A CASE STUDY FOR WETLAND RESTORATION TOWARDS SOCIO-ECOLOGICAL APPRECIATION OF NATURAL RESOURCES IN KWAZULU-NATAL (SOUTH AFRICA)

by

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Submitted in accordance with the requirements for the degree

Master of Nature Conservation

in the

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES
DEPARTMENT OF ENVIRONMENTAL SCIENCES

at the

UNIVERSITY OF SOUTH AFRICA
FLORIDA CAMPUS

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November 2022

DEDICATION

I dedicate this work to my beautiful children, Jasmine and Lilly, who I hope will have a better world to live in because of the efforts that have gone into this and future work of this nature.

UNISA college of agriculture and environmental sciences

DECLARATION

I, Cherise Acker (UNISA Student Number 34880550), hereby declare that the dissertation, A CASE STUDY FOR WETLAND RESTORATION TOWARDS SOCIO-ECOLOGICAL APPRECIATION OF NATURAL RESOURCES IN KWAZULU-NATAL (SOUTH AFRICA), which I hereby submit for the degree of Master in Nature Conservation at the University of South Africa, is my own work and has not previously been submitted by me for a degree at this or any other institution.

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I declare that during my study I adhered to the Research Ethics Policy of the University of South Africa, received ethics approval for the duration of my study before the commencement of data gathering, and have not acted outside the approval conditions.

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ACKNOWLEDGEMENTS

I am extremely grateful to Ms B Brand, my lecturer and supervisor, who has been with me since the start of my academic career; thank you for your patience and kind support of me throughout this journey. I would also like to thank Professor N de Crom for her valuable guidance and support. I also could not have undertaken this journey without Dr Jeanne Tarrant, Ryan Edwards, Dr Lizanne Roxburgh, Dr Victoria Goodall, Jiba Magwaza, Nonkululekho Nzama, Nomonde Ngidi and Arlene Mkhize, who have provided support, valuable knowledge and expertise. Additionally, I would like to thank UNISA, the Rainforest Trust and RMB for their financial contributions to this research.

I am also grateful to my parents who have been instrumental in getting me to this point and if it were not for them I would not be where I am today. Special thanks should go to my dear husband, who has provided me with unwavering support and encouragement.

Lastly, I would like to thank this beautiful world and all the people in it who have influenced and inspired me.

ABSTRACT

Social cognitive theory suggests that in order to bring about change in society an environment conducive to change is imperative. This theory was investigated within a socio-ecological framework using a comparative study of a semi-rural community and an urban transit camp community located within the Adams Rural Wetland and the Isipingo Wetland (KwaZulu-Natal), respectively. These communities are located in the vicinity of critically endangered wetlands where the endangered *Hyperolius pickersgilli* (Pickersgill's reed frog) occurs. As such, the Endangered Wildlife Trust's Threatened Amphibian Programme conducted ecological rehabilitation and habitat protection to secure a suitable habitat for this frog. As part of these initiatives, wetland health assessments were conducted using WET-Health and socio-ecological assessments using questionnaires administered to local residents as a basis for measuring changes in the wetland system and associated community attitudes towards these systems, respectively. WET-Health results showed the Adams Rural Wetland to be in a better ecological state with a health score of 81% while Isipingo scored just 22%. The socio-ecological assessments revealed that 85% of the Adams Rural Wetland community members felt positive about where they lived, citing "peace" and "quiet" as the main benefits. On the other hand, only 17% of the Isipingo Wetland community felt positive in this regard, citing accessibility and economic savings as the realised benefits. The attitude assessments revealed that 54% of the Adams Rural Wetland community scored above average in positivity towards the environment in comparison to 29% of community members from the Isipingo Wetland. It was also observed that the community at Adams Rural Wetland made more use of local natural resources (36%) than the Isipingo Wetland community, where only 8% of community members use locally sourced natural resources. This indicates that a person's positivity and attitude towards the environment decreases as natural resource availability and ecological health decrease. Furthermore, social and ecological restoration interventions improve attitudes towards the environment and ecological conditions. It may be concluded that, firstly, an intact ecological infrastructure allows communities to utilise their environment more effectively, which may foster a greater appreciation of the natural environment and, secondly, restoration interventions can positively affect social and ecological systems, providing a strong basis for ecological restoration towards the promotion of socio-ecological integrity.

