et al., 2017). Once they reach the estuaries, eels adapt to freshwater and mature from glass eels to elvers, to yellow and to silver eels (Kato and Kobayashi, 2003), and live most of their life in freshwaters (Ege, 1939; Watanabe et al., 2009). After several years (~ 7 years), silver eels return to their spawning ground in marine waters (Wasserman et al., 2011). Unfortunately, the proportions of individuals who move up rivers, stay in estuaries or completely stay in rivers remains unknown; therefore, learning about their riverine life cycle is important as they represent an essential part of the local biodiversity (Hanzen et al., 2022).

In this metamorphosis, eels encounter anthropogenic and environmental stressors as they adapt into freshwater species (Wasserman et al., 2011). These stressors include dam/ impoundment and weir construction that disrupts river connectivity (Masters et al., 2006; Wasserman et al., 2011), which alters the natural river flow (Meixler et al., 2009). Environmental stressors such as water quality, temperature, altitude, and changing chemical and biological factors, form part of the habitat for anguillid eels that affect their survival in water (either promote or stress anguillid eels) (Dekker et al., 2003; Baran et al., 2012; Jacoby et al., 2015; Funge-Smith, 2018).

Techniques such as aquaculture have been used (mostly in developed countries) to produce anguillid eels artificially (Okamura et al., 2013). Overfishing, use of detrimental equipment in

fishing, fishing of juvenile species, chemical contamination, and mortality from hydro-power turbines drastically affect the population of juvenile (glass and elver) and mature eels in the river systems (yellow eels and silver eels – mature life stages), resulting in anguillid eels listed as endangered in Europe and Asia (Miller et al., 2009; Castonguay and Durif, 2016).

In eastern and southern Africa, freshwater eels historically exploited all the inland aquatic landscapes available (Hanzen et al., 2022). A decrease has been observed over time as a result of increasing alteration of water quality, habitats, and fishing (Welcomme et al., 2010; Jacoby et al., 2015; Funge-Smith, 2018; Weyl et al., 2020), which has been reported to impact their population significantly (fragmentation of rivers limiting migration). However, there have not been reports that expand on fishing activities targeting eels, nor a well-known market of value of anguillid eels, nor their use to support livelihoods to explain their decline in these freshwater systems.

Southern Africa has the potential to alleviate poverty and meet food security goals through inland fisheries if the policies address employment benefits and sources of income in inland fisheries (Welcomme et al., 2010; McCafferty et al., 2012; Tapela et al., 2015). As reported by the UN Food and Agriculture Organisation (FAO, 2020), inland fisheries support ~4.8 billion people in Africa, with good inland fishing policies which were recently introduced in 2021 by Umnyango Wezamahlathi, Ezokudoba Nezemvelo (i-DFFE, 2021). The policies refer to small-scale fisheries and recreational anglers and side-line the subsistence user (Britz et al., 2015; Tapela et al., 2015; i-DFFE, 2021; Potts et al., 2022), subsidising inland catches which have been overlooked for a long time in South Africa resulting in no formal structures regulating inland fisheries (Britz et al., 2015). The lack of these management structures/strategies has prioritised water resource use over fisheries, jeopardising fish stocks and threatening fish species such as freshwater eels (Bruton et al., 1987; Britz et al., 2015; Castonguay and Durif, 2016; Hanzen et al., 2022). Furthermore,

regulating freshwater will also govern human daily use of rivers, including cultural and spiritual purposes, to ensure sustainable use of rivers (Britz et al., 2015; Funge-Smith and Bennett, 2019).

Eels are embedded in various cultures throughout their distribution ranges as long-distance migratory species. These include anguillids that spawn outside the western Indian Ocean region, such as the Japanese eel, *Anguilla japonica*, European eel, *A. anguilla*, and American eel, *A. rostrata*. Anguillid eels are globally important for their cultural and spiritual values in society with some of these values emanating from religious beliefs, some from cultural beliefs, and conserving and preserving natural resources by land users (Davis et al., 2004; Algonquins of Ontario, 2012, 2014; Denny et al., 2012; Feunteun and Robinet, 2014; McCarthy et al., 2014; Giles et al., 2016; Whaanga et al., 2018). Countries where these eels occur have or hold a relatively high economic value as a food delicacy for their rarity and tastiness (Liao et al., 2002). The eel ranching technique was developed in Japan for glass and elvers (less than 10 cm in length), followed by Taiwan (Liao et al., 2002), and later practised by Italy and France (Gousset, 1990; Heinsbroek, 1991; Ciccotti and Fontennelle, 2000) and the United States of America (USA) (Gallagher and Degani, 2000). These techniques were developed and adopted to be more efficient and increase harvested eels, ensuring better yield than wild harvest (Liao et al., 2010). The high economic value and declines in Japanese eels in Japan have shifted the market to Taiwan to supply to Japan (Liao et al., 2002). Strict regulations and bans on freshwater eel harvest in Japan and Europe have been because of declining population numbers, affecting trade in Japanese eels (Nijman, 2017). Consequently, the trade of live and frozen eels shifted from Europe and Japan to Japan and America, and Japan and Africa (Morocco and Tunisia) (Crook and Nakamura, 2013; Nijman, 2015).

In southern Africa, *A. marmorata*, *A. nebulosa*, and *A. mossambica* are distributed in the southwestern Indian Ocean, while *A. bicolor* is distributed along Seychelles (Robinet et al., 2007;

2008; Hanzen et al., 2022). Literature from southern Africa, including Comoros, Seychelles, and Mauritius, reported on beliefs associated with eels, whereas in other parts of the world, most of the literature search reported on their economic value. In southern Africa, some mythical beliefs that are often associated with freshwater systems, including the *Inkanyamba* in South Africa (Wood, 2007), *Nyami Nyami* in Zimbabwe (Matanzima, 2022), and numerous other legends and stories in Madagascar (Stifel et al., 2011).

We undertook a systematic review to understand the use and value of eels in southern Africa. We aimed to review the use and economic and social value of freshwater eels in southern Africa and their linkages to cultural practices around rivers. Furthermore, we identified knowledge gaps where data might be available in other regions with regard to the rivers and freshwater eels. Our objectives of the study were to explore the contribution of human activities (socio-cultural and economic) to the dynamics and persistence of eels in freshwater systems globally, then in southern Africa. Lastly, we documented beliefs about fishing for freshwater eels and beliefs associated with river systems in southern Africa.

2.3 Methods

In reviewing the literature, we followed the guide in writing a systematic review of Foo et al. (2021). We conducted literature searches (primary and grey) from March to September 2022. We followed a method provided by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009; O'Dea et al., 2021). Firstly, we searched the literature using similar keywords in different search engines and databases. We obtained relevant publications using different academic journal databases, search engines and government databases. These included the following databases and search engines such as Web of Science©

(<https://apps.webofknowledge.com>), Google Scholar© (<https://scholar.google.co.za/>), Taylor and Francis Online Library© (<https://www.tandfonline.com/>), Wiley Online Library (<https://onlinelibrary.wiley.com/>), ResearchGate© (<https://www.researchgate.net/>), Elsevier ScienceDirect© (<https://www.sciencedirect.com/>), Scopus© (<https://www.scopus.com/search/>), Google©, and the University of Natural Resources and Life Sciences (Vienna). Our search terms included publications on bacteria affecting eels, *Anguilla bicolor bicolor*, *Anguilla japonica*, *Anguilla anguilla*, inland catches for recreation, conservation of freshwater systems and species: dams and lakes, sustainability of freshwater resources, assessment of freshwater species richness, the spatial distribution of anguillid eels in KwaZulu-Natal, illegal fishing of eels, aquaculture technique in Taiwan, snake folklore in Eastern Cape, and Mountain snake. The relevant studies were included upon relevance to the keywords using the following keywords: anguillids, indigenous knowledge, cultural value, spiritual value, livelihood, and inland waters. In addition, a set of keywords, *Nyami Nyami*, mermaids, and *Fady*. Furthermore, peer-reviewed studies and grey literature were reviewed, and relevant studies in English, French and African languages were included. Relevant publications without access (no digital or printed version available) were excluded from the list of references. Relevant theses (MSc and PhD), when available, were included. Articles were selected for relevance to the southern African countries (Fig. 2.1). When conducting the review, we tried to minimise biases by using the same keywords in different search engines, rationalise the synthesis, and review the data through the literature available (Chalmers and Altman, 1995).

Secondly, we screened each article found briefly with the title and abstract screened (as per the rule and procedure of PRISMA) to select relevant articles (Fig. 2.2). All non-relevant articles, including duplicate articles, were then removed or excluded. Thirdly, we conducted a second

screening and read the article for further relevant articles and data analyses of relevant studies. We searched the reference sections of all the papers we used in this review for additional studies. Lastly, any additional articles were recorded in the PRISMA flowchart. This method helped us collate the studies on which our systematic review was conducted. We created a database of all relevant papers organised by authors, year, title, type of publication, topic(s), country or geographic area, and, finally, species (Supplementary information Table S2.1). We used descriptive statistics to determine and show the trends. We generated a word cloud after gathering all the literature using <https://monkeylearn.com/word-cloud>

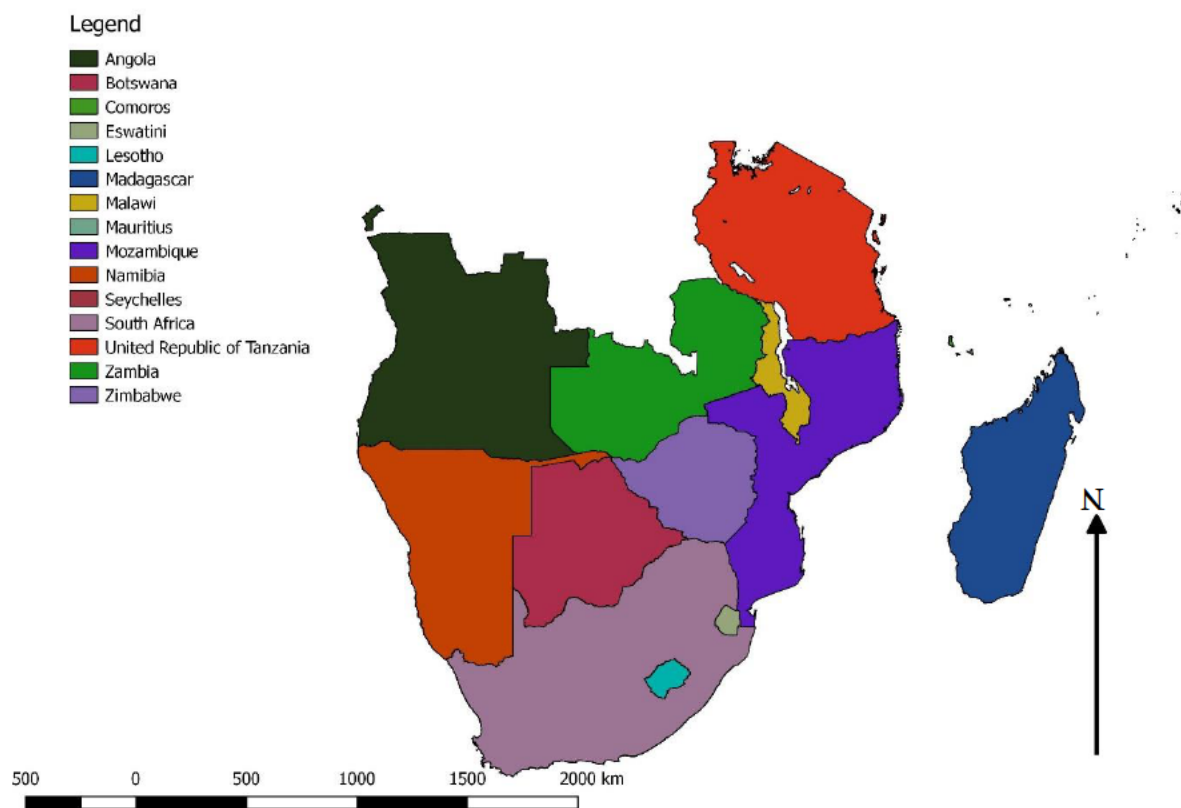


Fig. 2.1. Map of southern African countries and islands.

2.4 Results

2.4.1 General trends

Our literature searches produced 104 publications (Fig. 2.2, Supplementary information Table S2.1) relevant to our aims from 1990 to December 2022, with one article from 1939 and one from 1987. These consisted of peer-reviewed studies ($n = 52$), theses (MSc, $n = 2$, and PhD, $n = 2$), and books ($n = 10$). As outlined in the PRISMA flowchart (Fig. 2.2), we screened articles and reports twice (abstract and full document screening), and then, based on the paper's content, we accepted or excluded the non-relevant literature.

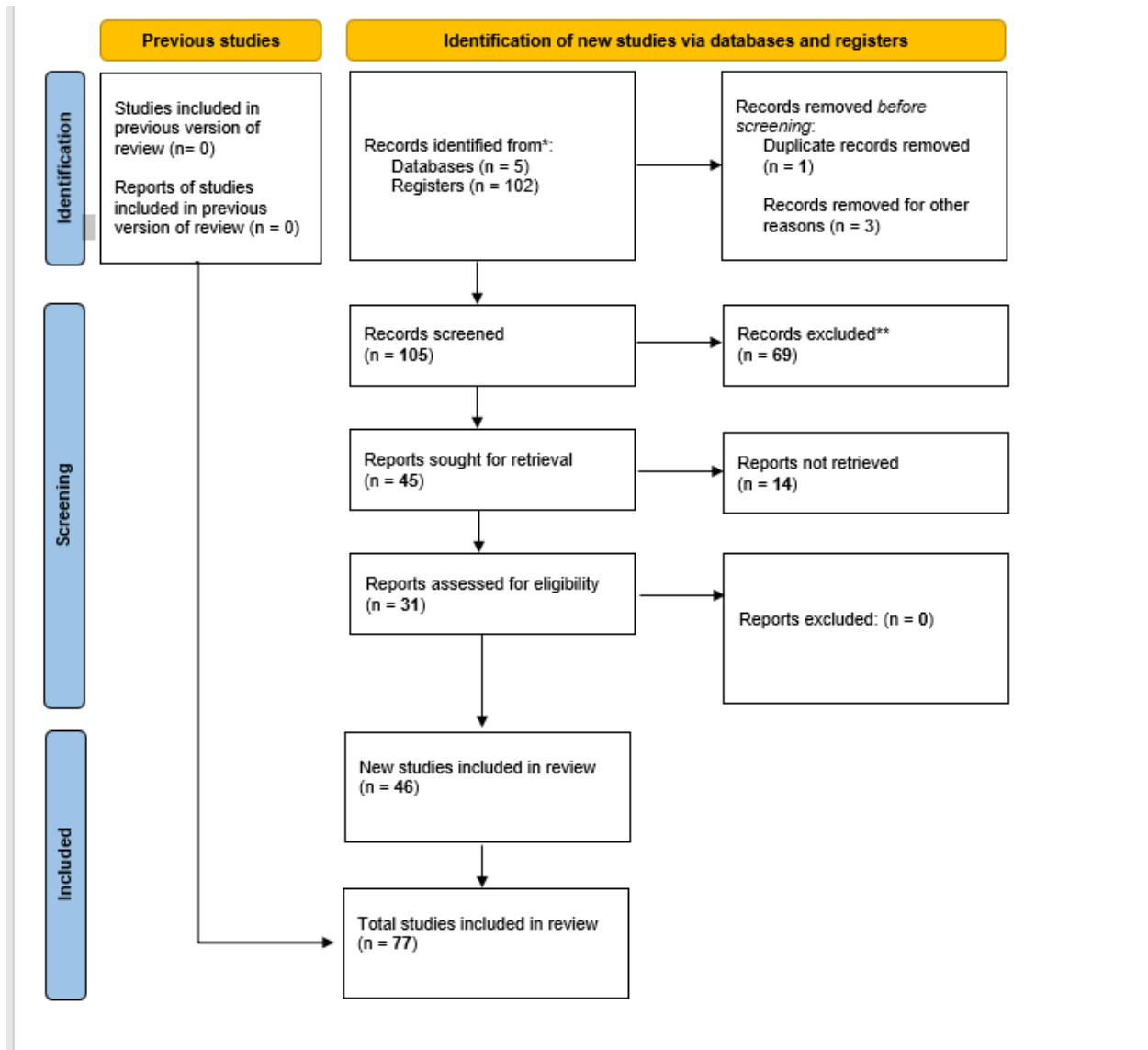


Fig. 2.2. Method of screening and selecting data for the systematic review in the present study.

Of the 77 articles found and used in the review (Fig. 2.2), 25% (n = 19) were from Africa, including 1% (n = 1) from Tanzania, 7% (n = 5) from Madagascar, 1% (n = 1) from Ghana, 13% (n = 10) from South Africa, 1% (n = 1) from Mozambique, and 1% (n = 1) from Zimbabwe, with the latter three countries in southern Africa. A minority of 5% (n = 5) were articles from the islands in the region of southern Africa. These included n = 2 (3%) from Mauritius (alone), and n = 2 (3%)

were a collective from Comoros, Seychelles, and Mauritius. In addition, four were from the United States of America (USA), four were from Asia, and 11 were from Europe. Most articles were in English, one in French, and none in Zulu, Xhosa, Sotho, or Portuguese. Four articles were about *Fady* in Madagascar and one on the Zimbabwean mermaid. The latter articles constituted the number of new studies (Fig. 2.2). A summary of the common words found in the literature search in the present study is shown in the word cloud generated after gathering all the literature using <https://monkeylearn.com/word-cloud> (Fig. 2.3).



Fig. 2.3. A word cloud summary of common words found in the literature search in the present study.

2.4.2 Eels as a source of food and income in southern Africa

Only 14% (n = 11) of articles reported on freshwater eels *Anguilla* spp. in southern Africa. Several (n = 5, 7%) reported on freshwater eels' migration, in-stream barriers or obstacles in river systems, and migration between East African rivers and the western Indian Ocean. One reported the bar-coding and genetics of African eels. Another (n = 1) (report from Taiwan) was about techniques used in artificially growing freshwater glass eels. The remaining (n = 25) papers were about other fish species consumption in the context of Africa and recreational fishing as a culture in southern Africa. The articles included in-stream barriers, fishing in general (small-scale commercial, subsistence), and indigenous livelihood activity. The studies reviewed mostly reported more on the sustainable exploitation of fish species and the maintenance of healthy aquatic ecosystems. Only 1% (n = 1) (Supplementary information S2.1) of the 77 articles mentioned the use of eels for cultural and spiritual purposes in southern Africa. Only 3% (n = 2) of articles reported on the use of eels as a source of income in Africa.

Only one stated that freshwater eels of Madagascar and South Africa had attracted the international trade of anguillid eels. Firstly, Liao et al. (2002) alluded to using aquaculture techniques in Taiwan to produce eels for Japan after the ban on eel trade in Europe, which shifted the eel market to places such as Taiwan, Southeast Asia, America, Morocco, and Tunisia (which were trading wild-caught eels). Secondly, Hanzen et al. (2017) referred to Kuroki et al. (2014), who mentioned the high value of eels in other continents, such as Europe and Asia, but made little mention of Africa, although the article was about African eel species. The observed global decline calls for a well-designed management strategy for these freshwater eels to understand their catadromous lifestyle for better management as they hold such high economic value in some parts

of the world (Kuroki et al., 2014). The literature gathered, however, had no reports on eels as a source of income in southern Africa, nor their value in the market.

2.4.3 Eels as a source of spiritual and cultural practice and beliefs

In attempts to document the value and importance of eels in society, Kuroki et al. (2014) recognised the Buddhist belief associated with anguillid eels, specifically Japanese eels (*Anguilla japonica*). Culturally, eel behaviour has been used as proverbs and sayings that constitute indigenous knowledge about eels and a particular situation. French people use phrases like “*se fauller comme une anguillae*”, which translates to “*slips away like an eel*” and to some tribes, eels are a totem species (e.g., Tribes in Micronesia) (Kuroki and Tsukamoto, 2012). Reported by Kuroki et al. (2012). Some Buddhist religious communities do not eat eels as they are believed to be messengers from Buddhist saints (Kuroki et al., 2012).

The knowledge and beliefs associated with freshwater eel beliefs are part of the literature on storytelling, morals of upbringing, and metamorphic phrases for French, Japanese, and Chinese-speaking people (Kuroki and Tsukamoto, 2012; Kuroki et al., 2012). These extend to the religion of Japanese people, the Buddhist religion (Kuroki et al., 2012).

Malagasy people conserve some of their natural resources under the concept of *fady* and have strong restrictive traditional rules made by Madagascar citizens that differ from place to place (Andriamarivololona and Jones, 2012). Off the coast of Africa in Madagascar, there are the beliefs of the presence of water spirits in water called “*fady*”, a belief in Madagascar that forbids people of certain clans from fishing for eel or exploiting natural resources (Stifel et al., 2011). According to Colding and Folke (2001), taboos and myths are there to instil morals, especially in the social (including cultural practice and traditional governance) and religious (spiritual) aspects of life.

Madagascar is one of the most diverse places in the globe, with most of its species endemic to it (Colding and Folke, 2001), and *fady* is used to conserve the natural resources, especially those understood to be endangered (Ruud, 1960; Jones et al., 2007; Bradt, 2007).

The origins of *fady*, however, were not species-specific (Country Miles, 2015) but were socially unacceptable actions or did not conform to custom (Golden and Comaroff, 2015). As a result, *fady* can be about anything deemed against the customs. Andriamarovololona and Jones (2007) allude to certain eel species not eaten in Madagascar. For example, eels with “ears”, *Anguilla mossambica*, are believed to be the ancestors in animal form; thus, local people would not eat these, and a waterfall in a river is named *Besofina* (big ears) and considered sacred, where ancestors reside (the value of the river) (Andriamarovololona and Jones, 2007). Pregnant women are not allowed to eat eels as they are slippery and might cause miscarriage (Andriamarovololona and Jones, 2007).

2.4.4 Rivers association with beliefs and cultural practices

Religious beliefs or indigenous practices are passed through narrating as stories from generation to generation. Gondo and Kolawole (2017) discuss integrating indigenous knowledge, *myths*, *folklore*, and *taboos* into conservation, which is passed to generations and educated about the conservation of natural resources and can be backed up by events or occurrences in a context. Joseph (2021) mentions a famous myth: when one urinates in a river, it will dry up, and that person will suffer from bilharzia. This is also a common myth in KwaZulu-Natal and the Eastern Cape, South Africa (Maseko et al., 2018; Anyolitho et al., 2022). Such taboos in history formed the basis of good behaviours in using natural resources sustainably (Golden and Comaroff, 2015).

The African Traditional Religion of Zimbabwe explains that water spirits were known for several functions, such as summoning rain, fighting evil spirit, and protecting people from evil spirits and witchcraft, which blight crops and withhold rain (Gondo and Kolawole, 2007; Machoko, 2013). Before the colonisation of Zimbabwe, this was all understood as an environmental religion, where the spirits ensure a natural flow or process to occur or progress, especially in water (Machoko, 2013). The water spirits were believed to be at peace, and if the flow of water/rivers, the supply of rain, and growing crops were undisturbed and normal (Machoko, 2013). However, should anything unusual occur and disturb this natural flow, the belief was a problem in the community (amongst people) or amongst leaders, or it was a bad omen (Machoko, 2013). A reported case of such an event in Zimbabwe was when a mermaid was found stuck in a big pipe downstream of a dam/ impoundment, blocking a large amount of water flow (Gondo and Kolawole, 2017). In this instance, sacrifices were offered to water spirits using slaughtered cows, traditional beer, and prayers, after which the mermaid was released from the pipe (Gondo and Kolawole, 2017). These offerings were made after consultation with leaders' faith in the African Traditional Religion of Zimbabwe (Gondo and Kolawole, 2017).

Documented findings from the Eastern Cape, South Africa, report that snake-like creatures were said to be present in some of the rivers in the Eastern Cape (Wood, 2007). These creatures reside in rivers and in the sky and are hence termed sky-snake (Wood, 2007). Their common Xhosa names are "*Inkanyamba*" or "*Mamlambo*", which is someone who resides in the river, and *uMlambo* is a Xhosa name for a river. Rivers then become sacred places populated by these creatures (Wood, 2005). People with a special calling can set foot in the river and communicate with these creatures, which are said to appear with a horse head, snake body, and a fishtail. A herbalist named *Khotso*, who lived in the Eastern Cape, was said to be able to interact with the

river in the Eastern Cape (Wood, 2005). A similar phenomenon, *Nyami Nyami*, which translates as ‘water spirits’ (Matanzima, 2022), has been documented in Zambia, Kenya, and Zimbabwe (Kaoma, 2017). Some other findings concerning *Nyami Nyami* are said to be human beings who are possessed and then taken to live in the river to safeguard the natural resources (Machoko, 2013). These humans take the form of a fish in the lower abdomen while retaining that of a human being from the upper abdomen to the head (Machoko, 2013; Gondo and Kolawole, 2017). In addition, a snake was said to live in the Tswaing crater (salt crater in Pretoria, Tswaing), where it would safeguard salt from salt thieves (Malan and Grossberg, 1998).

2.5 Discussion

2.5.1 General trends

This review focused on the economic, cultural, and spiritual values of anguillid eels in southern Africa. This study interrogated fisheries incorporating the socio-cultural and economic impact of eels (and rivers only on socio-cultural and spiritual) on people’s lives. Few studies reported about eels as migratory species or their migration ecology. A single study provides insight into possible beliefs regarding eels, which, in other parts of the world these beliefs are not well reported. The available literature in the region of southern Africa mostly reported on fisheries as a collective, incorporating other freshwater species such as *Claris gariepinus*, *Oreochromis mossambicus*, and *Labeobarbus natalensis*, with few mentions of *Anguilla* spp. Furthermore, the available literature on anguillid species in southern Africa tends to report on the effects of river fragmentation as a negative factor in eel survival, habitat disruption, and water chemistry. There was no mention of human impacts and engagement with anguillids in fisheries as a source of income or food and the cultural and spiritual aspects of freshwater eels and rivers.

2.5.2 Eels as a source of food

Freshwater eels are appreciated as having high nutrient content and value, especially in Japan, India, Europe (Austria, Spain, Italy), and the United States of America (Welcomme et al., 2010; Parill, 2012; Funge-Smith, 2018; Weyl et al., 2020). Consequently, anguillid eels are highlighted as an important commodity in the market (Parill, 2012; Sakurai and Shibusawa, 2020). Such importance has led to over-harvesting (Parill, 2012) and illegal harvesting (e.g., in Mondego Estuary in Portugal (Neves, 2014)) of glass eels. This illegal harvesting of eels has been high in eel recruitment season (Neves, 2014). A similar trend was recognised in Japan with the illegal harvesting of glass eels (Neves, 2014). The focus on the economic value found in the majority of the literature cited in the present study overlooked the recreational, social, and ceremonial values of anguillid eels for people in rural areas (Parill, 2012), which is what the following studies examined (Chapters 3 and 4).

In southern Africa, the consumption of freshwater fish was inclusive of several species, including eel species and studies showing a way of living where fisheries are explored as a possible source of income and means of survival in general (Tapela et al., 2015; Britz et al., 2015). There was no exploration of eels in terms of market prices, major food sources, and individual species in this region. In addition, no studies reported on strategies for artificial breeding of eels using aquaculture to increase production elsewhere in the region, as Liao et al. (2002) reported.

2.5.3 Eels as a source of income

In southern Africa, income from fisheries is not only generated from small-scale commercial or subsistence fishing, but recreational fisheries have a considerable percentage of the economy (Embke et al., 2022), which incorporates eels as freshwater species in the detailed monetary reports

of other freshwater fish, such as tilapia *Oreochromis mossambicus* (Tapela et al., 2015). Fish consumed from recreational fishing has not been quantified to represent the value of consumed fish caught in the recreational fishery (Embke et al., 2022). About 220 – 700 million people globally engage in recreational fishing and catch about 40 billion fish annually, valued at ~US\$ 190 billion (Kelleher et al., 2012; Arlinghaus et al., 2015; Funge-Smith and Bennett, 2019).

Southern African fisheries recognise inland fisheries as a means of living, sustainable use, and development (Tapela et al., 2015; Funge-Smith and Bennett, 2019). There is a slight overlap in using rivers and dams for fishing (Tapela et al., 2015). About 77% of rivers and dam uses are for subsistence fishing, while 69% are for recreational fishing, as reported in a study conducted in various parts of South Africa (Western Cape, northern KwaZulu-Natal (Pongolapoort Dam), Limpopo Province, the Eastern Cape, and the Northern Cape) (Tapela et al., 2015). It examined freshwater fish species caught (including carp *Cyprinus carpio*, tilapia, black bass *Centropomus striata*, catfish *Clarias gariepinus*, eel *Anguilla* spp., and silverfish *Lepisma saccharina*) but was not specific to freshwater eels (Tapela et al., 2015).

Until recently, inland fishing in southern Africa was regarded mainly for recreational activities, and there were few reported values of freshwater fish. Ellender et al. (2009) stated that from the exclusion of fishing for subsistence coming from an apartheid era, the lowest value of freshwater fish was ZAR 6/kg recorded in 2010, with no specific assessment of individual species, including freshwater eels.

The ban on selling *A. anguilla* as it is endangered in Europe likely increased the market for eels in America, Tunisia, Morocco, and Taiwan (Kelleher et al., 2012). Such complexities and demand for freshwater eels have not been reported in southern Africa.

2.5.4 Eels as a source of spiritual and cultural practice and beliefs

Beliefs associated with freshwater eels, which differ from one place to the other (e.g., Madagascar, Japan, France), from the results obtained in this study, showed a significant role played by knowledge in different places or countries (Gondo and Kolawole, 2007). In Africa, there are cultural and traditional values about freshwater eels in Madagascar, highlighting values that conserve freshwater eels (Andriamarovololona and Jones, 2012). *Fady* in the Malagasy culture prohibits some of the tribes in Madagascar from the wild harvesting of freshwater eels because of ancestral beliefs associated with eels (Andriamarovololona and Jones, 2012; Golden and Comaroff, 2015). There exist beliefs associated with freshwater eels in other parts of the world (Kuroki et al., 2012). The Buddhist religion rules do not allow people to consume freshwater eels because of religious beliefs that eels are saints with important messages (Kuroki et al., 2014).

Apart from cultural, religious, and spiritual values (and beliefs), it is essential to appreciate the development of societies where the characteristics of eels have played a role in explaining concepts. Tribes in Micronesia have incorporated eels in their literature, and they are used in daily talking or deliberations (Kuroki and Tsukamoto, 2012). The importance of language in society and how it shapes how humans see the world and understand systems through language choice of terms which influence culture and tradition, further influences speech, subcultural norms, and conduct (Montgomery, 2008). As Helu (1983) explained, it is hard to believe in something and concurrently believe false information about the same thing, a way humans make up. Future studies should assess people's perceptions of why and how important freshwater eels and associated freshwater systems are to them in southern Africa (Chapters 3 and 4). In addition, the economic value of eels for people who fish and sell or use them in whatever way, and who interact with rivers for different purposes need to be assessed in southern Africa (Chapters 3 and 4).

2.5.5 Rivers associated with beliefs and cultural practices

Southern Africa hosts different tribes and people with different cultures, forming the African Traditional Religion, which overlooks the differences in traditions and spirituality in each sub-region (Shaw, 1990). The use of sacred sites in nature are practices that are well known to most southern African people but are not practised in a similar way (Shaw, 1990; Machoko, 2013; Matanzima, 2022). Water Spirits, the sacredness of natural resources, especially water, is an interpretation of the Creator's undisturbed purity, cleanliness, and peacefulness, according to Matanzima (2022). Some people believe that there are supernatural creatures or human beings who safeguard the rivers, which are interpreted as the Creator's sacred space, and people's place of worship and encountering their Creator (usually used for healing), and are understood as a resting place for the spirits of the deceased (Matanzima, 2022). Following this belief, to members of communities, it only makes sense to have mediators or people who are called into the service of spirituality, e.g., *Khotso* in the Eastern Cape (Woods, 2005), be the only ones who communicate through water and use of other incentives, the world of the living and that of the supernatural beings.

2.6 Conclusions

Many studies on *Anguilla* spp. have occurred in Europe, Asia, and America. Studies in southern Africa are sparse, with some looking at parasitology (Moravec et al., 2016), ecology (Hanzen et al., 2017; Righton et al., 2021; Hanzen et al., 2021, 2022) and physical habitat (Weyl et al., 2020) to answer the question the declining of freshwater eel environments, rather than fisheries and their associated values.

This review highlights eels' socio-cultural and economic aspects in other countries, mostly in the northern hemisphere, and their economic and cultural value. It further highlights documented regulations and beliefs crucial in conserving these catadromous species as natural resources. The review briefly examines the importance of rivers in shaping people's lives in the southern African context. The use of rivers in the southern African context has been a phenomenon for a long time, resulting in rivers being viewed as living resources instead of renewable resources available for exploitation. Matanzima (2022) states that the use of water by African people started as early as before the Judeo-Christian religion was introduced by missionaries.

The lack of freshwater eel studies in the southern African context puts the anguillids in the region's waters at risk of over-exploitation. The attention drawn by research to different natural phenomena requires a detailed assessment of a unique phenomenon, which enables strategies for conserving and regulating exploitation. Having stated the value of freshwater eels in other countries, the unavailability of regulation on eel harvest in southern Africa may increase pressure on southern African eels from external trade with increased demands for freshwater eels in places such as Japan. Folklores and taboos around the use of rivers have, to some degree, created a sense of preserving the state of freshwater in places such as Madagascar, according to the available literature. Beliefs about the extent of freshwater eel harvest may highlight if there is a possibility of human activities causing the freshwater eel to decline in southern African river catchments, as to how the population of eels in areas with certain beliefs.

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2.9 Supplementary Information

Supplementary information Table S2.1. List of references sourced in the systematic review.

Keyword	Author/s	Publication title	Search engine	Source	Year	Vol	Issue	Link
Freshwater eels	Ame, E.C., & Mayor, A.D.	Efficient fishing method to control the population of rice eel, <i>Monopterus albus</i> (Synbranchidae) in rice fields in Cagayan Valley, Philippines	Google Scholar	Philippine Journal of Fisheries	2021	1	28	https://doi.org/10.1007/s10641-021-01000-0
Livelihood	Andriamarivololona, M.M., & Jones, J.P.G.	The role of taboo and traditional belief in aquatic conservation in Madagascar	Google Books	Cambridge University Press	2012			https://doi.org/10.1017/9781107305550
Livelihood	Anyolitho, M.K., Poels, K., Huyse, T., Tumusiime, J., Mugabi, F., Tolo, C.U., Masquiller, C., & Nyakato, V.N.	Knowledge, attitudes, and practices regarding schistosomiasis infection and prevention: A mixed-methods study among endemic communities of western Uganda	Google Scholar		2022	16	2	https://doi.org/10.1016/j.scp.2022.100700
Anguillid eels	Aoyama, J.	Life history and evolution of migration in catadromous eels (genus <i>Anguilla</i>)	Google Scholar	Aqua-BioScience Monographs	2009	2	1	https://doi.org/10.1007/978-1-4020-9111-1
Anguillid eels	Aoyama, J., Wouthuyzen, S., Miller, M. J., Inagaki, T., & Tsukamoto, K.	Short-distance spawning migration of tropical freshwater eels	Google Scholar	Biological Bulletin	2003	204	1	https://doi.org/10.1007/s10545-003-0001-0
Anguillid eels	Arai, T., Chino, N., Zulkifli, S. Z., & Ismail, A	Notes on the occurrence of the tropical eel <i>Anguilla bicolor bicolor</i> in Peninsular Malaysia, Malaysia	Google Scholar	Journal of Fish Biology	2012	80	3	https://doi.org/10.1111/j.1095-8649.2012.03331.x
Anguillid eels	Arlinghaus, R., Tillner, R., & Bork, M.	Explaining participation rates in recreational fishing across industrialised countries	Google Scholar	Fisheries Management and Ecology	2015	22	1	https://doi.org/10.1111/fme.12111

Anguillid eels	Baran, P., Basilio, L., Larinier, M., Ragaud, C., & Travade, F.		Google Scholar	Open Archive Toulouse Archive Ouverte	2012			https://gl
Livelihood	Bradt, H.	Madagascar	Google Scholar	The Globe Pequot	2007			http://gl
Livelihood	Britz, P.J., Hara, M.M., Weylf, O.L.F., Tapela, B.N., & Rouhani, Q.A.	Scoping Study on the Development and Sustainable Utilisation of Inland Fisheries in South Africa	Google Scholar	UWC Scholar - Publication	2015	1	1	https://r
Inland fisheries	Bruton, M.N., Bok, A.H., & Davies, M.T.	Life history style of diadromous fishes in inland waters of southern Africa	Scopus	American Fisheries Society	1987	1		https://l
Anguillid eels	Castonguay, M., & Durif, C.M.F.	Understanding the decline in Anguillid eels	Google Scholar	ICES Journal of Marine Science	2016	73	1	https://c
Anguillid eels	Chalmers, I., & Altman, D. G.	Systematic reviews	Google Scholar	Natural Center for Biotechnology Information	1995	311	7007	https://v
Anguillid eels	Ciccotti, E., & Fontennelle,	Aquaculture of European eel (<i>Anguilla anguilla</i>) in Europe: a review	Scopus	Sustainability of Resources and Aquaculture of Eels	2000			
Livelihood	Cleverdon, R.G	Tourism development in the SADC region: the opportunities and challenges	Google Scholar	Development Southern Africa	2002	19	1	https://c
Livelihood	Colding, J., & Folke, C.	Taboo: "Invisible" system of local resource management and biological conservation	Google Scholar	Ecological Application	2001	11	2	https://c
Fady	Country Miles	The Role Of Fady In Conservation Of Native Species In Madagascar	Google Scholar	Word press	2015			https://t
Eel economic value	Crook, V., & Nakamura, M.	Assessing supply chain and market impacts of a CITES listing on Anguilla species	Google Scholar	Traffic Bulletin	2013	25	1	https://v
Eel fisheries	Dekker, W., Casselman, J.M., Cairns, D.K., Tsukamoto, K., Jellyman, D., & Lickers, H.		Google Scholar	Fisheries Management and Ecology	2003	28	1	https://c