Keywords

Socio-ecology, wetland restoration, environmental attitude, community land engagement, ecological infrastructure, environmental appreciation, socio-ecological restoration.

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ABC	Attitude, behaviour and context
ANOVA	Analysis of variance
ARW	Adams Rural Wetland
EGS	Ecological goods and services
EM	eThekwini Municipality
EWT	Endangered Wildlife Trust
ITB	Ingonyama Trust Board
IW	Isipingo Wetland
KZN	KwaZulu-Natal
PES	Present ecological state
PRF-RP	Pickersgill's Reed Frog Recovery Project
SANBI	South African National Biodiversity Institute
SCT	Sobonakhona Community Trust
SCT	Social cognitive theory
SER	Socio-ecological restoration
SLT	Social learning theory
SMART	Specific, Measurable, Attainable, Relevant and Timebound
STA	Sobonakhona Traditional Authority
TAP	Threatened Amphibian Programme
UN	United Nations
UNEP	United National Environment Programme
UNISA	University of South Africa
WHO	World Health Organisation

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Local and global authorities are increasingly recognising the effect of anthropogenic activities on the environment. Such activities affect the health and well-being of the natural environment and may also be correlated to human well-being and economic stability (Department of Environmental Affairs, 2016; Manisalidis *et al*., 2020).

Essentially, the natural environment, its ecosystems and related goods and services provide the basis for survival on earth (Millennium Ecosystem Assessment, 2005). Ecological goods or provisioning ecosystem services (Value of Nature to Canadians Study Taskforce, 2017) are the products or material goods of the processes and interactions of natural systems (Mitsch *et al*., 2015), including clean water and food, and are of benefit to all life forms. Ecological services or regulating ecosystem services (Value of Nature to Canadians Study Taskforce, 2017) are the result of the processes and interactions between organisms and their natural environments (ecological infrastructure), for example, the cycling of water, basic nutrients and flood attenuation (Mitsch *et al*., 2015). Human health and well-being are dependent on the availability and quality of these ecological goods and services. A good example of this relationship is the impact of water quality on human health; more than 80% of untreated sewage generated by human activities is discharged into rivers and oceans, resulting in over 50 different diseases. Poor water quality has been linked to 80% of diseases and 50% of child deaths globally (Yang & Xu, 2022). Unfortunately, threats such as water pollution are not singular but occur together with a multitude of other threats such as climate change. In addition, the overutilisation of resources and alien invasive plant infestations compound and increase the rate and degree of ecological degradation (Chu & Karr, 2017). These compound effects are further exacerbated by the zone of influence which may be local, as with alien invasive plant infestations, or may be as a result of a global influence such as climate change. These compound effects, together with local and global influences, make the management of ecological resources complex (Chu & Karr, 2017).

In terms of biodiversity, no better case study demonstrates the link between biodiversity and human well-being than the collapse of the amphibian population, which has led to an increase in malaria cases in Central America (Springborn *et al*., 2022). Meanwhile, the collapse in the pollinator population could lead to malnutrition for millions across the world (Ellis *et al*., 2015).

Economically, biodiversity, ecological infrastructure and related goods and services contribute significantly to the economy. For example, over three-quarters of global food crops (estimated to be valued between US$235 and US$577 billion (Pasca Palmer, 2019)) rely on insect or animal pollination. Therefore, a collapse in the insect and animal pollinator population would be detrimental to economic stability. Consequently, it is of little surprise that there is increasing evidence demonstrating the importance of ecological restoration that reinstates ecological goods and services to support social well-being (Cross *et al*., 2019).

Furthermore, psychologically, people need conducive conditions to be able to shift to embrace a more positive relationship and connection with their environment (Sawitri *et al*., 2015). This is supported by social cognitive theory (SCT) which looks at the interconnection between three aspects: a person's physical state, their environmental conditions and their behaviour (Sawitri *et al*., 2015). Seen in this light, if ecological integrity is poor, it will have an impact on people's well-being, leading to demotivation and apathy which will be reflected in their attitudes and behaviour (Kideghesho *et al*., 2017; Shackleton *et al*., 2008).