Livelihoods	i-Department of Forestry, Fisheries & the Environment	Inqubomgomo ewuhlaka yokwambiwa nokuphathwa kwamalungelo okudobela ukuhweba emkhakheni wezokudona izinhlanzi ngentambo njengasemandulo ngenhloso yokuhweba	Google Scholar		2021				https://v
Anguillid eels	Ege, V.	A revision of the genus <i>Anguilla</i> Shaw	Google books	Dana reports	1939	16			https://b
Freshwater systems	Ellender, B.R., Weyl, O.L., & Winker, H.	Who uses the fishery resources in South Africa's largest impoundment? Characterising subsistence and recreational fishing sectors on Lake Gariep	Scopus	Water SA	2009	35	5		https://h
Freshwater systems	FAO (Food and Agriculture Organisation of the United Nations)	The State of World Fisheries and Aquaculture in 2020	Google Scholar	Sustainability In Action	2020				https://c
Freshwater systems	Feunteun, E., Laffaille, P., Robinet, T., Brian, C., Baisez, A., Olivier, J., & Acou, A.	A review of upstream migration and movements in inland waters by Anguillid eels: Towards a general theory	Google Scholar	SpringerLink	2003				https://c
Systematics Review	Foo, Y.Z., O'Dea, R.E., Koricheva, J., Nakagawa, S., & Lagisz, M.	A practical guide to question formation, systematic searching and study screening for literature reviews in ecology and evolution	Google Scholar	Methods in Ecology and Evolution	2021	12	9		https://c
Inland fisheries	Funge-Smith, S., & Bennett, A.	A fresh look at inland fisheries and their role in food security and livelihoods	Google Scholar	Fish and Fisheries	2019	20	6		https://c
Livelihood	Golden, C.D., & Comaroff, J	Effects of social change on wildlife consumption taboo	Google Scholar	Ecology and Society	2015	20	2		https://c

		in northern Madagascar							
Water Spirits	Gondo, R., & Kolawole, O.D.	Utilization of indigenous knowledge system in water management in Hurungwe District, Zimbabwe	Google Scholar	Research And Innovation Symposium	2017				https://r
Anguillid eels	Gousset, B.	European eel (<i>Anguilla anguilla</i> L.) farming technologies in Europe and in Japan: Application of a comparative analysis	Google Scholar	Aquaculture	1990	87	####		https://c
Anguillid eels	Hanzen, C., Weyl, O., Lucas, M., Brink, K., Downs, C.T., & O'Brien, G	Distribution, ecology and status of anguillid eels in East Africa and the Western Indian Ocean	ScienceDirect	<i>Eels–biology, monitoring, management, culture and exploitation. Proceedings of the International Eels Sciences Symposium</i>	2017				https://b
Anguillid eels	Hanzen, C., Lucas, M.C., O'Brien, G., Calverley, P., & Downs, C.T.	Spatial ecology of freshwater eels in South Africa: implications for conservation.	SpringerLink	Hydrobiologia	2021	848	10		https://c
Anguillid eels	Hanzen, C.C., Lucas, M.C., Weyl, O.L., Marr, S.M., O'Brien, G., & Downs, C.T.	Slippery customers for conservation: Distribution and decline of anguillid eels in South Africa	Wiley Online Library	Aquatic Conservation	2022	32			https://c
Anguillid eels	Heinsbroek, L.T.N.	A review of eel culture in Japan and Europe	Wiley Online Library	Aquaculture Research	1991	22	1		https://c
Livelihood	Helu, I. F.	Thinking in Tongan society	Google Books	The Franklin Institute Press	1983				https://b

Anguillid eels	Jacoby, D.M.P., Casselman, J.M., Crook, V., DeLucia, M.-B., Ahn, H., Kaifu, K., Tagried, K., Sasal, P., Silvergrip, A.M.C., Smith, K., Uchida, K., Walker, A.M., & Gollock, M.J.	Synergistic pattern of threat and the challenges facing global anguillid eel conservation	ScienceDirect	Global Ecology and Conservation	2015	4		https://o
Fady	Jones, J.P.G., Andriamorovolona, M.A., & Hockley, N.J.	Taboo, social norms and conservation in the eastern rainforests of Madagascar	Google Scholar		2007			http://bi
Water Spirits	Joseph, C.	A mermaid in a dry city: A watery reading of Yvonne Vera's butterfly burning	Google Scholar	International Journal of Postcolonial Studies	2021	24	3	https://o
Water Spirits	Kaoma, K. J.	The Serpent in Eden and in Africa: Religions and Ecology	Wiley Online Library	The Wiley Blackwell companion to religion and ecology	2017			https://o
Eel Aquaculture	Kato, M., & Kobayashi, M.	Aquaculture and genetic structure in the Japanese eel <i>Anguilla japonica</i>	Google Scholar	UJNR Technical Report	2003	30		https://v Japan I Aquacult
Inland fisheries	Kelleher, K., Westlund, L., Hoshino, E., Mills, D., Willmann, R., de Graaf, G., & Brummett, R	Hidden harvest: The global contribution of capture fisheries	Google books	World Fish	2012			https://b WOxb2jg
Anguillid eels	Kuroki, M., Miller, M. J., Aoyama, J., Watanabe, S., Yoshinaga, T., & Tsukamoto, K.	Offshore spawning for the newly discovered anguillid species <i>Anguilla luzonensis</i> (Teleostei: Anguillidae) in the	SpringerLink	Pacific Science	2012	66	4	https://o

Western North
Pacific

Eels and Livelihood	Kuroki, M., & Tsukamoto, K.	Eels on the move – Mysterious creatures over millions of years	SpringerLink	Eels and Humans	2012			https://l
Eels and Livelihood	Kuroki, M., Righton, D., & Walker, A.	The importance of anguillids: Cultural and historical perspective introducing papers from the World Fisheries Congress	Wiley Online Library	Ecology of Freshwater Fish	2014	23	1	https://c
Eel Aquaculture	Liao, I. C., Hsu, Y. K., & Lee, W. C.	Technical innovations in eel culture systems	Google Scholar	Reviews In Fisheries Science	2002	10	####	https://c
Water Spirits	Machoko, C.G.	Water Spirits and the conservation of the natural environment: A case study from Zimbabwe	Google Scholar	The Internation Sociology of Anthropology	2013	5	8	https://c
Water Spirits	Malan, C.W., & Grossberg, A	The socio-cultural contexts of development communication at the Tswaing Crater a South African case study	Web of Science	Communicare: Journal for Communication Sciences in Southern Africa	1998	17	1	https://h
Livelihood	Maseko, T.S., Mkhonta, N.R., Masuku, S.K., Dlamini, S.V., & Fan, C.K.	Schistosomiasis knowledge, attitude, practices, and associated factors among primary school children in the Siphofaneni area in the Lowveld of Swaziland	ScienceDirect	Journal of Microbiology, Immunology and Infectio	2018	51	1	https://c
Livelihood	Masters, J.E., Jang, M.H., Ha, K., Bird, P.D., Frear, P.A., & Lucas, M.C.	The commercial exploitation of a protected anadromous species, the river lamprey (<i>Lampetra fluviatilis</i> (L.)), in the tidal River Ouse, north-east England	Google Scholar	Aquatic Conservation: Marine and Freshwater Ecosystems	2006	16	1	https://c
Water Spirits	Matanzima, J.	Exploring the origins and expansion of the Nyaminyami (Water	Google Scholar	Journal of Religion in Africa	2022	51	####	https://c

		Spirit) belief among the BaTonga People of North-western Zimbabwe							
Freshwater systems	McCafferty, J.R., Ellender, B.R., Weyl, O.L.F., & , P.J.	The use of water resources for inland fisheries in South Africa	Google Scholar	African Journal of Aquatic Science	2012	38	2	https://o	
Inland fisheries	Meixler, M.S., Bain, M.B., & Walter, M.T.	Predicting barrier passage and habitat suitability for migratory fish species	ScienceDirect	Ecological Modelling	2009	220		https://o	
Anguillid eels	Miller, M.J., Kimura, S., Friedland, K.D., Knights, B., Kim, H., Jellyman, D.J., & Tsukamoto, K	Review of oceanic-atmospheric factors in the Atlantic and Pacific Oceans influencing spawning and recruitment of anguillid eels	Google Scholar	American Fisheries Society	2009	69	1	https://v Atmosph Influenci	
PRISMA	Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., & Prisma Group	Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement	Google Scholar	Annals of Internal Medicine	2009			https://o	
Livelihood	Montgomery, M.	An introduction to language and society	Google Scholar	Taylor and Francis Group	2008	2		https://o	
Anguillid eels and economic value	Neves, J.F.B.	Impact of illegal glass eel (<i>Anguilla anguilla</i>) fishery on estuarine fish stock: A case study in the Mondego Estuary	Google Scholar	Repositório Científico da UC	2014			http://h	
Anguillid eels and economic value	Nijman, V.	CITES-listings, EU eel trade bans and the increase of export of tropical eels out of Indonesia	ScienceDirect	Marine Policy	2017	58		https://o	
Anguillid eels and economic value	Nijman, V.	North Africa as a source for European eel following the 2010 EU CITES eel trade ban	ScienceDirect	Marine Policy	2015	85		https://o	

Systematics Review	O'Dea, R.E., Lagisz, M., Jennions, M.D., Koricheva, J., Noble, D.W., Parker, T.H., Gurevitch, J., Page, M.J., Stewart, G., Moher, D., & Nakagawa, S.	Preferred reporting items for systematic reviews and meta-analyses in ecology and evolutionary biology: a PRISMA extension	Wiley Online Library	Biological Reviews	2021	96	5	https://doi.org/10.1111/bir.12500
Aquaculture	Okamura, A., Horie, N., Mikawa, N., Yamada, Y., & Katsumi, T.	Recent advances in artificial production of glass eel for conservation of anguillid eel populations	Wiley Online Library	Ecology of Freshwater Fish	2013	22	1	https://doi.org/10.1111/erf.12000
Inland fisheries and Livelihood	Parill, E.	<i>We Always Did Fish For Eels. Master of Arts</i>		Environmental Policy	2012			http://ru.nl
Anguillid eels	Righton, D., Piper, A., Aarestrup, K., Amilhat, E., Belpaire, C., Casselman, J., Castonguay, M., Díaz, E., Dörner, H., Faliex, E., Feunteun, E., Fukuda, N., Hanel, R., Hanzen, C., Jellyman, D., Kaifu, K., McCarthy, K., Miller, M.J., Pratt, T., Sasal, P., Schabetsberger, R., Shiraishi, H., Simon, G., Sjöberg, N., Steele, K., Tsukamoto, K., Walker, A., Westerberg, H., Yokouchi, K., & Gollock, M.	Importance questions to progress science and sustainable management of anguillid eels	Wiley Online Library	Fish and Fisheries	2021	22	4	https://doi.org/10.1111/fish.12500
Eels in Seychelles	Robinet, T., Feunteun, E., Keith, P., Marquet, G., Olivier, J. M., Réveillac, E., & Valade, P.	Eel community structure, fluvial recruitment of <i>Anguilla marmorata</i> and indication for a weak local production of spawners from rivers of Réunion and Mauritius islands	SpringerLink	Environmental Biology for Fishes	2007	78	2	https://doi.org/10.1007/s10641-007-9200-0

Eels in Seychelles	Robinet, T., Réveillac, E., Kuroki, M., Aoyama, J., Tsukamoto, K., Rabenevanana, M. W., Valade, P., Gagnaine, P., -A., Berreti, P., & Feunteun, E.	New clues for freshwater eels (<i>Anguilla</i> spp.) migration routes to eastern Madagascar and surrounding islands.	SpringerLink	Marine Biology	2008	154	3	https://o
Fady	Ruud, J.	<i>Taboo: A study of Malagasy custom and belief</i>	Google Scholar	International Bibliography of Theology and Religious Studies	1960			https://i
Anguillid eels and economic value	Sakurai, K., & Shibusawa, H.	The economic impact of the inland fisheries/aquaculture industry: The case of eel industry in Japan	Wiley Online Library	Regional Science Policy and Practice	2020	13	6	https://o
African Religion	Shaw, R.	The invention of 'African traditional religion'	Google Scholar	Religion	1990	20	4	https://o
Fady	Sodikoff, G.M.	Totem and taboo reconsidered: Endangered species and moral practice in Madagascar	Google Scholar	The Anthropology of Extinction	2012			https://v
Fady	Stifel, D., Fafchamps, M., & Minten, B.	Taboos, agriculture and poverty	Google Scholar	Journal of Development Studies	2011	47	10	https://o
Inland fisheries and Livelihood	Tapela, B.N., Britz, P.J., & Rouhani, Q.A.	Scoping study on the development and sustainable utilisation of inland fisheries in South Africa: Volume 2. Case studies of small-scale inland fisheries	Google Scholar	UWC Scholar - Publication	2015			http://h
Anguillid eels	Tesch, F.W., & Thorp, J.E. (eds)	The Eel	Wiley Online Library	Blackwell	2003	3		https://o
Freshwater systems	Wasserman, R.J., Weyl, O.L.F., Strydom, N.A.	The effects of instream barriers on the distribution of migratory marine-spawned fishes in the lower reaches of	Google scholar	African Journals Online	2011	37	4	https://o

the Sundays River,
South Africa.

Anguillid eels	Watanabe, S., Aoyama, J., & Tsukamoto, K.	A new species of freshwater eel <i>Anguilla luzonensis</i> (Teleostei: Anguillidae) from Luzon Island of the Philippines	SpringerLink	Fisheries Science	2009	75	2	https://doi.org/10.1007/s10641-009-9500-0
Inland fisheries	Welcomme, R.L., Cowx, I.G., Coates, D., & Bene, C.	Inland Capture Fisheries	Google Scholar	Philosophical Transaction of the Royal Society African Journal of Aquatic Science	2010	365	1554	https://doi.org/10.1093/aq/365.1554
Inland fisheries	Weyl, O.W.L., Barkhuizen, L., Christison, K., Dalu, T., Hlungwani, H.A., Impson, D., Sankar, K., Mandraka, N.E., Marr, S.M., Sara, J.R., Smit, N.J., Tweedle, D., Vine, N.G., Wepener, V., Zvavahera, M., & Cowx, I.G.	Ten research questions to support South Africa's Inland Fisheries Policy	Google Scholar		2020	46	1	https://doi.org/10.1080/03781909.2020.1811111
Inkanyamba	Wood, F.	'The Snake Will Swallow You': Supernatural Snakes And The Creation of Khotso Legend	Google Scholar	Critical Arts	2005	4	1	https://doi.org/10.1080/03781909.2005.10557111
Inkanyamba	Wood, F.	The Snake In The Sky: Tornadoes in clay and local narratives in the Hogsback-Alice Area		Critical Arts	2007	14	2	https://doi.org/10.1080/03781909.2007.10557111

CHAPTER 3

The importance of eels (*Anguilla* spp.) for inland small-scale fisheries in local communities of the uMngeni and uThukela catchments, KwaZulu-Natal, South Africa

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Running header: Importance of freshwater eels in South Africa

3.1 Abstract

The conservation status of global inland fishery resources and freshwater systems is vulnerable, threatening the livelihoods of communities that benefit from these. The benefits include freshwater eels. Little is known about the economic contributions of catadromous eels (*Anguilla* spp.) to livelihoods in KwaZulu-Natal Province, South Africa. Here, a decline in the range distribution and decline of freshwater eel species has been documented from 1957 to 2020. Using a questionnaire and interviews, we interrogated the importance of freshwater eel species linked to fisheries in KwaZulu-Natal, particularly in different local municipalities in various districts in the uMngeni and uThukela catchments during 2021 - 2022. We interviewed 154 people in urban and rural areas, the majority being males at a total of $n = 102$ (66%), and most were 45 – 59 years of age (15%). Most (76%) were isiZulu-speaking people. We found freshwater eel fisheries across the study area (uMngeni and uThukela catchments). Of the respondents, 74% were subsistence fishers, and most were male. Of these fishers, 56% ($n = 42$) had caught freshwater eels, and 41% ($n = 17$) specifically targeted eels. All the fishers that targeted eels depended on eel catches for income because of the relatively high demand and value. We also found other fishers who catch and sell freshwater eel to traditional healers who use their products of medicinal products for different uses. The overall findings of this study highlighted how eel fisheries contribute to generating revenue for some subsistence fishers in KwaZulu-Natal.

Keywords: Economic value of eels, indigenous knowledge, subsistence fishers, small-scale fishers, exploitation of freshwater eels

3.2 Introduction

Nineteen species of anguillid eels occur in global freshwater and marine environments in South America and Antarctica's waters (Aoyama, 2009). Many of these species are exploited for subsistence or commercial fisheries and are economically valuable (Kuroki et al., 2014). The Japanese eel, *Anguilla japonica*, and the European eel, *A. anguilla*, are economically and culturally (discussed in detail in sequel Chapter 4) important as they are considered a food delicacy in their respective distributions (Stein et al., 2016; Kaifu et al., 2019). For these species, there is a high demand for glass eels (Heinsbroek, 1991), and elvers eels (Bornarel et al., 2018) in many European and Asian countries. The demand has triggered practices of eel ranching to meet consumer demands (Heinsbroek, 1991; Shiraishi and Crook, 2015). The high demand and harvest for glass eels (Stein et al., 2016; Dekker, 2019) has resulted in the ban (restriction of eel trade outside Europe) on export for *A. anguilla* as a management of the critically endangered species according to the International Union for Conservation (IUCN) (Nijman, 2015) and their reduced abundances and drastic decline from wild catches (Shiraishi and Crook, 2015). As a result, there has been an increase in illegal harvesting (Neves, 2014) and international trade of *A. japonica* and *A. anguilla* eels in inland river systems in their native ranges to support food markets (Stein et al., 2016).

Four anguillid eels occur in southern African freshwater systems (Skelton, 1993), which, according to Hanzen et al. (2019), have possibly attracted Asian fishermen to KwaZulu-Natal's freshwaters for eel fishing. The exports included live and chilled or frozen eels (Kaifu et al., 2019; Hanzen et al., 2019). This new trade could be triggered by the ban on the export of *A. anguilla* by the European Union to international markets in response to its IUCN listing as 'critical' (Jacoby and Gollock, 2014; Nijman, 2015). There was an increasing demand for freshwater eels for the

Asian markets following *A. japonica* being listed and the enactment of policies that protect the over-harvesting of this species (Jacoby and Gollock, 2014; Nijman, 2015). The limitation in eel fishing and harvesting resulted in international investors' growing interest in farming the African eel species (Crook and Nakamura, 2013; Nijman, 2015). Having fewer restrictions on inland fisheries (until recently), unlike in Europe and Asia, fishing and harvesting of freshwater species, eels in particular, was relatively easily undertaken (Sowman et al., 2014; Britz et al., 2015; Nijman, 2015; 2017).

African freshwater eels, African longfin eel *Anguilla mossambica*, the giant mottled eel *A. marmorata*, the Indian mottled eel *A. bengalensis*, and the shortfin eel, *A. bicolor*, occur in all South Africa's east flowing rivers, including KwaZulu-Natal (Lin et al., 2015; Hanzen et al., 2022). These eels spawn on the west Mascarene Ridge in the Indian Ocean (Réveillac et al., 2009). They migrate to continental waters as larvae (leptocephali stage) and metamorphose into transparent glass eels when they reach the coast (McCleave, 1993; Tesch and Thorpe, 2003). When the juvenile glass eel gains colour, it is considered an elver (Tesch and Thorpe, 2003) and enters freshwater. Elvers have strong climbing abilities and can climb up obstacles, such as waterfalls, as part of their migration up freshwater systems for about twelve to fourteen months, then mature into yellow eels (Barnard, 1953; Tesch and Thorpe, 2003). Yellow eels can survive up to fourteen years before maturing to silver eels and then return to the marine environment to spawn and die (Tesch and Thorpe, 2003; Hanzen et al., 2019). The yellow eels can inhabit several types of freshwater ecosystems, from high altitudinal streams to estuaries (Lin et al., 2015; Hanzen et al., 2022), making them available to be harvested at different life stages and parts of the river. In North America, Europe, and Asia (where freshwater eels are in demand), eels are harvested during their glass, elver, yellow and silver stages (Heinsbroek, 1991; Arai et al., 2012; Shiraishi and Crook,

2015; Stein et al., 2016; Nijman, 2017). While in South Africa, anguillid eels are not generally targeted in inland fisheries but can be caught as by-catch (Tapela et al., 2015; Hanzen et al., 2022).

Not being able to breed anguillids in captivity viably meant a strong dependence on the wild harvest of glass eels farming to grow aquaculture facilities and meet market demands (Jacoby and Gollock, 2014). In a review of aquaculture in Africa, South Africa was found to be a key player in freshwater fish production (Adeleke et al., 2020). South Africa was placed 10th in Africa, producing 0.28% of total aquaculture fish (FAO, 2010-2010a), but the reported information did not report on eels specifically – but collectively freshwater fish species. The production was estimated at ~5418 tons per annum in 2015, a value of ~ZAR696 million (~US\$48.2 million) (DAFF, 2015). Freshwater species cultured in South Africa do not include the anguillids, but rather other species that have high recreational and commercial values, for example, trout (*Oncorhynchus mykiss* and *Salmo trutta*), tilapia (*Oreochromis mossambicus*, *O. niloticus*, and *O. rendalli*), catfish (*C. gariepinus*), carp (*Cyprinus carpio*), marron crayfish (*Cherax tenuimanus*), and ornamental species (Quinn, 1993; Brummett, 2007; DAFF, 2015).

With the growing international interest in African freshwater eels to support international demand, our study attempts to determine any possible harvesting of freshwater eel species for recreational, commercial, and subsistence purposes. We assessed local communities, including inland fishers, perspectives on African freshwater eels (*Anguilla* spp.) in the Thukela and uMngeni Rivers, KwaZulu-Natal Province, South Africa and if and how they use these resources and the associated river systems. We predicted that the economic value of eels in KwaZulu-Natal might be adding to the decline of these species and reduced geographical range distribution (Hanzen et al., 2022). In addition, we predicted that socio-cultural and spiritual values were linked to the harvest of African freshwater eels. Therefore, we aimed to understand the perceptions of fishers

and their potential impact on African freshwater eels and contribute to the knowledge gap on the importance of these eel species in human lives to enable a holistic approach to their management.

3.3 Methods

3.3.1 Study areas

South African north-east flowing rivers have a relatively higher flow throughout the year than most rivers in other provinces (Fig. 3.1). KwaZulu-Natal (Fig. 3.1) is considered the only province in South Africa that is generally not water-scarce (Rivers-Moore et al., 2011; Roffe et al., 2019). Several inter-basin water transfer schemes were built to move water to urban hubs, often resulting in the reduction of water in natural ecosystems (Cyrus, 2001). The uThukela River, in KwaZulu-Natal, is an important river that supplies other catchments with water (Cyrus, 2001), for example, the Vaal River and the uMngeni River to supply water to the cities of Johannesburg and Durban, respectively (Fig. 3.2) (Elliot and Escott, 2014). The uThukela and uMngeni Rivers are socio-economically important rivers, the uThukela River as a water supply to other regions listed above, and the uMngeni River as the economic hub for KwaZulu-Natal. They also provide important ecosystem services (Hughes et al., 2018). Historically, all four African freshwater eels occurred in these river catchments (Hanzen et al., 2022). We divided these catchments according to local municipalities for ease of data sorting and recording, as access to most communities was possible if a municipality was sampled instead of following a river course (Fig. 3.2).

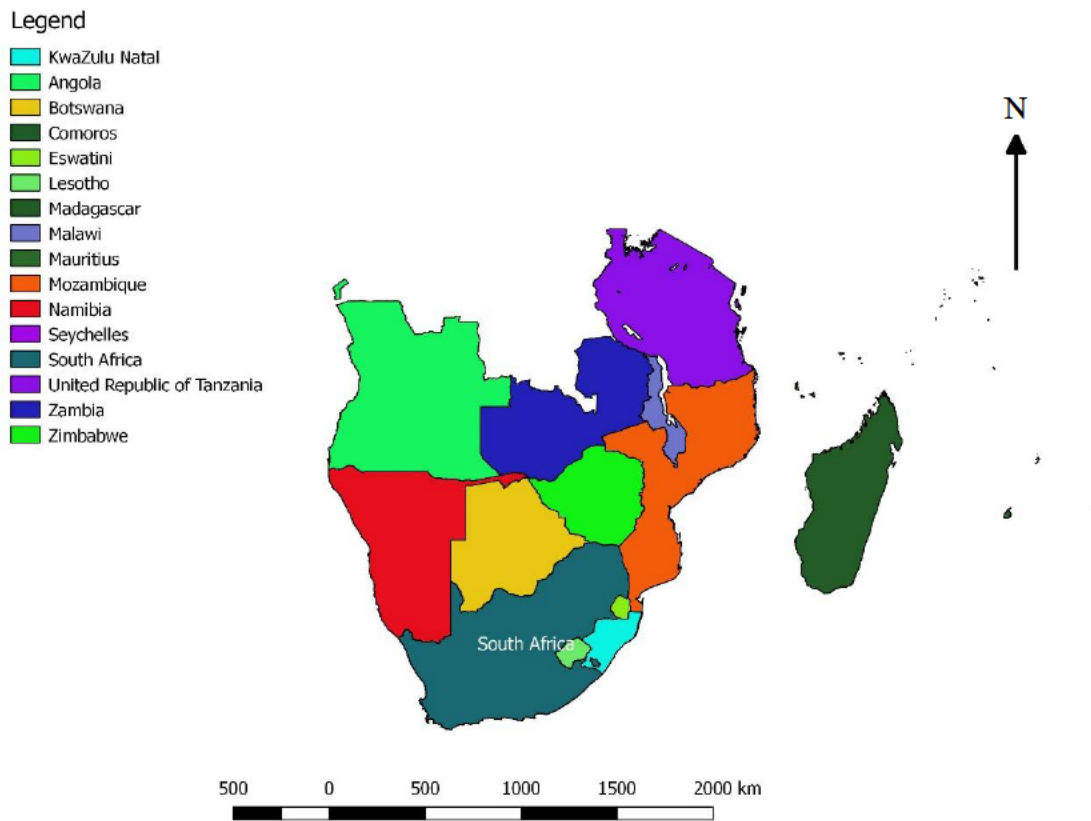


Figure 3.1. Location of KwaZulu-Natal (in blue) in the region of southern Africa (Source: M.N. Nkomo using QGIS).

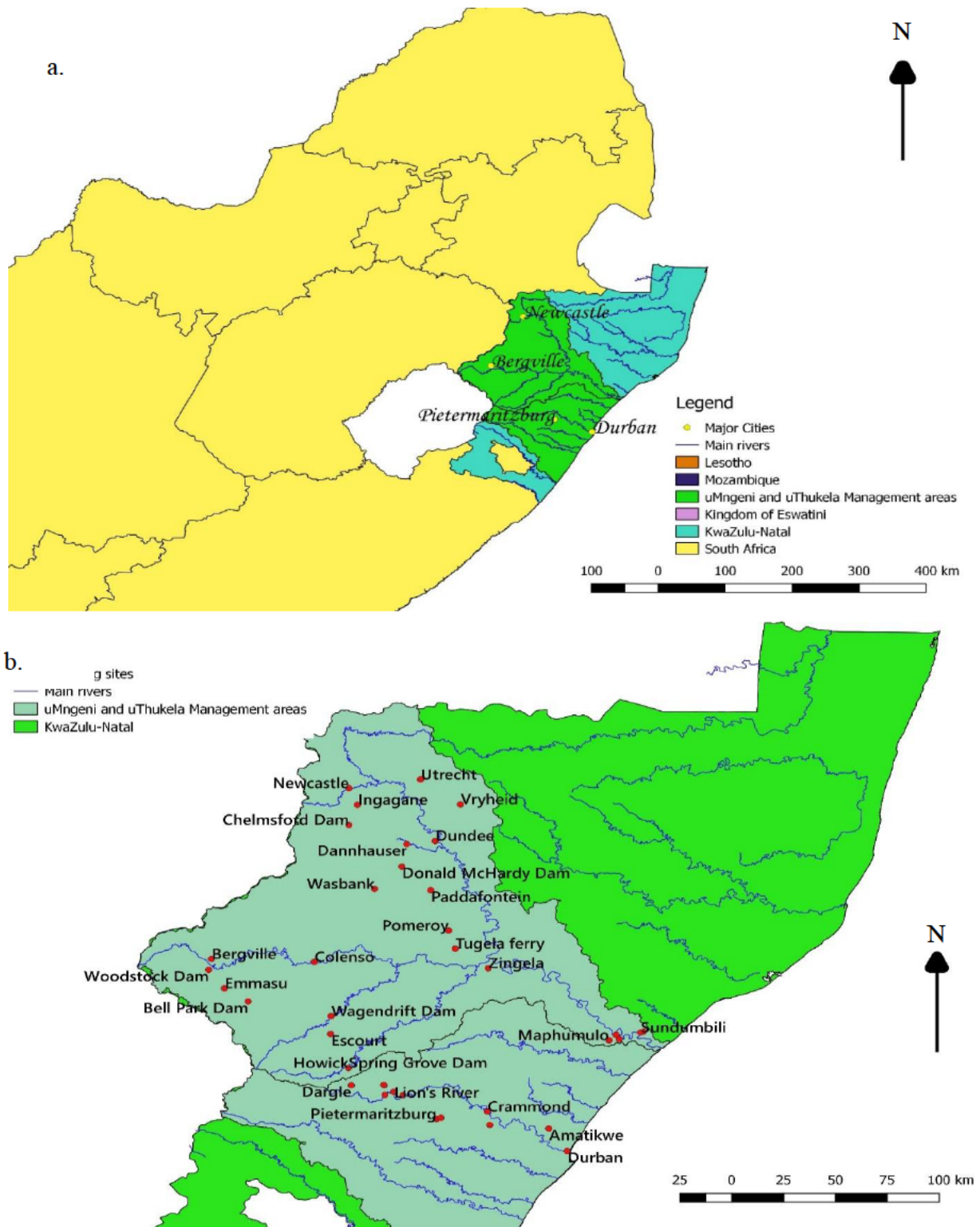


Figure 3.2. Maps showing a. the management areas of uThukela and uMngeni (shown in green) catchments in KwaZulu-Natal, South Africa, and b. the sampling sites in these (shown in red).

The municipalities sampled were Abaqulusi, Endumeni, eThekweni Metro, Mandeni, Newcastle, Okhahlamba, uMngeni, uMshwathi, uMsunduzi, uMzinyathi, and Uthukela. Additional municipalities visited were uMvoti, uMlalazi, and Dr Nkosazane Dlamini Zuma. UMvoti catchment (in uMvoti Municipality) flows between uMngeni and uThukela catchments, attempting not to miss any information, so the uMvoti was also sampled. Dr Nkosazane Dlamini Zuma Municipality consists of tributaries bordering the uMngeni catchment and uMkomaas catchment, and being closer to the Drakensberg Mountains, people living here were also interviewed. Interviews were for anyone who used the river and to ensure respondents were people who interacted with rivers almost daily. Interviews were conducted with anyone using the rivers that we met along the rivers (Fig. 3.2).

3.3.2 Sampling techniques

We designed a questionnaire to use in individual interviews or group interviews (Supplementary information Table S3.1). We obtained ethical clearance to use the questionnaire from the University of KwaZulu-Natal School of Ethics Humanities Ethics (HSSREC/00003175/2021). We conducted interviews with single individuals or with groups at sampling sites in uThukela and uMngeni catchments (Fig. 3.2). The first author and an assistant conducted all interviews.

The respondents in this study were individuals 18 years and older. Invitation to participate in an interview was made to individuals found using the river for any purpose (fishing, fetching water for drinking, irrigation, washing clothes or utensils, cleansing, praying, etc.). Scholars (older than 18 years), traditional leaders, and members of the community at large were interviewed after referrals from previous participants. The people referred to by participants interviewed had further

knowledge on either eel belief in the area, more information about the use of the river, and more about fishing activities (changes in fishing and water use).

Interviews took place opportunistically from March 2021 to October 2022 during working hours, 08h00 to 17h00 and lasted approximately 20 min. The interviews were conducted in either English or isiZulu, depending on the respondents' chosen language. All persons interviewed were first asked to participate and had to give their permission to participate. No personal details of the persons interviewed were recorded. We recorded the time, date and location (using a global positioning system (GPS, Garmin, USA)) of where each interview took place.

3.3.3 Data analyses

We mainly used descriptive statistics to show the trends in the data obtained. These included the number of sites sampled, the number of respondents that were interviewed, and the relevance to African freshwater eels. In addition, we summarised respondents' dependence on eels, the recreational value of eels, the value attached to eels, and the people targeting eels. We used the Chi² test (IBM SPSS) to assess significant differences. We also used word clouds to show relevance in responses using monkey word software (<https://monkeylearn.com>). We used QGIS to make maps of the areas (<https://www.qgis.org/en/site/>).

3.4 Results

3.4.1 General trends

A total of 154 people were interviewed, the majority were males (n = 102, 66%), and most (15%) were of the ages 45 – 59 years (Table 3.1). There were significantly more male (except for Uthukela) than female respondents (n = 52, 32%) ($\chi^2 = 194, 608, \text{d.f.} = 74, P = 0.001$, Table 3.1,

Fig. 3.3). From the majority of men interviewed, 51% (n = 52) resided in the localities of uThukela catchment and 49% (n = 50) from uMngeni catchment (Fig. 2.2), and these included rural and urban areas. The sample consisted of participants who shared their knowledge in greater detail of the river and freshwater species. In contrast, the other percentage of the sample only answered technical questions with no added narratives regarding belief or religion or changes in habitat impacting eel abundance or scarcity in their local rivers. Most respondents were isiZulu-speaking people (76%). The highest education level completed by respondents was grade 12 (matric), obtained by 32% of respondents, followed by 29% with no access to education (Table 3.1). Forty-four per cent of respondents earned above the minimum wage (ZAR23.19 per hour, ZAR4174.2 per month), 37% earned under the minimum wage, 16% were unemployed, and 3% were pensioners (Table 3.1). Lastly, 51% (n = 78) subscribed to their respective ethnic traditions, 36% (n = 55) were Christian, and 13% (n = 21) did not subscribe to any religion (Table 3.1).

Table 3.1 Summary of respondents' demographics in the present study.

Parameter	Number of respondents		%
Gender			
Female	52		44
Male	102		66
Age			
Under 25 years	21		14
26 - 34	29		19
35 – 44	256		52
45 – 59	43		28
60 – 75	25		16
Over 76 years	2		2
Education			
None	45		29
Secondary	23		15
Completed matric	49		32
Tertiary education	37		24
Employment status			
Unemployed	25		16
Under minimum wage	57		37
Above minimum wage	68		44
Pensioner	4		3
Ethnicity			
Zulu	117		76
Afrikaans	2		1
Indian	11		7
Sotho	7		5
Xhosa	1		1
Shona	3		2
Mixed Race	1		1
English	12		8
Religion			
None	21		13
Traditional	66		43
Hindu	6		4
Muslim	3		2
Nazareth Baptist Church	3		2
Christian	55		36

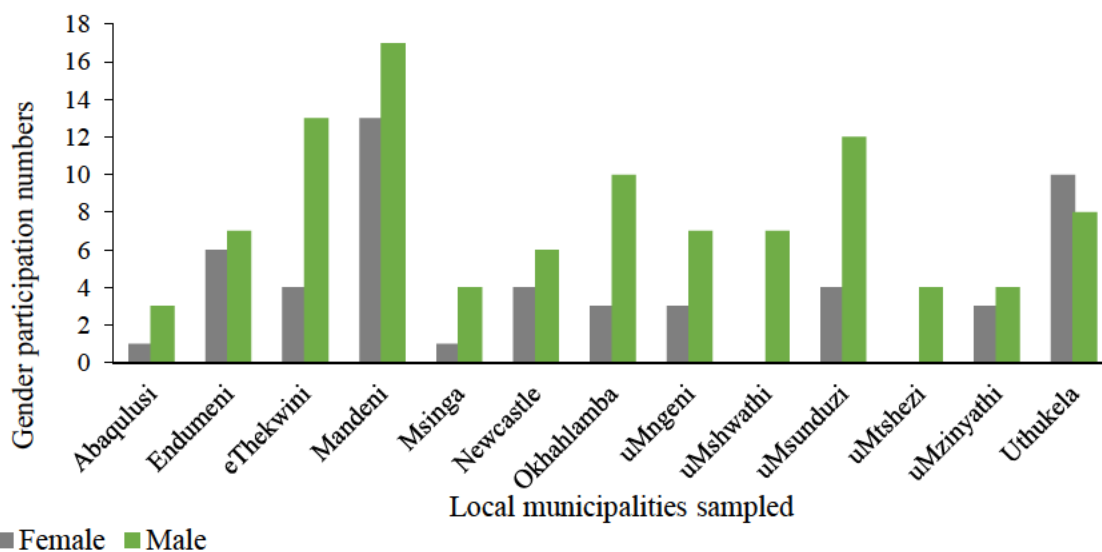


Figure 3.3. Comparison of respondents by gender in local municipalities sampled across uMngeni and uThukela management areas in the present study.