Social change theory suggests that to bring about change in society, an environment conducive to change is imperative. As such, to bring about an appreciation for natural resources it is necessary to ensure that the ecological infrastructure that supplies the natural resources remains intact. This study, initiated under the Endangered Wildlife Trust's Threatened Amphibian Programme in 2016, aimed to investigate this theory through a comparative study to demonstrate the interconnection between social and ecological integrity. Based on ecological assets, two communities with different ecological and social circumstances were identified for this study. Both communities lie within the vicinity of critically endangered coastal wetland vegetation where two amphibian species, *Hyperolius pickersgilli* (Pickersgill's reed frog) and *Natalobatrachus bonebergi* (Kloof frog), are found. Both species are classified as endangered and serve as bioindicators of ecological and social health (Saber et al., 2017). They are therefore targets for rehabilitation interventions towards a desired state of ecological integrity.

One of the study sites, the Isipingo Wetland, falls under the municipal authority in an industrialised area and is severely degraded and, as such, requires rehabilitation. Access to funding and the political will to undertake the rehabilitation is, however, not forthcoming (eThekwini Municipality, personal communication, 17 October 2022). This is despite the fact that rehabilitation efforts will not only benefit the ecological system and the endangered species but may also improve community well-being, especially through reduced flood and disease risk. The second study site, the Adams Rural Wetland, is managed by the Traditional Authority, an authority appointed by the Ingonyama Trust Board (the landowner) based on long-standing customs. The Adams Rural Wetland is a largely unfragmented wetland system that is in the process of being declared a Protected Environment under Biodiversity Stewardship – an approach whereby agreements to protect and manage biodiverse priority areas are formalised between landowners and conservation authorities in South Africa (South African National Biodiversity Institute (SANBI), 2015).

Socio-ecological restoration interventions such as alien invasive plant clearing, environmental education and social development activities were implemented at each site between 2016 and 2022. Baseline surveys for both the social and ecological components of the sites were conducted and post-intervention data were collected.

This study compares these two sites on an ecological and social level. Through this lens, the study aimed to demonstrate that the social state of local communities at each site is interdependent on the ecological state and that investing in the ecological infrastructure will improve access to natural resources, demonstrate ecological value to the community and thereby improve the attitude of local people towards the natural environment (Manisalidis *et al.*, 2020).

1.2 RESEARCH AIM

The main aim of this study was to demonstrate that ecosystem health, land use and a community's attitude towards the environment are interrelated.

1.3 RESEARCH QUESTIONS

1.3.1 Main research question

Is there a link between the ecological state and biodiversity of the environment and a community's land use and attitude towards the environment?

1.3.2 Objectives and key questions

Objective 1: To determine the ecological state of the environment.

- What fauna and flora are found at the two study sites?
- What are the vegetation types found at the two sites?
- What is the present ecological state of the vegetation at the two study sites?

Objective 2: To determine the current land use of the environment.

- What natural resources are being used?
- What are these natural resources being used for?
- In terms of flora, what is the proportion of indigenous and alien plants being used?
- How many people in the area are using the land for farming purposes?

Objective 3: To determine the community's attitude towards the environment.

- What proportion of people enjoy or do not enjoy living in their respective areas?
- Why do these people enjoy or not enjoy living in their respective areas?
- What are people's general attitudes towards the natural environment?

Objective 4: To determine a possible link between ecological state, biodiversity, land use and attitude.

- Based on the data collected, is there a correlation between ecological state, biodiversity, community land use and attitude towards the environment?

A mixed-method approach was used to collect data. Social data such as attitude and community land use were collected through a qualitative approach using questionnaires, while ecological data were collected through a quantitative approach using wetland health assessments.

1.4 CHAPTER LAYOUT

Chapter 1: This introductory chapter provides background and context for the study to support the rationale, provides the research questions and discusses the methodology used.

Chapter 2: In this chapter, the study sites are described and the socio-ecological components of each study site are specified.

Chapter 3: This chapter outlines the research design and methodologies used to conduct the study.

Chapters 4–6: These chapters outline the theoretical core conceptual framework on environmental psychology (chapter 4), wetlands in relation to biodiversity and human well-being (chapter 5) and, finally, socio-ecological restoration (chapter 6).

Chapter 7: The first section of this chapter presents the results of the study. This is followed by a discussion of the results.

Chapter 8: This chapter provides an overall conclusion to the study and makes a number of recommendations.