Of the respondents, 74% were subsistence fishers, with most ($n = 75$, 73%) male, while there was only one ($n = 1$, 1%) female fisher who lived in the Mandeni area (Fig. 3.2). Of these fishers, 56% ($n = 42$ of 75 fishers) had caught freshwater eels, and 40.5% ($n = 17$ of 42 fishers) specifically targeted eels, which was a significantly small component of all respondents interviewed ($\chi^2 = 197, 195$, d.f. = 10, $P = 0.001$). The remaining 59.5% ($n = 25$) of fishers had caught freshwater eels but did not specifically target eel species.

In totality, fishers interviewed in this study that targeted catching eels were males between 24 and 67 years (in the year range of an employable citizen), and most depended on freshwater eel catches for income because of the relatively high demand and value. Most of these fishers reported being subsistence fishers. Selling of eels emanated from other household needs, which required money, thus generating money by selling eels. Consequently, these fishers depended on freshwater eels for their livelihoods. Of these fishers, 59% ($n = 10$) earned under the minimum wage

(ZAR4174.2 p.m.), 35% (n = 6) earned above the minimum wage, and 1% (n = 1) were unemployed. The fishers who earned below the minimum wage reported having fishing (that of freshwater eels and other freshwater species) as their main source of income.

3.4.2 Ecological and biological aspects of eel fisheries

Of the respondents who had caught eels, 7% (n = 3 out of 42 respondents who had caught eels) were fishermen who could not distinguish and identify life-stage features. 45% (n = 19 of 42 respondents) reported having caught yellow eels, while 48% (n = 20) reported having caught mostly silver eels.

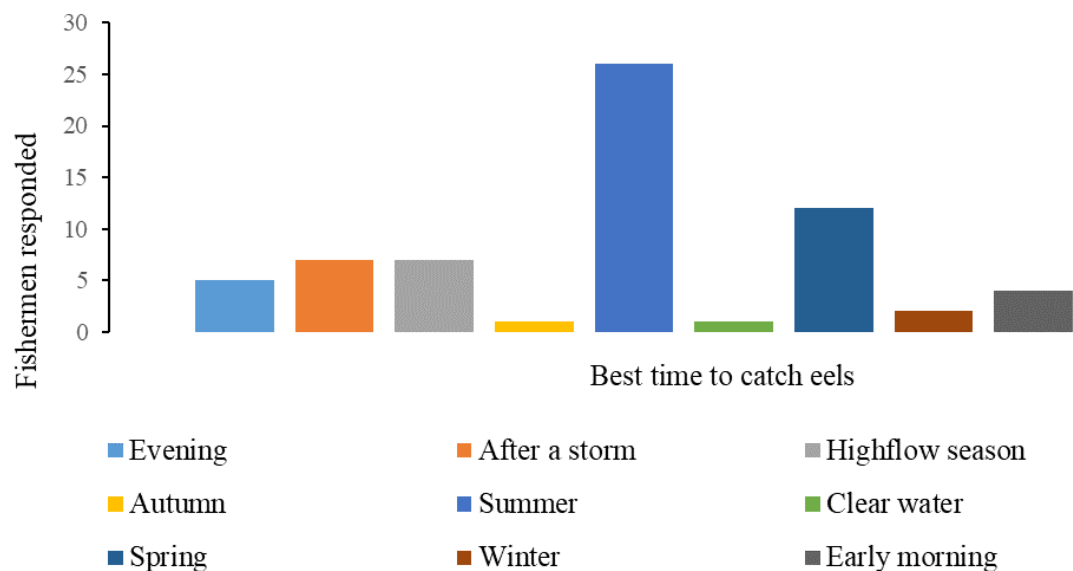


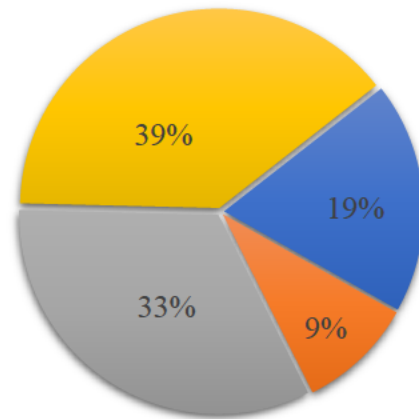
Figure 3.4. The best times to catch freshwater eels, according to those interviewed who were fishers in the present study.

Of the fishermen who targeted freshwater eels ($n = 41$), they reported different preferred times for the possibility of catching an eel. Summer was the most preferred time to catch eels, reported by 61% ($n = 26$), while 19% ($n = 8$) preferred targeting eels in spring when water appears dirty because of frequent rain, with less light penetrating the water surface freshwater eels swim freely and closer to the surface (Fig. 3.4). Furthermore, 17% ($n = 7$) of fishers reported high flow or immediately after a flooding event as the best time to catch eels (Fig. 3.4). Four fishers reported that dawn (immediately after sunrise, especially in winter) or dusk (the late evening before sunset) was the best time for catching eels (Fig. 3.4).

Of the respondents, 41% ($n = 64$ of 154) reported the occurrence or presence of eels from their knowledge (Fig. 3.5). This included respondents who had purchased eels from local fishers or seen one from a fisher's harvest, or were fishers themselves (81%, $n = 52$, fishers; and 19% $n = 12$ non-fishers). A total of 72% ($n = 46$) of these combined responses were respondents from the uThukela management area, and 28% ($n = 18$) were respondents from the uMngeni management area out of a total of 64 respondents who responded to know the occurrence of eels on rivers in their local communities in the areas sampled (Fig. 3.5). According to the participants, the majority of eels occurring in the KwaZulu-Natal freshwater areas occurred in the uThukela catchment and were mostly in the tributaries. This perception was common among respondents in the upper part of the catchment (Fig. 3.2). From local fishers interviewed, *“ukwakhiwa kwamadamu kwenza imibokwane igcware edamini ingakwazi ukwehlela ngezansi nomfula. Kuphela uma line kakhulu imu lachichima, ike iphume namanzi nezinye izinhlanzi ukuza ngezansi nomfula”*. This was reported by a fisherman in Kwadabeka (uMngeni catchment) that dam infrastructure tends to hold a large number of eels, and other fish, stopping them from swimming downstream in the river. When the dam overflows, it so happens to find them downstream (usually in the summer after a

flooding event). Several fishermen in this area mentioned above further confirmed this, explaining the type and number of eels caught after the 2022 floods.

a.



■ uMngeni Main River ■ uMngeni Tributaries ■ uThukela Main River ■ uThukela Tributaries

b.

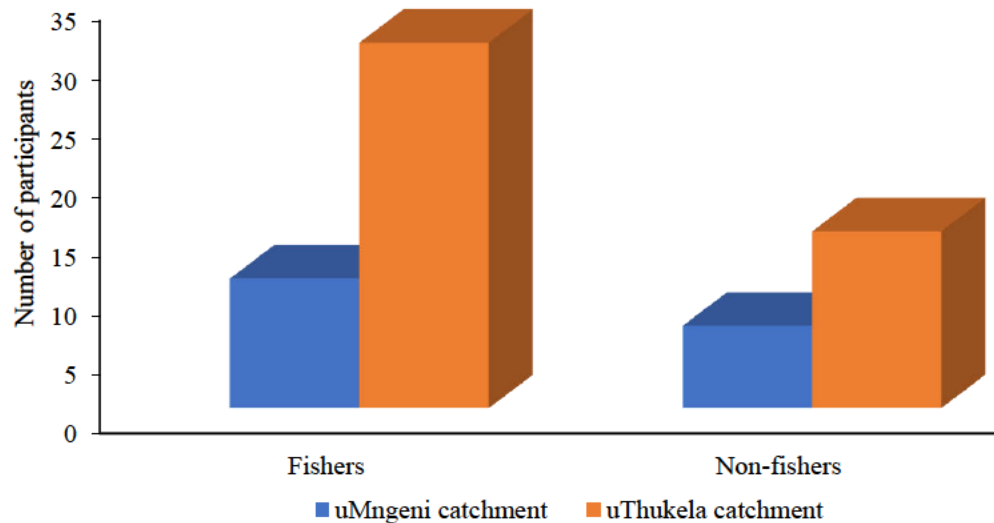


Figure 3.5. Proportion of respondents (%) knowledge of a. *Anguilla* spp. occurrence in the main rivers and tributaries of uThukela and uMngeni, and b. the presence of freshwater eels in uMngeni and uThukela catchments.

3.4.3 The value of eels to fisheries

Respondents living in the municipalities in the northwest of KwaZulu-Natal (Newcastle, Okhahlamba, Dannhauser, and Abaqulusi) used a common name of *Mukhane*, while those in the central to the east of KwaZulu-Natal (uMsunduzi, uMngeni, uMzinyathi, Uthukela, Endumeni, Msinga, and eThekweni) used *Umbokwane*, both being isiZulu names for ‘eel’. In addition, not restricted to location, *Falangu* was a term used by Indian English speakers and *Paling* by Afrikaans-speaking people. Fishers and the general public responded and shared their knowledge of the importance of eels according to their knowledge and reported different uses of freshwater eels and their benefits. Freshwater eels were consumed as a source of nutrients, were said to be tastier than other freshwater species, and had larger amounts of meat. Beyond this, respondents shared that the various parts of the eels can be useful for different aspects of medicinal healing. These were the skin/ integument, mucus (scrapped from the skin), and some inside parts of the eel. Many (60%) reported medicinal benefits from mostly the mucus. In these findings, eel mucus and skin were used for healing and protection. In comparison, the inside components were consumed as a source of food. In the Okhahlamba region towards the Maloti-Drakensburg region, some other parts of eels (which are believed to be in the form of eggs) were used for livestock management (protection and increased reproduction). Some payments for eels were in the form of livestock, as reported by some respondents. For example, one farmer traded a matured goat for any eel received from a local fisherman. In rural areas, the present price of a mature goat ranges from ZAR2500 to ZAR3300.

Another importance of eels highlighted by various respondents was their selling price depending on the size of each caught. Eels (mostly in the uThukela catchment) were reported to have a higher price value (~ ZAR200 to ZAR1200) if sold to community members, in town, or to

traditional healers than most freshwater fish species (~ max. of ZAR75). This was reported by 31% (n = 13 of the 42) fishers. Fishers in the area of Newcastle mentioned that eels are mostly purchased by local traditional healers and tourists (Indian, Chinese and English). Around Estcourt, Wembezi and Weenen, Indian fishermen fish and sell freshwater eels to their Chinese customers. Some (n = 4, 10%) local fishers reported that some Indian fishers buy eels from them in these areas and sell them to Chinese people. The prices at which the fishers sold freshwater eels depended on the size of the individual eel or the amounts of skin extract obtained from the eel species. Responses ranged from ZAR100 to ZAR800 per eel. However, those purchasers who then sold these eels to other buyers were reported to earn significantly more. In Durban Berea Station, the eel market mostly supports subsistence and small-scale fisheries selling eels in the market of traditional medicine. One fisher on the uMngeni main river (area of Kwadabeka, downstream for Inanda Dam) expressed that the money generated from eels (and other freshwater fish species) was used not only as a source of income but assisted him in paying for education for his children. The overlap in the market of freshwater eels occurred when fishermen generated income by selling eels mostly to traditional healers for medicinal use and/ or protection, and then traditional healers sold processed products of eels to people in the community (including fishermen). This sustains the small-scale eel fisheries and keeps the business functioning.

The word cloud (Fig. 3.6) illustrated the most frequent responses and reasons in larger font sizes for targeting freshwater eels in freshwater systems and prioritising catching them over other freshwater species. The most frequent response was the selling of eels to traditional healers. The second highest response was related to money, as the sellers' price of eels was the highest of fish species when trading (Fig. 3.6). Some fishers reported that they sold entire eels as a source of food or sold them in parts (skin, mucus, and meat) for other uses.



Figure 3.6. Some of the uses and/ value of eel species provided by respondents who targeted freshwater eel species in the present study.

3.5 Discussion

The east of southern Africa is a warm region influenced by Agulhas and Benguela oceanic currents (Whitfield, 2005), and these currents control water movement, affecting the species-rich estuarine regions (Maree et al., 2000; Whitfield, 2005). There are no anguillid eel records in the cooler south western regions of South Africa (Scott et al. 1951). The four *Anguilla* species present are only recorded in the warm regions and only distributed and recruited in estuaries (Beckley, 1984). This region's climate favours these species' occurrence (Scott et al., 1951; Whitfield, 2005), with temperatures suitable for the anguillid species found in this region in both marine and freshwater environments. One species, *A. mossambica* is endemic to Africa (Lin et al., 2015; Hanzen et al., 2019, 2022). Our findings in this study showed that there were populations of various eel species

in the freshwater systems of our study areas in KwaZulu-Natal, and most were in the yellow and silver life stages, according to the respondents' descriptions.

There is a paucity of information on the values of eel species in the southern African context compared with Europe and Asia (e.g., studies of *Anguilla anguilla*, *A. rostrata*, and *A. japonica*) (Shiraishi and Crook, 2015; Kaifu et al., 2019; Pike et al., 2020; Chapter 2). The study showed relatively few people in the study areas specifically targeted eels, but those that did included fishers from both catchments in our study area. Respondents shared the benefits and uses of freshwater eels, including nutritional, medicinal, cultural, and social benefits. These had not been previously documented (Chapter 2). It highlighted the importance of these resources in the natural freshwater ecosystems in KwaZulu-Natal. Fishers reported that fishing for eels, unlike most freshwater species, required specific techniques and timing to catch them. The catch technique discourages other fishers from specifically targeting freshwater eels as they only fish when they get time from their day or part-time jobs.

The sample of responses provided by our study does not represent the number of people in our study areas who interact with rivers for fisheries and other benefits but represents the distribution areas of freshwater eel species occurrence. The probability of encountering people who had not caught eels in the study areas was as high as meeting people who had caught eels; thus, there was a dichotomy in respondents' responses, with some having no idea of what eels were nor how they looked. Similarly, in a study of angler interactions with the American eel (*Anguilla rostrata*), nearly half of the respondents declared a limited or lack of knowledge about the species and their value (both ecological and economical) (Litt et al. 2021).

We found inland small-scale fisheries in local communities in the sampled local municipalities of KwaZulu-Natal were male-dominated, with relatively few females taking part

directly. We encountered only one female fisher. However, most female respondents interacted with the rivers daily, especially for domestic use (fetching water for drinking water, cleaning, and cooking). However, as members of these local communities, fishing was part of their daily life activity, which made them knowledgeable about what activities happened in the rivers, including daytime fishing, the price of freshwater fish, and the presence of eel species.

Western Indian Ocean eels are globally exploited species (Kaifu et al., 2019). They recruit in different rivers in various countries and are culturally and economically important (Hanzen et al., 2019). The freshwater eel trade was historically in Asia and Europe until the species in these regions were endangered, resulting in international trade between Asia, America, and Africa (especially Tunisia and Morocco) (Burger, 2002; Kaifu et al., 2019). In 2010, the European Union under CITES declared *A. anguilla* an Endangered species, thus banning the sale of eel to any other parts except Europe. This ban meant no eels could be sold to Asia or other parts of the world. In Europe, after this ban on eel trade, European fisheries demanded that every fisherman/company obtain special permission to fish and harvest eels (Dekker, 2019).

The pressure and demand for eels caused Asians to seek alternatives to meet the demand for these economically important freshwater fish species. Asian countries then targeted American freshwater eels (*A. rostrata*) and tropical *Anguilla* spp. and developed strategies for artificially producing eels using aquaculture (Shiraishi and Crook, 2015), despite Japanese preferring wild-caught freshwater eels (Kaifu et al., 2019). The increasing demand for freshwater eels triggered black markets and the illegal trade of juvenile, wild-caught freshwater eels (Kaifu et al., 2019). The demand emanates from the economic and cultural importance of fishing for *A. japonica* in China, Korea, Taiwan, and Japan, which has further endangered the species (Jacoby and Gollock, 2014). Shirairi and Crook (2015) highlighted that the illegal trade of eels was linked to the failure

to obtain these permits and the pressure that comes with the economic value of eels in the economy of different countries (estimated at ~US\$36 million per annum, 11 tonnes of eels per annum) (Laffoley et al., 2011). The high revenue generated for freshwater eels in the northern hemisphere countries shows that the sustainable management of these species is important elsewhere. The South African inland fisheries policies have not yet explicitly catered for anguillid eels. If these eel species were common in South Africa, specifically KwaZulu-Natal, there might be a missed opportunity to generate revenue with export, recreational fishing, and commercial markets for these species for the reported cultural and religious uses. However, the decline in the abundance and distribution range of eel species in KwaZulu-Natal is of concern (Evans et al., 2022; Hanzen et al., 2019, 2022), especially if there is no sustainable management nor policing of offtake nor enforcement of regulations. Furthermore, the degradation of freshwater environments, particularly the construction of instream barriers to meet water security demands in KwaZulu-Natal and pollution (Rivers-Moore et al., 2011; O'Brien et al., 2019; du Plessis, 2023), are likely also impacting eel presence and abundance.

Some respondents reported that non-African fishers or buyers were interested in wild-caught eels in some of our study areas, particularly Estcourt and Weenen. This has led to other fishers purchasing and selling eels from local fishers, especially Chinese individuals who are interested in buying these species. In addition, we found traditional healers, other fishers, and non-fishers buy eels from local fishers. According to many respondents, there were no regulations for fishing for eels or the selling and purchasing of eels. However, provincial ordinances control the fishing and sale of these species (Francolini et al., 2023). However, in our study in areas of KwaZulu-Natal, there was an absence of the enforcement of regulations. Some of our respondents suggested that there has not been an over-harvesting of these eel species at this stage, but rather,

few fishers focus on eels as they are difficult to catch, discouraging other fishers from fishing for eels. However, the population decline of eel species in KwaZulu-Natal remains a concern, as highlighted by Hanzen et al. (2022).

In our study, most fishers confirmed the river's conditions were relatively suitable for anguillid eels (judging by the size of previously caught species), whose presence was low in winter, making the season less favourable for targeting these species. However, flooding occasionally flooded dams and weir pools, enabling freshwater fish to move downstream, including eels. These times were most favourable for targeting eels. From local fishers interviewed, the anthropogenic infrastructure in the river courses hinders the migration of these freshwater species, resulting in eels concentrating in dams. In a Zimbabwean study, damming, agricultural pollution, and mining interference have decreased the abundance of the *A. bengalensis labiata* in Mushumbi Pools (Utete et al., 2022). Anthropogenic activities affect water quality and the environment, thus, the fish species present in freshwater systems (Utete et al., 2022).

Eels have a significant role in the economy of Asian countries (Kaifu et al., 2019) and are globally important species for recreation and sustainable fisheries (Cooke et al., 2016). Our findings showed eels hold market economic value enough to support the livelihoods of some subsistence fishers. However, their economic importance or demand in the market mostly emanates from their significance in medicinal use and benefits, as shown in other southern African studies (Utete et al., 2022).

Artificial production of freshwater eels has successfully met the demand for juvenile eels (glass and elver eels) (Tanaka et al., 2003). In the increase of consumption of eels in Japan (~150 000 tonnes per annum in 2012 and 2013) (Shiraishi and Crook, 2015), the aquaculture techniques have also increased significantly to meet the demand from 69 926 tonnes in 1960 to 236 344 tonnes

in 2012 (Laffoley et al., 2011; Shiraishi and Crook, 2015). We found the economic importance of eels in KwaZulu-Natal was not to the same extent as that of Europe and Asia. Although some fishers indicated a demand for it as a food source, it was presently relatively low. The use of eels is still largely subsistence and informal trade for medicinal or cultural benefits. For example, eel mucus is preferred in traditional medicines, but low eel catches and high demand have caused the use of catfish (*Clarias gariepinus*) mucus as catfish mucus displays similar slippery properties to eels, as suggested by respondents. Targeting of eels focuses on the yellow or silver-like stages, which have components consumers require in the market, not the juvenile glass and elver eels as in other countries. Harvesting eels includes selling catches to support families and everyday living expenses. Fishers occasionally reported selling their harvest of eels or eel products at a Durban marketplace called Berea Centre, near Berea train station. The economic values of eels in KwaZulu-Natal were relatively difficult to fully estimate as some payments were in the form of livestock, as reported by respondents. The cultural significance of eels was interlinked with socio-economic benefits in the uses of these eel species in most responses, so the targeting and harvesting of eels were linked to these. Therefore, there was exploitation (through fishing) of freshwater eels, which is likely unsustainable given the decline and geographical range contraction of eel species in KwaZulu-Natal (Hanzen et al. 2022).

This contextual study was influenced by the occurrence of eels, the degree of subsistence fishing, and the demand, socio-economic and cultural values of eels. Fishers who responded reported mostly fishing for eels and other fish species only for subsistence, while others derived livelihoods. In addition, some reported difficulties in catching eels. However, given the decline of the eel species in river systems in KwaZulu-Natal Province (Evans et al., 2022; Hanzen et al.,

2022), it is not clear if this is sustainable or if it is over-exploitation of the available *Anguilla* spp. in the KwaZulu-Natal River systems.

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3.8 Supplementary information

Supplementary Table S3.1 The questionnaire used in the present study

Fisheries and eels in the WIO – Questionnaire					
COUNTRY:		RIVER:		SN:	
1. RESPONDENT INFORMATION					
Village:	Gender: M/F		Marital status:		
Education (yrs):	Age:		Tribe/ethnicity:		
Religion: ☐ Christian ☐ Muslim ☐ Traditional ☐ None ☐ Others (specify):	Monthly Income: ☐ Grant ☐ No Grant ☐ Under minimum wage ☐ Above minimum wage Are other people in your household earning an income? YES or NO		Occupation: ☐ Farmer ☐ Fisher ☐ Business ☐ None ☐ Others (specify):		
2. Can you tell us about the river(s) around your village? How important are they to you?					
3. How often do you use the rivers around you community for the following purposes?					
	Daily	Weekly	Monthly	Yearly	Never
Drinking water					
Washing utensils					
Washing clothes					
Washing yourself					
Irrigating crops					
Watering livestock					
Fishing					
Aesthetic					
Spiritual					
Cultural					

Others (specify):					
4. General fisheries					
4.1 Have you ever fished in the river(s)? YES or NO					
4.2 If yes, how frequently? ☐ Daily ☐ Weekly ☐ Monthly ☐ Seasonally ☐ Others (specify):	4.3 Why do you fish? ☐ To eat ☐ To sell ☐ For fun or sport ☐ Others (specify):	4.4 How often do you consume fish? ☐ Daily ☐ Weekly ☐ Monthly ☐ Seasonally ☐ Other (Specify):	4.5 Where do you sell extra fish caught? ☐ Own village ☐ Neighboring village(s) ☐ Town ☐ Do not sell ☐ Others (specify):		
4.6 Do you use a boat (YES/NO); what type?					

4.7 Which income generating activities do you and other members of your household participate in?				
	Check	# of people	Rank importance	Notes
Fishing				<i>If no longer fishing, why ?</i>
Agriculture				
Informal trade				
Salaried employment				
Tourism				
Others (specify):				
4.8 Which fishing gears do you own and use?				
Gear	Rank	Which gears do you own?	If not, do you borrow or rent the gear?	
Hand line				
Longline (many hooks)				
Gillnets				

Seine nets			
Harpoon/Spear-gun			
Fish traps/pots			
Fish Weirs			
Explosives/Poisons			
Others (specify):			

4.9 What are the 5 most common fish you catch?	4.10 How many do you catch on a good day?	4.11 How many do you catch on a bad day?	4.12 How much do you sell them for?
1 -			
2 -			
3 -			
4 -			
5 -			

5. Eel fisheries				
5.1 Do you know if there are eels in your rivers? YES or NO				
5.2 How many different types of eels do you know from your river(s) and their local names?				
5.3 How do you differentiate between these different types of eels?				
5.4 Do you know about the different eel stages? YES or NO				
5.5 What are the local names for the different eel stages?				
5.6 Have you ever caught eels in your river(s)? YES or NO				
5.7 If yes, what kind of eel and what stage do you catch? 1 = <i>sometimes</i>, 2 = <i>always</i>, 3 = <i>never</i>				
	Longfin eel	Giant mottled eel	African mottled eel	Short fin eel
Glass				

Elver				
Yellow				
Silver				
5.8 Do you specifically target eels? YES or NO				
5.9 Why do/don't you target eels ?				
5.10 How frequently do you fish for eels ? DAILY – WEEKLY – MONTHLY – YEARLY – NEVER				
5.11 How do you catch eels ? ☐ Hook and rod ☐ Fly fishing ☐ Net ☐ Traps ☐ Weirs ☐ Others (specify):	5.12 Where in the river do you catch the most eels ? ☐ Open water ☐ Vegetation edges ☐ Rocky edges ☐ Fast flowing water ☐ Slow flowing water ☐ Others (specify):	5.13 When is the best time of the year to catch eels ?		
5.14 Why do you fish for eels? ☐ To eat ☐ To sell ☐ For fun or sport ☐ Others (specify):	5.15 Where do you sell the eels caught? ☐ own village(s) ☐ neighboring village(s) ☐ Town ☐ Export ☐ Do not sell ☐ Others (specify):	5.16 How much do you sell the eels for?		
5.17 In your opinion, has the fishery changed in the recent past? ☐ More eels ☐ Less eels ☐ Bigger eels ☐ Smaller eels ☐ Do not know ☐ Others (specify):		5.18 In your opinion, what are the reasons for the change? ☐ Overfishing ☐ Poor land use (over fertilising, erosion etc.) ☐ Less water in the river ☐ Water is dirty or contaminated ☐ Climate change ☐ Deforestation ☐ Don't know ☐ Others (specify):		

5.19 Do you like fishing for eels? YES or NO

5.20 And Why?

5.21 Are there any belief(s) associated with eels in your communities? YES or NO

5.22 If yes, what are they?

5.23 Are there any beliefs associated with this river, known by the community?

CHAPTER 4

Cultural and spiritual values of rivers and freshwater eels in the uMngeni and uThukela catchments, KwaZulu-Natal, South Africa

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Running header: What are the cultural values of rivers and eels?

4.1 Abstract

Beyond using freshwater systems for domestic purposes and meeting basic needs, people use them for other purposes that speak to their culture, beliefs, spirituality, and/ or religion. In this study, we examined the use of freshwater eels (*Anguilla* spp.) beyond harvesting them to sell or consume. In particular, we investigated the spiritual and cultural values of African freshwater eels and their associated freshwater environment in the uMngeni and uThukela catchments, KwaZulu-Natal, South Africa. Using a questionnaire, we interviewed people (n = 154) along these river systems during 2021 and 2022. We found that people had various beliefs associated with eels and rivers. The responses showed that people valued clean rivers for various cultural, religious, and recreational activities. Some valued eels as they were associated with their beliefs. People who use freshwater for their respective cultural and spiritual, fishing, and domestic purposes voiced a considerable challenge in using freshwater systems, water pollution and water contamination from industrial waste or eutrophication from agricultural waste. In some areas, such as Estcourt and Molweni, there was limited access to the river for many community members because of private ownership, leaving the available water used for domestic, irrigation, and washing. The smaller portion of river water accessible to people was concentrated with household waste, making the accessible part of the river highly polluted. This pollution affected people around where pollution had accumulated and further downstream. Without community participation, there is no guaranteed sustainability of the water resources for the spiritual and cultural values of freshwater eels and freshwater systems. The respondents stated that the community and water management bodies (including traditional and community leaders) must create long-term sustainable use and protection of inland water and fisheries resources in KwaZulu-Natal, which will govern people and industries in local communities on river management.

Keywords: freshwater systems, rivers, eel species, beliefs, Ethnozoology, indigenous knowledge

4.2 Introduction

Freshwater ecosystems that are variable (moving through dry and wet periods/seasons) comprise between 34% to 69% of the world's inland waters (Acuña et al., 2014; Arthington et al., 2014). Non-perennial (temporary) rivers dry out entirely in dry seasons, exposing the former aquatic system to a terrestrial system (Thorp and Covich, 2015). This is exasperated by continual human development, which increases the demand for water as a resource and cannot be ignored (Datry et al., 2018; Leigh et al., 2019). Various studies highlight the sociocultural and -economic values that importantly benefit both freshwater ecosystems and humans (Jorda-Capdevila et al., 2021), which continues to increase the demand for freshwater with an increasing population (Datry et al., 2018). These values encourage people to manage these ecosystems (Jorda-Capdevila et al., 2021), maintaining good water quality and habitat conditions for various ecosystem services (Gibbs, 2010). However, other studies (Datry et al., 2018; Leigh et al., 2019) importantly show that despite a river's value, they are generally ignored and disregarded in managing these ecosystems, seen primarily as natural water conduits to move water around. The lack of understanding and proper decision-making affects the overall management of these ecosystems, contributing to freshwater ecosystem degradation (Molobela and Sinha, 2011; Datry et al., 2018; Leigh et al., 2019), especially in water-stressed ecosystems (Acuña et al., 2014). It is important to consider the value of water not only as a basic need but also to understand the importance of rivers to humans (Jorda-Capdevila et al., 2021). The socio-cultural and -economic benefits from the rivers remain a necessity in most communities (Kenter et al., 2015) at any location or part of the community (along perennial or non-perennial rivers) (Acuña et al., 2014). Sustainable management of freshwater

systems can support social-ecological needs to support livelihoods; however, maintenance of the present freshwater ecosystem needs to be improved for the better conservation of cultural values and regulate economic benefits (Jorda-Capdevila et al., 2021).

Cultural ties with freshwater ecosystems in southern Africa are understudied (Chapter 2). Wood (2005) documented some of these cultural relationships. For example, a snake-like creature believed to reside in freshwater contains supernatural powers; a man called *Khotso Sethuna* from Kokstad-Pondoland in the Eastern Cape was said to be connected to this snake; thus, he was powerful and wealthy (Wood, 2005). This snake is also said to be a rain-making snake, *Inkanyamba*, which only a few people can connect with for their benefit (Wood, 2005). While the rain plays a considerable role, it was said to be very violent (Wood, 2005). The snake-like imagery tied to water is ever present in local cultural beliefs. According to anthropologist W.D. Hammond-Tooke, these water snakes are respected by people and thus shape people's way of life regarding the part of the river that can be used, the times of use, and the people who can use these sites (Wood, 2005). A similar concept of water monsters *Nyami Nyami* occurs in the Zambezi River where the Zambezi Snake Spirit or River God have an important cultural and spiritual factor in the lives of the Tonga people and shapes their way of life (Musona, 2011).

The Malagasy people in the Western Indian Ocean (Ruud, 1960; Lambek, 1992) have a concept called *fady*, a taboo. This restricts the use or exploitation of natural resources at a certain place (Langley, 2006). It may be limited to a particular family or lineage and thus differs from community to community. Working hand in hand with *fady* is *dina*, a law approved by village members regulating the exploitation of natural resources (Rakotoson and Tanner, 2006). This recognises sacred places and ancestors' connection with the natural ecosystem (Cinner, 2007). Anyone who breaks these taboos or the laws of the land taboos is said to have disturbed the resting

of ancestors whose anger can only be calmed by sacrifices (Lambek, 1992; Sharp, 1994; Cinner, 2007).

There are relatively few snake-like freshwater fish in southern Africa that fit the descriptions from some texts apart from the African freshwater eels (*Anguilla* spp.). Although African rock pythons (*Python natalensis*) do take to water, it is suggested that the 'Nkamyamba' could be associated with the anguillid eels (Wood, 2005).

The anguillid eels are catadromous migrators and globally important species for recreation and sustainable fisheries (Cooke et al., 2016). Beyond their economic and nutritional value, anguillid eels are globally important for their cultural and spiritual values in society (amongst people) (Davis et al., 2004; Algonquins of Ontario, 2012, 2014; Denny et al., 2012; Feunteun and Robinet, 2014; McCarthy et al., 2014; Giles et al., 2016; Whaanga et al., 2018). Some of these values emanate from religious beliefs, some from cultural beliefs, and some from conserving and preserving natural resources by land users (Davis et al., 2004; Algonquins of Ontario, 2012, 2014; Denny et al., 2012; Feunteun and Robinet, 2014; McCarthy et al., 2014; Giles et al., 2016; Whaanga et al., 2018). As migratory species, anguillid eels are greatly affected by limited movement as a result of river fragmentation (Cooke et al., 2016), which may affect the users that benefit from these species (Hanzen et al., 2019).

African freshwater eels, *Anguilla mossambica*, *A. bengalensis*, *A. marmorata*, and *A. bicolor* are the four of the nineteen eel species (Feunteun et al., 2003; Tech, 2003; Righton et al., 2021) found globally, with *A. mossambica* endemic to Africa (Hanzen et al., 2022). African anguillid eels spawn in the western Indian Ocean, and currents carry the leptocephalus larvae to the estuaries along the east coast of Africa, including South Africa (Hanzen et al., 2019). Eggs hatch in the ocean into larvae, then reach estuaries and recruit in freshwater systems as glass eels

(McEwan and Hecht, 1984). Gaining pigment marks their first transition into freshwater, turning into elver eels (McEwan and Hecht, 1984; Sloane, 1984). As elvers, they can climb up on rocks under waterfalls, cascades, and other wet surfaces in the course of the river (McEwan and Hecht, 1984; Sloane, 1984). They grow into yellow eels from the elver stage and take up residency (Tesch and Thorpe, 2003; Hanzen et al., 2021). From yellow eels, they morph into silver eels and start to migrate back to the spawning ground, which, according to Robinet et al. (2008), is located near Mascarene Island in the Indian Ocean, to start their life cycle again. This makes the African anguillid eels relatively widespread along the east-flowing rivers of Africa, including Madagascar, Comoros, Mauritius and Seychelles (Hanzen et al., 2022).

The Malagasy people have a concept called *fady* that plays a role in the conservation of freshwater species and in cases specific to anguillid eels. The anguillid eel, according to Malagasy people, has human features (fish with ears) and is assumed to belong to the spirits; therefore, there are sacred implications for the anguillid eels and river associated with where they occur (Andriamarovololona and Jones, 2012). As a result, anguillid eels and other freshwater products (rice, crabs, crayfish, etc. caught) cannot be consumed (Andriamarovololona and Jones, 2012). This was from a restriction on freshwater species exploitation known as *fady mivarotra laokandrano*, which is a taboo linked with any product of freshwater (Andriamarovololona and Jones, 2012). For some aquatic species, the control of this *fady* has played a significant role in conserving and managing harvest, thus protecting the population of freshwater species and maintaining balance in the food chain and the ecosystem (Andriamarovololona and Jones, 2012). There is little knowledge of this for the main continent of Africa, where anguillid eels occur, and an important knowledge gap is not yet filled.

To understand the cultural value associated with anguillid eels and their associated rivers, we assessed the response from people living and using two rivers in KwaZulu-Natal, South Africa, namely the uMngeni and uThukela catchments. In this study, we report on the cultural value of freshwater eels (*Anguilla* spp.) in South Africa. This study aims to understand the value of human socio-economic and cultural perspectives. We hypothesised that rivers and eels hold a high and significant value in people's everyday lives and are associated with cultural and spiritual (religious) beliefs that shape social well-being. We attempted to evaluate and understand rivers' cultural values or resources for people above water provision as a basic need.

4.3 Methods

4.3.1 Study area

Our study was conducted in the uThukela and uMngeni catchments along the main rivers and the tributaries, KwaZulu-Natal, South Africa (Fig. 4.1). These are socio-economically important river systems in KwaZulu-Natal that flow eastward to the Indian Ocean. The uThukela River mainstem is 531 km long, the longest in KwaZulu-Natal. The uThukela catchment is 11500 km² and extends from the Drakensberg mountains, covering areas from the north and northwest of KwaZulu-Natal to the coast, where it enters the Indian Ocean downstream of Mandini at the Tugela Mouth town (Fig. 4.1). The mainstream of the uMngeni river is 232 km, and supplies water to uMgungundlovu (a district of the local municipalities of Mkhambathini, uMsunduzi, uMngeni, and uMshwathi) and eThekweni Metropolitan. The uMngeni catchment covers an area of 4 432 km², with the upper catchment bordering the uThukela catchment in the Drakensberg mountains near Thaba Ntlenyana flowing southeast and entering the India ocean north of Durban city centre, eThekweni (Fig. 4.1).