CHAPTER 2
THEORETICAL FRAMEWORK: ENVIRONMENTAL PSYCHOLOGY

2.1 INTRODUCTION

Environmental psychology is a subdiscipline of the science of psychology and examines the psychological processes of people within their built and natural environments (Stern, 2000). The study of environmental psychology seeks to understand this relationship in terms of a person's perception of their environment, attitude towards their environment and accompanying behaviour (Moser & Uzzell, 2003). The starting point for analysis is often within the physical characteristics of the environment which act directly on the person, including through the social structures within the environment (Moser & Uzzell, 2003).

According to Ackerman (2018), several theories have been developed which take specific perspectives:

Geographical determinism considers the environment to have shaped civilisations through their response to environmental challenges and opportunities (Chumakov, 2016).

Ecological biology considers biological and sociological systems to be interdependent.

Behaviourism considers the shaping of behaviours through conditioned responses to a stimulus in the environment.

Gestalt psychology – this school of thought is centred on cognitive processes which seek to understand a person's environmental cognition.

This study uses a Gestalt psychology perspective to determine the relationship between people and their environment based on their attitude to and level of engagement with their environment in relation to the condition of their environment. The study endeavours to better understand people's relationship with their natural environment based on SCT taking a Gestalt psychology perspective.

2.2 SOCIAL COGNITIVE THEORY

Social cognitive theory adapted from social learning theory (SLT) by Albert Bandura in 1968 (LaMorte, 2019). The foundation of the theory rests on dynamic learning, which occurs through the joint interaction between person, environment and behaviour (LaMorte, 2019). Social cognitive theory looks at how individuals acquire and maintain their behaviour with consideration of environmental influences and their personal history of experiences (LaMorte, 2019). In addition to these constructs, personal agency or self-efficacy influence an individual's motivation to change their behaviour. Personal agency is the ability of a person to deliberately choose, execute and manage their actions towards a specific outcome (Bandura, 1997; Usher & Ford, 2022). Personal agency influences a person's attitude and behaviour through their perception of whether they would be able to make a change (Bandura, 1997; Usher & Ford, 2022). Effective changes in behaviour, therefore, depend on identifying positive supports and detractors in each of these constructs (Lazaro, 2020); i.e. the person, their environment, the behaviour and personal agency, as well as how these factors interconnect (Figure 7).

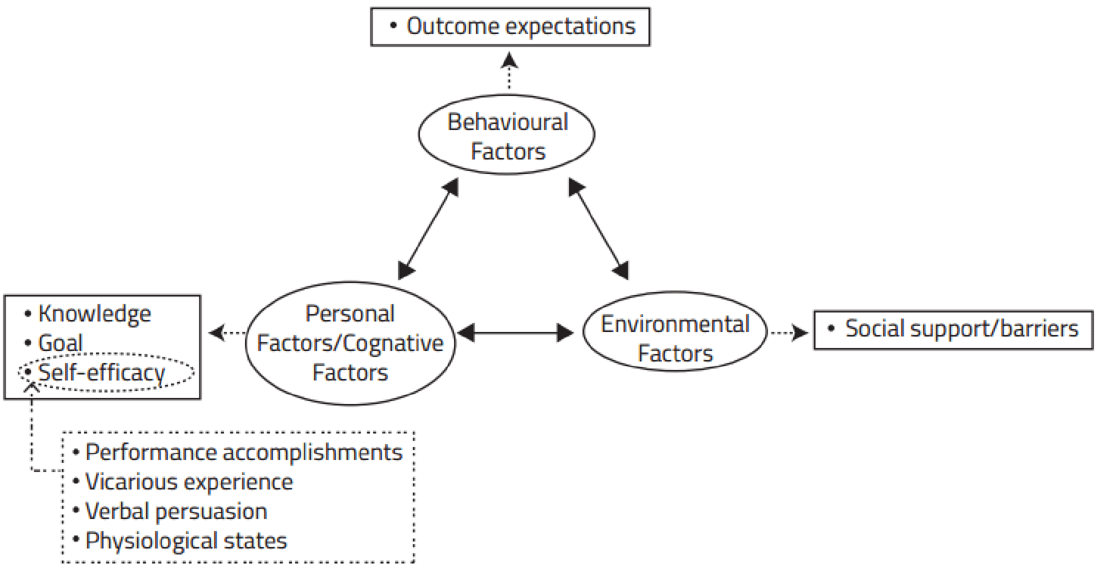

Figure 1: Diagram illustrating the constructs of social cognitive theory in social change (adapted from Chin & Mansori, 2018).

Bandura (1989) referred to this interconnectedness as reciprocal causation, where all the constructs operate as interacting determinants that influence each other bidirectionally (Bandura, 1989). However, Bandura states that the constructs of reciprocal causation do not have equal influence and nor do they all have influence at the same time.

2.3 PERSON–ENVIRONMENT RELATIONSHIP

The outcomes of the individual's perception of their environment and the resulting attitudes and behaviour towards the environment culminate in the person–environment relationship (Suresh *et al*., 2006). A person's relationship with their environment can be influenced by the condition of that environment, the opportunities that it presents to the person as well as the impact of challenges on the person (Suresh *et al*., 2006). These conditions determine how a person will use or engage with their environment which, in turn, has an impact on their attitude towards the environment (Munasinghe, 2005) (see Figure 8).

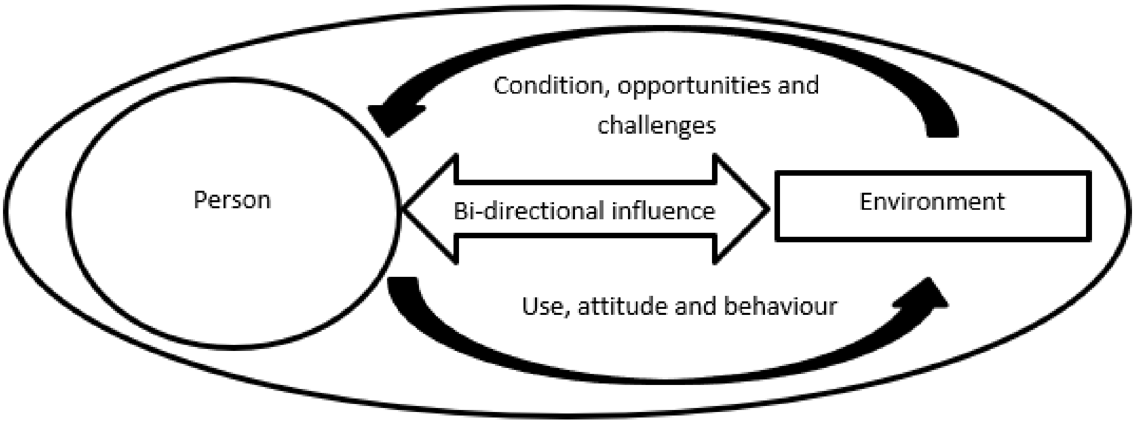

Figure 2: Person–environment relationship illustrating the influence the environment has on a person and the resulting attitudes and behaviours towards the environment (adapted from Munasinghe, 2005).

2.4 ATTITUDES AND BEHAVIOUR

An attitude is an underlying construct mentally formed by or towards a concrete or abstract object (Gifford & Sussman, 2012). Attitudes are sometimes confused with other concepts such as values and beliefs but although they are related they do differ (Gifford & Sussman, 2012). Values are internalised cognitive structures that guide a person's choices and are related to a basic set of right and wrong principles (American Psychological Association, 2022a), while beliefs are based on a person's truth and reality about something, which is not necessarily substantiated (American Psychological Association, 2022b). In environmental psychology, attitudes, as they relate to an individual's environment, are known as environmental attitudes (EA) and are defined as psychological responses expressed positively or negatively based on a person's perception of or belief about their environment (Milfont, 2007).

According to Katz (1960) and Albarracin *et al*. (2014), attitudes serve four main functions:

> **Knowledge function**. This involves acquiring knowledge and the motivation to acquire knowledge about the environment. The motivation to gain knowledge is often related to a person's goals and level of interest in the subject or object.
>
> **Ego defensive function**. This function serves to protect the integrity of a person and avoid embarrassment or shame. A person will justify their attitude towards the environment or aspects thereof, whether right or wrong, in order to socially validate their attitude.
>
> **Value expressive function**. Attitudes expressed are based on a person's instilled values and beliefs about the environment.
>
> **Adjustment function**. To avoid unpleasantness, a person will adjust their attitude according to their environment to accommodate it and ensure that their experience is pleasurable.