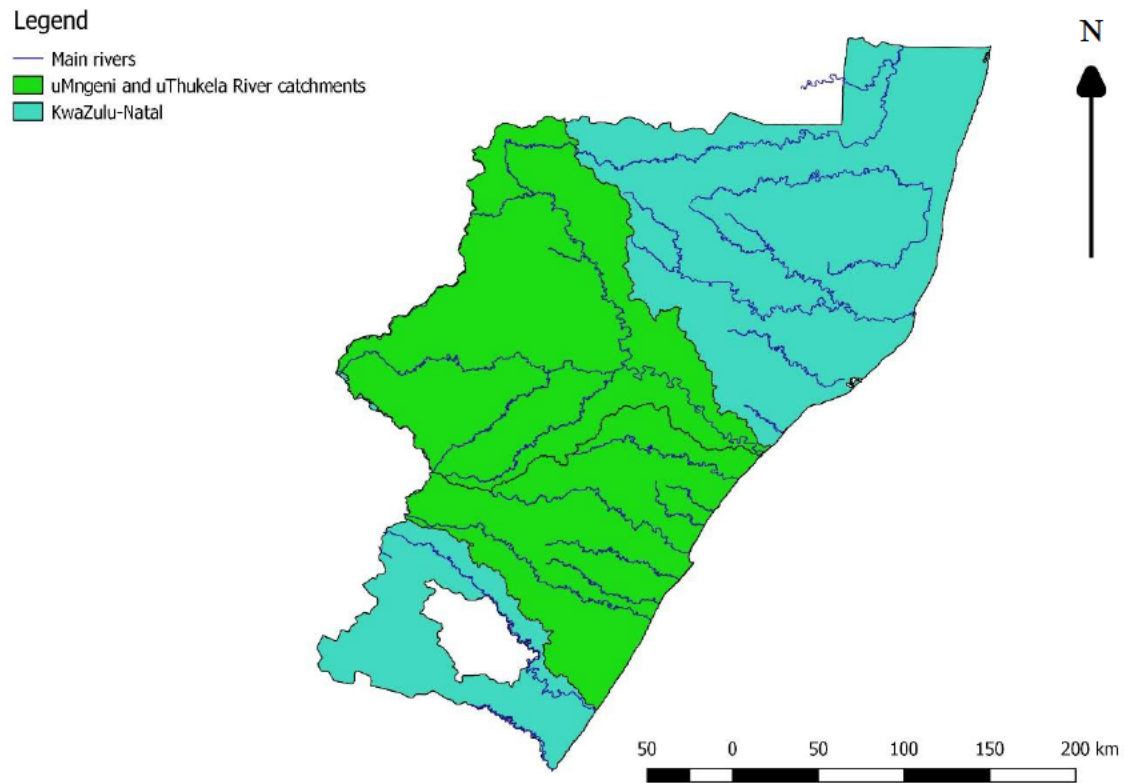


Figure 4.1. Map showing the uThukela River and uMngeni River catchments in KwaZulu-Natal Province, South Africa.

4.3.2 Data collection

After obtaining ethics permission from the University of KwaZulu-Natal Humanities Ethics Committee, we undertook interviews using a questionnaire. We targeted people residing in the communities along the two focal rivers, especially those who use the river for any purpose (e.g., small-scale commercial and subsistence fishing, recreational, spiritual, and domestic purposes). In the focal area (being along the rivers), any person who met on either using the river (for cultural, spiritual, domestic, agricultural, subsistence purposes – fishing) was interviewed. There was no

pattern or selection of participants, it was anyone the first author and research assistant met as they walked along the rivers. Interviews were along the rivers around the local communities or within the village; thus, participants were sometimes at home, fishing, or fetching water for irrigation (in large containers), or washing (laundry and utensils) in the river around 09h00 to 15h00. With attempts to interview people outside these times, we found people were busy with other, more personal tasks. This reduced the time respondents were willing to answer questions, and their answers were brief. Respondents along the river were more likely to participate fully and engage with the questionnaire. Most of these respondents were people who were either herding their livestock or fishing or doing laundry – they would be using the river for a long time and thus had time to engage.

The responses used in the analysis and reporting of this study were questions 1, 2, and 3, and parts of question 5 (Supplementary information Table S4.1). We conducted interviews from March 2021 to October 2022. Individuals and small groups (<10) were interviewed. All individuals were asked for permission to be interviewed, and their ages were obtained to ensure respondents were older than 18. Only when the respondent along the river would refer to an individual in the neighbouring town or a community did we pursue these contacts to answer the questionnaire. Typically, interviews were in isiZulu, the first language of most people in the study area. We recorded no personal details of the persons interviewed. At each location where an interview occurred, we recorded the geographical coordinates using a global positioning system (GPS, Garmin, USA). In cases where a group of people gave distinctively different responses during their participation, the results were recorded as different interviews, though they had similar GPS coordinates. Interviews generally took between 20 min to 30 min.

4.3.3 Data analyses

We summarised the narrative data collected from the open-ended questions using descriptive statistics. These questions were question 2. “Can you tell us about the river(s) around your village? How important are they to you?”; question 5.21 “Are there any belief(s) associated with eels in your communities? 5.22 If yes, what are they?”; and question 5.23 “Are there any beliefs associated with this river known by the community?”. We analysed patterns in responses using the word MonkeyLearn word cloud generator (MonkeyLearn API v3, AI-Powered Word Cloud Generator, United States of America), which calculated and displayed different sizes of the word cloud according to how often a word appeared in the set of responses. We used a non-parametric chi-squared test to determine significant differences.

4.4 Results

4.4.1 General trends

We obtained a total of 154 responses to the questionnaire that were completed in full. A total of 79% (n = 122) respondents directly used the river for domestic purposes, and 32% (n = 49) for agricultural purposes, mainly irrigation. Many, 66% (n = 102) of respondents reported using the river for cultural and spiritual (healing and reverence to ancestors and God) purposes. A total of 51% (n = 79) used rivers for recreational purposes (Fig. 4.2).

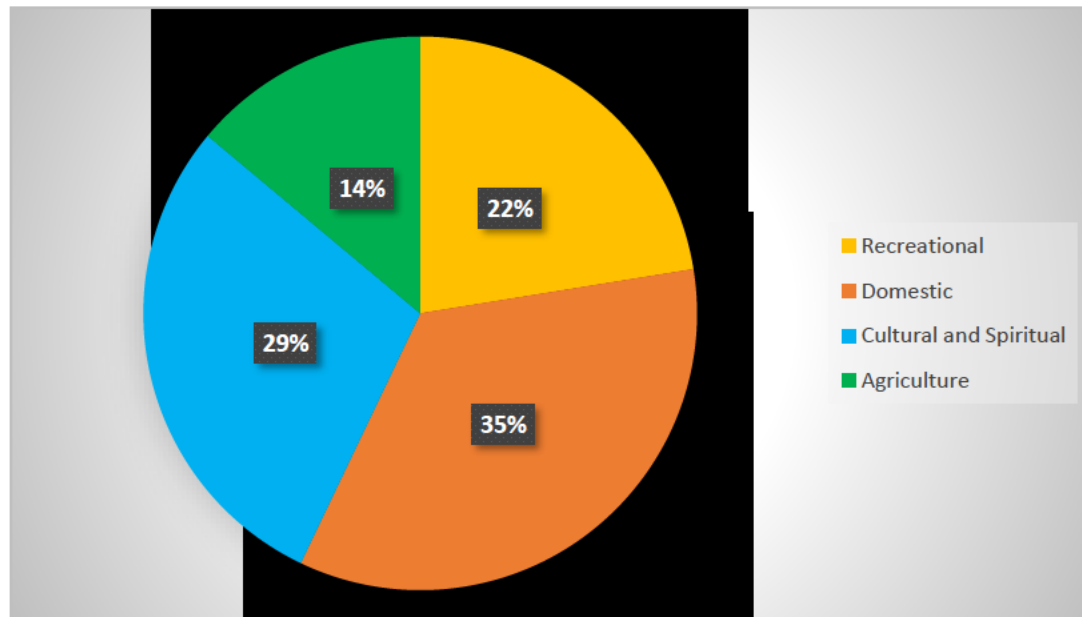


Figure 4.2. Responses on river use type by respondents.

Respondents from the uThukela and uMngeni catchment had a range of responses on what the rivers were used and known for (Fig. 4.2 and Fig. 4.3). The most common response (79%, $n = 122$ of 154) showed the uses of rivers were for domestic use (Fig. 4.2). Respondents in the community of Crammond reported that most of their water in the uMngeni River was controlled by the management releases for Albert Falls Dam, which generally regulated the river at a constant base flow. When flooding did occur, or there was a heavy rainfall event, respondents indicated an increase in the presence of Nile crocodiles, *Crocodylus niloticus*, and increased fish catches by anglers. Near Henley Dam on the uMsunduzi River, a tributary of the uMngeni River, respondents feared a “float” that has been responsible for the loss of lives in this river, and because of this, few people fished in this part of the river. Respondents ($n = 6$) mentioned rumours of two snake-like creatures accidentally colliding during migration underneath a bridge structure upstream of Henley Dam. They reported one of the creatures residing in Henley Dam and the other in the natural pool of uMsunduzi River towards the area of eMafakatini (Fig. 4.4)

There were 69 respondents with beliefs associated with the rivers (~45% of the total respondents in the study (Fig. 4.3), of which 64% (n = 44) were males, and 36% (n = 25) were females. Of the responses, 34.8% (n = 24) reported the presence of water creatures in different parts of the river, but mostly in the uThukela River catchment than the uMngeni River catchment. Types of belief uses associated with the rivers included 10.1% (n = 7) for prayers being offered/ recited in some sections of the rivers, while 8.7% (n = 6) for baptism and cleansing processes practices, respectively, which were performed in the rivers (Fig. 4.3). Some (4.3%, n = 3) respondents from the uMngeni River catchment reported on the ghost/ bad spirit in the main river of this catchment. Such has been observed by the number of murdered livestock, and people crossing the river, especially in low flow seasons. The conclusion was drawn after consultation with traditional healers and fortune tellers in trying to understand the alarming number of people dying similarly. One of which the cause of death would be the sucking of brain fluids. Respondents reported on various other beliefs associated with the river, and these included medicinal or healing powers in water; a Hindu religious member giving offerings in freshwater as part of reverence to nature; place of ancestors in water; the presence of '*inkanyamba*' sky snake; mediating by traditional healers between water creatures and people; the presence of mermaids in freshwater called water princesses or water spirits; an altar to offer sacrifices to God in nature; and initiation of both girls and boys (Fig. 4.3). Lastly, some (4.3%, n = 3) respondents reported on cases of people eaten by Nile crocodiles in Henley Dam (Fig. 4.3).

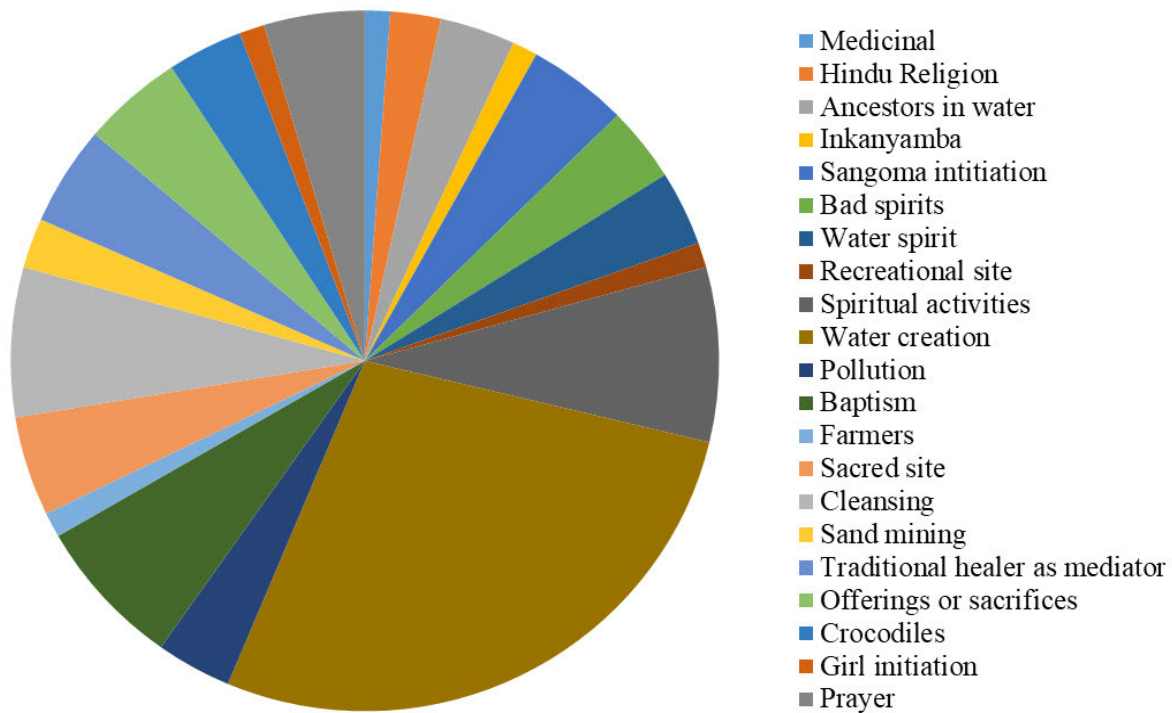


Figure 4.3. Uses and beliefs associated with rivers from those interviewed along the uMngeni River and uThukela River catchments.

4.4.2 Uses, beliefs and values associated with rivers

Respondents who used the rivers for cultural practices reported the importance of different water levels and flow rates in the river systems. When it is traditional healers' initiation, cleansing, or baptism, the water level plays a significant role in completing these processes. Fast-flowing water or higher levels than normal are required or preferred, as they are said to rapidly cleanse off all bad luck and remove darkness preceding or after a ritual. Contrary to the high-water levels preferred, some users benefit from low water levels. Only 1% (n = 2 of 154) of respondents made good use of sediments (mining sand to sell) deposited during high flows, which were later not covered by water. This was positive in that some people were able to feed their families by selling

sand; however, it remains negative as it destroys riverine habitats and other freshwater species and has long-term negative impacts. The sand sediments that these sand miners preferred consisted mainly of the mineral quartzite - free of silt, clay, and organic matter particles.

Another set of responses (7%, n = 11 of 154) acknowledged the use of impoundments in the catchments (mostly in the uMngeni catchment) as ideal for fishing and recreational use and as sacred sites (Umsamo Sacred Site in Albert Falls) (Fig. 4.4). The latter consisted of water creatures and water spirits and were used for healing and initiation. Lastly, 5% (n = 8 of 154) of respondents expressed how water bodies, for example, small dams or wetlands, could naturally remediate or treat wastewater for human use. These responses were widespread, for example, in places such as Mandini, Dundee, Newcastle, Pietermaritzburg, and Durban. Despite this, some respondents expressed concerns about the impact of wastewater treatment facilities (especially in Estcourt and Dundee) and companies releasing chemically diluted water into the streams/ rivers. They reported that these killed fish species (e.g., in the area near Mandeni where there is a paper mill, and in the Bushman's River in Uthukela local municipality, where a chicory company disposing of waste turns the water black). Another concern raised was limited access to the river because of privately owned land around parts of the river.

Legend

- Sampling points
- uMgeni and uThukela management areas
- KwaZulu Natal

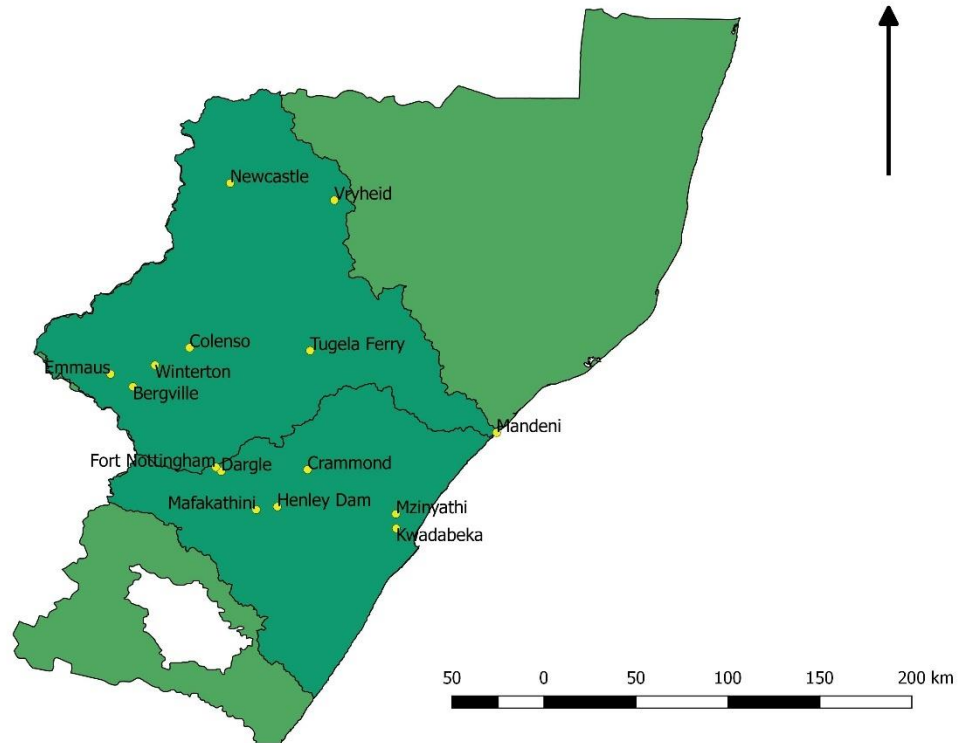


Figure 4.4. Map showing sites in the study areas where beliefs associated with freshwater eels were reported to exist in the present study.

4.4.3 Beliefs associated with anguillid eels

Out of 154 respondents, only 15% ($n = 23$) responded to knowing beliefs associated with freshwater eels, which was a significantly lower number than the 85% ($n = 131$) who responded to not knowing any beliefs associated with eel species ($n = 23$ of 154, $\chi^2 = 197, 195$, d.f. = 10, $P = 0.001$). From the respondents that knew about beliefs associated with eels, it was notable that their localities ranged widely (Fig. 4.4). Of those knowing beliefs associated with anguillid eels, 22% ($n = 5$ of 23) were individuals and/ or communities along the uMgeni River mainstem, namely, Kwadabeka, uMzinyathi, and Crammond (Fig. 4.4). Only 9% ($n = 3$ of 23) of respondents were along the uMgeni river tributary near Dargle and Fort Nottingham (Fig. 4.4). In the

uThukela River, 35% (n = 7 of 23) of responses came from Colenso, Mandeni, Tugela Ferry, and Bergville (Fig. 4.4). Only 35% (n = 8 of 23) of responses were from individuals along the uThukela River tributaries near Emmaus, Winterton, Vryheid, and Newcastle (Fig. 4.4). In total, 35% (n = 8 of 23) were respondents from the uMngeni catchment, and 65% (n = 15) were respondents from the uThukela catchment (Fig. 4.4). The distribution of these responses showed the extent in the management areas where the beliefs of eels are known (Fig. 4.4).

We found that the most frequent beliefs associated with freshwater eels were related to the importance of eel integument ‘mucus’ and/or integument used for healing, defence, improving livestock, treating women in labour or delivery pains, and making concoctions for healing (Fig. 4.5). Some respondents narrated about the use of eel eggs mixed with livestock feed which was said to be good for livestock expansion (increase in number and body mass and increased fertility). *Umuthi* is a Nguni term for medicine (used for healing) and a mixture usually from natural resources (used for protection and cleansing). In cases where someone was summoned for questioning on an investigation/ enquiry, the slipperiness of eels was transferred to that person so they may not be found at fault. The skin would be treated with a mixture of certain herbs prepared by an herbalist for maximum protection against evil and physical and spiritual attacks. In tribal battles, this was to protect warriors from being killed or injured by the opposing party. The strength of the protectiveness lay in the experience of the herbalist or traditional healer who prepared these elements, usually worn on the upper body. At present, these benefitted people mostly in dangerous occupations, e.g., some of the bodyguards, taxi drivers/owners, and unlicensed occupation a hitman. The eel ‘mucus’, prepared by mixing specific herbs, helped women in the last trimester of pregnancy to ensure safe childbirth. Women wore eel skin around the waist to protect the unborn child and minimise chances of infant mortality.

Lastly, communal farmers in Bergville used what they believed to be eel eggs (extracted from the inside of an eel and found in certain eels believed to be female eels). Mixing these contents with livestock feed protected livestock from being stolen, mostly by people from the other side of the Drakensberg Mountains. Furthermore, the feed (stalk) mixed with these contents increased individual livestock's weight (the meat content) and fertility of female livestock.



An important value or belief was the use of eels for defence or protection against personal threats (Fig. 4.5). People believed that using an eel extract as traditional medicine, *umuthi*, with the assistance of traditional healers, could transfer protection to people. These eel products were the integument or skin, and the ‘mucus’ extracted near the dorsal fin. The skin is usually worn on

the upper arm or around the waist. The ‘mucus’ was generally used in ointments or concoctions. This is used mostly by some who wish not to be caught for a crime or protection against being shot with a gun. The main characteristic conferred on the user was the ability to slip away. Similarly, when eel eggs and mucus were mixed with feed, livestock was not easy to steal, as they ‘slip away’ from a thief’s hand. The latter seemed to be associated with people from Lesotho coming into South Africa in the upper catchments of the uThukela River to steal livestock. People mostly in Bergville and Underberg areas used eels in this way rather than for consumption. In one of the responses, an old man who owned livestock mentioned, “*I usually exchange a goat for an eel from every fisherman*”. In his response, he mentioned the usefulness of different parts of the eels before consumption, mainly skin, ‘mucus’, and sometimes bones. Females about to give birth are encouraged to drink a mixture of herbal products from a traditional healer that contained eel ‘mucus’ (*isihlambezo*) to make delivery easier. Some respondents also believed that the eels provided protection from any evil spirit or witchcraft that might attack the unborn baby, leading to mortality.

4.5 Discussion

The cultural and spiritual value associated with rivers and sometimes individual fish species have been documented (Harmsworth and Awatere, 2013). Utete et al. (2022) mentioned that different fish species are significant for specific uses beyond consumption, including medicinal, spiritual, and cultural purposes, in Zimbabwe. Our study examined human perspectives on the values of freshwater eel and rivers for some indigenous people groups living in KwaZulu-Natal. The responses represent municipalities surveyed and may overlook other areas or individuals that are aware of other cultural practices with the sensitivity of the study, where there is an overlap of users

and those who directly benefit from freshwater eels. We found most respondents valued the riverine systems for cultural and spiritual purposes but were concerned about anthropogenic effects on them, such as pollution. Most respondents used rivers for domestic use but also for other activities, including fishing, recreation, sacred sites, healing, and initiation. The beliefs associated with respondents follow no pattern to a group of people or type of settlement but were rather the individual's understanding of these natural resources. Despite all this, the study has quantified the values associated with rivers and anguillid eels, reported as important to human livelihoods, beliefs, and culture. River systems and habitat management need to consider migratory species and their impact on human lives.

Jorda-Capdevila et al. (2021) showed that inland river systems have significant sociocultural and economic benefits, especially those that vary temporally. In dry seasons, when these systems, especially non-perennial streams, experience reduced water levels and flow rates, aquatic species generally migrate to deeper water, while the shallower sections are still important for cultural uses (Martínez et al., 2013; Iniesta-Arandia et al., 2014). In the shallow water parts of the river, sand mining thrives because of the quality of sand mined and sold (Marschke and Rousseau, 2022). In our study, although the responses about beliefs were separated from what people know about rivers, we found an overlap of responses in these questions, as people would mention the importance of different water levels and flow conditions. The water levels were important for completing these activities when using the river systems for various social-religious-culture activities such as initiation, cleansing, or baptism. Consequently, few of these activities take place in dry seasons as the belief from responses was that fast-running water was necessary to remove the bad luck during the cleansing process.

Globally, beyond their economic and nutritional value, anguillid eels are important for their cultural and spiritual values in society, with some of these values emanating from religious beliefs, some from cultural beliefs, and some from conserving and preserving natural resources by land users (Davis et al., 2004; Algonquins of Ontario, 2012, 2014; Denny et al., 2012; Feunteun and Robinet, 2014; McCarthy et al., 2014; Giles et al., 2016; Whaanga et al., 2018). In particular, our study found similarity in our results and what is already known, particularly in the North American context of the American eel, *Anguilla rostrata* (Davis et al., 2004; Algonquins of Ontario, 2012, 2014; Denny et al., 2012; McCarthy et al., 2014; Giles et al., 2016). It is remarkable that societies so unrelated and distant from each other when associated with eels, come to similar conclusions. In our study, we found anguillid eels to have significant beliefs associated with cultural practices, especially for people who knew about them.

Some respondents mentioned that the slipperiness of an eel makes them hard to catch, similar to the African catfish *Clarius gariepinus*. Similarly, in a study exploring perspectives and behaviours toward the American eel, fishers reported difficulties catching and handling the eels (Litt et al., 2021). In our study, the use of the components of these species (eels being of high priority) was based on the belief that it would be hard to catch an individual in any trap set for them. A similar understanding was embedded in childbirth and livestock protection, expansion, and fertility; however, only the eel ‘mucus’-based concoction was used and not that of the catfish.

Another important value and belief of using eel were assisting women in childbirth to ease the delivery. Women drank a product from a traditional healer that included eel mucus called *isihlambezo* (from isiZulu), which according to respondents, the extract provided lubrication that made the process of childbirth relatively easy and less painful. On the contrary, Malagasy people, under the concept or phenomenon of *fady*, prohibit pregnant women from

consuming crayfish or anguillid eel species in their first trimester since these species were said to increase the risks of miscarriage (Jones et al., 2007). In the present study, several respondents believed that consuming eel extracts further protects the unborn from any evil spirit or any form of witchcraft that might attack the fetus and cause mortality.

In KwaZulu-Natal, there is a range of different religions that people are subscribed to. According to Wilhelm-Solomon et al. (2016), the use of *umuthi* (a form of traditional medicine) is usually common to people who are members of the African Traditional Religion (consisting of different contexts), while Christians do not generally use *umuthi*. However, denominations such as the Zionists pay reverence to ancestors (Wilhelm-Solomon et al., 2016), which then creates an overlap in the group of people using *umuthi*. The number of people who benefit from these products may be undermined if religion is used to determine those who benefit from these traditional medicine *umuthi*, including those processed from anguillid eel components. In addition, in some parts of KwaZulu-Natal, mostly towards the Drakensberg region, the harvest of eels was predominately for small-scale commercial purposes, impacting the species' availability for cultural and/ or spiritual purposes upstream of the wall of Woodstock Dam and Driel Dam.

Participants who had knowledge of beliefs (both rivers and of eels) provided real-life experiences of what happens in the rivers at different times, working together with people of a calling, guiding them as to when to use rivers for any purpose. While other responses, even from the same community, sometimes were of people who had not heard of anguillid eels or had beliefs associated with the river. We found some people in KwaZulu-Natal believed water spirits and/ or water creatures exist, which restrict people from fishing, performing cultural and spiritual practices in some parts of the river, and/ or appreciating the aesthetics of nature. Historically this meant that

until local traditional healers advised the use of the river, no individual was to interact with the river system in any way due to their connection with water spirit.

A range of beliefs was associated with freshwater systems, including cleansing, healing, reverence to God, rebirth in faith through baptism, and/ or the presence of water creatures (*inkanyamba* or *umnikazi wamanzi*). Freshwater eels were not only consumable freshwater species but also played an important cultural role in healing and daily protection, as an important constituent in livestock feed for fertility and weight increase, and in childbirth. These beliefs play an important role in shaping people's thinking and the development of societies (Harmsworth and Awatere, 2013). Similarly, rivers are important for recreational use and religious ceremony (symbol or re-birth and purity), spirituality, tradition, and culture that often bind a community together (Semwal and Akolkar, 2006). Importantly, rivers in many rural localities are still directly used for domestic use (Shackleton et al., 2005), which was confirmed by this study. Furthermore, the intrinsic relationship that requires the conservation of rivers as hosts of some people's spiritual lives, as found in the present study.

Beliefs associated with freshwater eel and rivers cease to be common knowledge. Some participants explained these beliefs and further stated parts of information they could not disclose. Some traditional healers expressed that the virtue of disclosing some information would mean payment, a form of sacrifice and a ritual to access these depths of information. It may be for this reason some members of the community, and authorities at the governmental department, have no knowledge of this. Such studies in social sciences are termed 'contextual, as they include human speech, tradition, and language. Exploring these fundamentals of societies in the context of management and preserving of culture may lead to concepts such as *fady*, where both human societal development is preserved together with natural resources. Without community

participation, there is no guaranteed sustainability of the water resources for the spiritual and cultural values of freshwater eels and freshwater systems. This requires community and water management bodies to engage in long-term sustainable use and protection of inland water and fisheries resources in KwaZulu-Natal.

4.6 Acknowledgements

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4.7 References

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4.8 Supplementary information

Supplementary Table S4.1. The questionnaire used in the present study

Fisheries and eels in the WIO – Questionnaire					
COUNTRY:		RIVER:		SN:	
1. RESPONDENT INFORMATION					
Village:	Gender: M/F		Marital status:		
Education (yrs):	Age:		Tribe/ethnicity:		
Religion: ☐ Christian ☐ Muslim ☐ Traditional ☐ None ☐ Others (specify):	Monthly Income: ☐ Grant ☐ No Grant ☐ Under minimum wage ☐ Above minimum wage Are other people in your household earning an income? YES or NO		Occupation: ☐ Farmer ☐ Fisher ☐ Business ☐ None ☐ Others (specify):		
2. Can you tell us about the river(s) around your village? How important are they to you?					
3. How often do you use the rivers around you community for the following purposes?					
	Daily	Weekly	Monthly	Yearly	Never
Drinking water					
Washing utensils					
Washing clothes					
Washing yourself					
Irrigating crops					
Watering livestock					
Fishing					
Aesthetic					
Spiritual					
Cultural					

Others (specify):					
5. Eel fisheries					
5.1 Do you know if there are eels in your rivers? YES or NO					
5.2 How many different types of eels do you know from your river(s) and their local names?					
5.3 How do you differentiate between these different types of eels?					
5.4 Do you know about the different eel stages? YES or NO					
5.5 What are the local names for the different eel stages?					
5.6 Have you ever caught eels in your river(s)? YES or NO					
5.7 If yes, what kind of eel and what stage do you catch? 1 = <i>sometimes</i>, 2 = <i>always</i>, 3 = <i>never</i>					
	Longfin eel	Giant mottled eel	African mottled eel	Short fin eel	
Glass					
Elver					
Yellow					
Silver					
5.8 Do you specifically target eels? YES or NO					
5.9 Why do/don't you target eels ?					
5.21 Are there any belief(s) associated with eels in your communities? YES or NO					
5.22 If yes, what are they?					
5.23 Are there any beliefs associated with this river, known by the community?					

CHAPTER 5

Synthesis, conclusions and recommendations

5.1 Introduction

Freshwater eels (*Anguilla* spp.) have complex migratory life cycles that extend across marine to freshwater ecosystems throughout their life stages (Tesch and Thorpe, 2003). In particular, *Anguilla anguilla* and *A. japonica* have economic and cultural values, according to literature from countries in Asia and Europe that could be the cause for concern around the declining abundances of these species (Liao et al., 2002). The cause for concern around the African freshwater eel species has been highlighted in recent studies that show a decline in their distribution range and abundance in KwaZulu-Natal, South Africa (Evans et al., 2022; Hanzen et al., 2022). This can be attributed to the degradation of freshwater environments, in particular, the construction of instream barriers to meet water security demands and anthropogenic pollution (O'Brien et al., 2019; Evans et al., 2022; Hanzen et al., 2022; du Plessis, 2023). However, little is known about the cultural and fishery values associated with freshwater eels in South Africa. The export ban of *A. Anguilla* in Europe may stimulate the import of freshwater eel from other regions to meet the high demand (Chapter 1). Uses associated with African freshwater eels are important as international trade may negatively impact the populations of these species and potentially the cultural and biodiversity values associated with them (Chapters 1 and 2). The lack of records and the sporadic export of eels is a concern as either there is little demand for eels from South Africa or there is a decline of eel species reported by Hanzen et al. (2022), so few caught. This leaves speculation that degraded ecosystems can no longer support eels or that cultural nuances associated with eels may affect the eel population's persistence.

The available literature shows that the global conservation status of inland fishery resources and freshwater systems is vulnerable, threatening the livelihoods of communities dependent on these, especially in southern Africa (O'Brien et al., 2019; du Plessis, 2023). It does not, however, explain in detail the impact of the vulnerability of rivers on livelihoods in KwaZulu-Natal Province, South Africa. Beyond using freshwater systems for domestic purposes and meeting basic needs, people use freshwater systems for other purposes, which speaks to their culture, beliefs, spirituality, and religion. Similarly, there are beliefs associated with freshwater eels (*Anguilla* spp.) beyond harvesting them to sell or consume. This study was undertaken to understand the human perspectives on the use of rivers and eel fisheries, to try and find a possible reason behind the drastic declines of freshwater eel species, which might be linked to human activities in the local communities in uThukela and uMngeni catchment management areas of KwaZulu-Natal.

5.2 Summary of results

An adequate measure of the economic and cultural value of eel species in KwaZulu-Natal was not easy to quantify because of the different forms of use and payment for these species (Chapters 3 and 4). Eels played an important role for some select local small-scale and subsistence fishers as the values placed on eels were considerably higher than that of other species, although they were harder to catch (Chapter 3). The reasons for catching eels varied and included consumption and cultural practices (Chapters 3 and 4). It was of concern that some foreign nationalities had made agreements to purchase these freshwater eel species from local fishers for reasons not disclosed during data collection (Chapter 3). This leaves a question of how often African eels are purchased

and for which market. There is a possibility of an advanced black market and over-fishing of eels using unauthorised equipment such as gill nets, but this needs further investigation (pers. comm.).

Respondents' answers suggested that in different parts of the sampled catchment areas, eels were used for cultural purposes, including use by traditional health practitioners (Chapters 3 and 4). In addition, the river systems, at times associated with the presence of eels, have been reported to be essential aspects used for significant life events. These aspects included the following: as a symbol of peace (resting place), habitats for creatures that protect, rebirth in the Christian religion, cleansing (mainly under waterfalls) and transition into a different phase of life (initiation) in traditional religion (Chapter 4). Furthermore, these rivers were where the spirits of the departed rest and sometimes took the form of a species (Chapter 4).

5.3 Recommendations

The use of freshwater eels by the small-scale fishers in KwaZulu-Natal is some what important and contributes to people livelihoods. For example, trade in eels can provide the fishers with monies for their livelihoods as one fisher was able to pay their children's school fees (Chapters 3 and 4). Presently relatively few fishers specifically target eel species, but if the international demand increases, this may become unsustainable. Furthermore, there are already observed declines in the abundance and distribution of freshwater eels in KwaZulu-Natal, so the continued reliance of fishers on these species is at risk. In addition, there needs to be an investment into inland fisheries to protect African freshwater eels negatively impacted by water resource management. For example, constructing large water storage facilities on the inland river systems to provide water for human consumption and use does not incorporate passage structures for connectivity so eels or other fish species can migrate. This has been identified as one of the main

drivers behind the decline of eels in KwaZulu-Natal (Hanzen et al., 2022). Importantly more studies are needed on African freshwater eels to understand their biology, ecology and socio-economic use, as this may impact the productivity of harvests. Further investigation is needed into the potential illegal trade of African freshwater eels. An adequate economic assessment of freshwater eels in the cultural trade is needed.

The export of eels from KwaZulu-Natal should be strongly discouraged, and it is recommended that the export of eels be prohibited. It is apparent that eels are used and valued locally; this could not be replaced in any way. If locals are encouraged to understand and better appreciate eels as "water keepers", they would be strong advocates for protecting these species and their aquatic environments. Furthermore, the thesis highlights that African freshwater eels are considered not only an important source of nutrients and potential income but also hold cultural beliefs for many people in KwaZulu-Natal.

In the context of KwaZulu-Natal, the use of water goes beyond domestic and commercial purposes. It incorporates strong beliefs and involves deep cultural meaning in the people's lives. The degradation of the freshwater environment (du Plessis, 2023), will compromise the users' activities with all water interactions. This includes cultural uses of water as found by the present study as river users. Therefore, water resource management must consider the cultural values associated with freshwater and place mitigation measures to prevent the degradation of freshwater environments where these practices occur. Despite its importance, this has not been incorporated into conservation or water resource management plans.

Additionally, access to freshwater systems to practice culture needs to be accommodated where previously, this was not always the case (Hara and Bakeberg, 2014). Where these recommendations have been practised in Giba Gorge and Paradise Valley, near Durban, which

contain natural waterfalls used for cultural practices and are kept clean and safe, these are nature reserves surrounded by urban land use. Rural communities also need to regulate the cleanliness of these sites and support residents' sustainable use of rivers in this manner. AWF (2010) suggest a holistic approach to the sustainability of natural freshwater systems, including scientific and social research among stakeholders and affected local communities.

5.4 Conclusions

The findings of this study have identified and highlighted how important freshwater eels are to people. Anguillid eels play an important role in shaping the market, fisheries, and cultural purposes. However, the cultural benefits of freshwater eels remain private and are limited to use for the purposes mentioned in Chapter 4, which is mostly in connection with traditional healers. The freshwater eel fishery, fishers and members that source eels in the KwaZulu-Natal and other countries in southern Africa, such as Zimbabwe (Utete et al., 2022), are primarily related to the medicinal and social benefits and secondly for consumption. The pollution and fragmentation of river courses remain a conflict between the demand for water as a resource and the freshwater's ecological requirements. This has negatively impacted the distribution of migratory freshwater eels. River pollution, mostly from factories and industries, agriculture, sewerage and human refuse, impacts and compromises fish species' persistence, small-scale and subsistence fishers, and contaminates drinking water for communities. Without community participation, there is no guaranteed sustainability of the water resources for the spiritual and cultural values of freshwater eels and freshwater systems. This requires community and water management bodies to engage in long-term sustainable use and protection of inland water and fisheries resources in KwaZulu-Natal.

5.5 References

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