Environmental attitudes and how they are related to, or influence behaviour, that is, a person's reaction to their environment, is illustrated by Stern's (2000) integrated attitude-behaviour-context (ABC) theory where behaviour is an interactive outcome of a person's attitudinal variables and contextual or environmental factors. For instance, in the recycling example illustrated in Figure 9, a person will most likely recycle if they have a positive attitude towards recycling coupled with an environment that facilitates recycling.

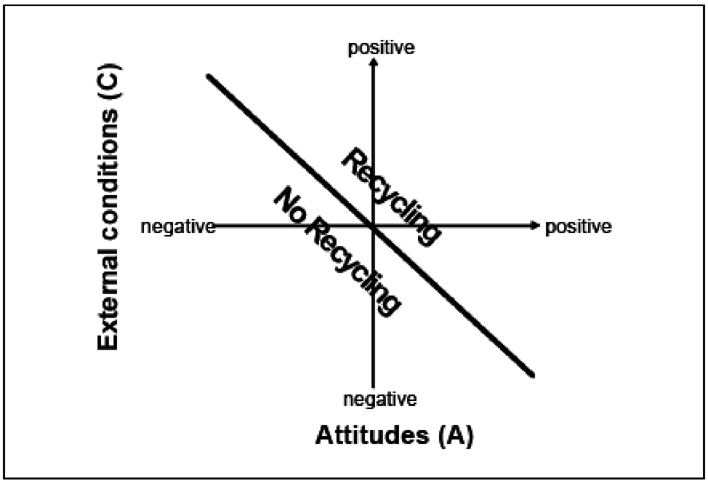

Figure 3: Diagram illustrating Stern's (2000) ABC model.
This figure shows, using recycling as an example, that a person will most likely have a positive attitude towards recycling if they have an environment conducive to being able to recycle.

2.5 CONCLUSION

Environmental psychology and its application in conservation is essential for enabling a society that supports conservation through its behaviour. Such behaviour will be reflected in people's attitudes and values, ultimately ensuring the sustainability and long-term security of the natural environment. As such, a founding principle in conservation should be to understand that environments and related systems that reflect the value of the natural environment and enable communities to change are necessary to create a shift in values towards environmental appreciation.

CHAPTER 3
THEORETICAL FRAMEWORK: WETLANDS, BIODIVERSITY AND HUMAN WELL-BEING

3.1 INTRODUCTION

The environment is defined as everything that surrounds a living thing and can be natural and/or manmade (Encyclopaedia Britannica, 2022). The natural environment includes everything both living (plants and animals) and non-living (water, air, soil, minerals, nutrients) and how these components interact (Encyclopaedia Britannica, 2022). Manmade or built environments are those environments constructed by humans, including land that has been urbanised or transformed through agriculture or livestock farming. Humans have transformed 70% (UNCCD, 2022) of the earth's land surface for economic (agriculture or industry) or social security (housing). The extent of land transformation and the related impact on the ecological infrastructure, through climate change or pollution, for example, affects the ability of the natural environment to provide the necessary resources or systems essential for all life on earth.

A wetland is a type of natural habitat and is a form of ecological infrastructure, which according to South Africa's National Water Act (Act 36 of 1998) is defined as

> … the land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

Wetlands are an integral part of catchments and provide essential goods and services through flood control, drought relief, water storage, sedimentation and nutrient retention, soil protection, water purification, erosion control, stream flow control, food security, fish nurseries, groundwater recharge and biodiversity support, as well as providing cultural and recreational services and contributing to the economy through tourism (Dickens *et al*., 2003; Gokce, 2018). Services provided by the water supply from wetlands sustain 60% of the country's population, more than 90% of urban water users, 37% of national economic activity and 70% of irrigated agriculture (Government of South Africa, 2022).

This chapter explores the wetland environment, its ecological infrastructure and the ecological goods and services it provides to support all life on earth.

3.2 TYPES OF WETLAND

Wetlands are found across South Africa (Figure 10) and although mostly found within areas where the land surface is flat and rainfall is high, they are also found in KwaZulu-Natal in the east through to the semi-arid Kalahari and Karoo region of the Northern Cape (Dickens *et al*., 2003; Edwards *et al*., 2018).

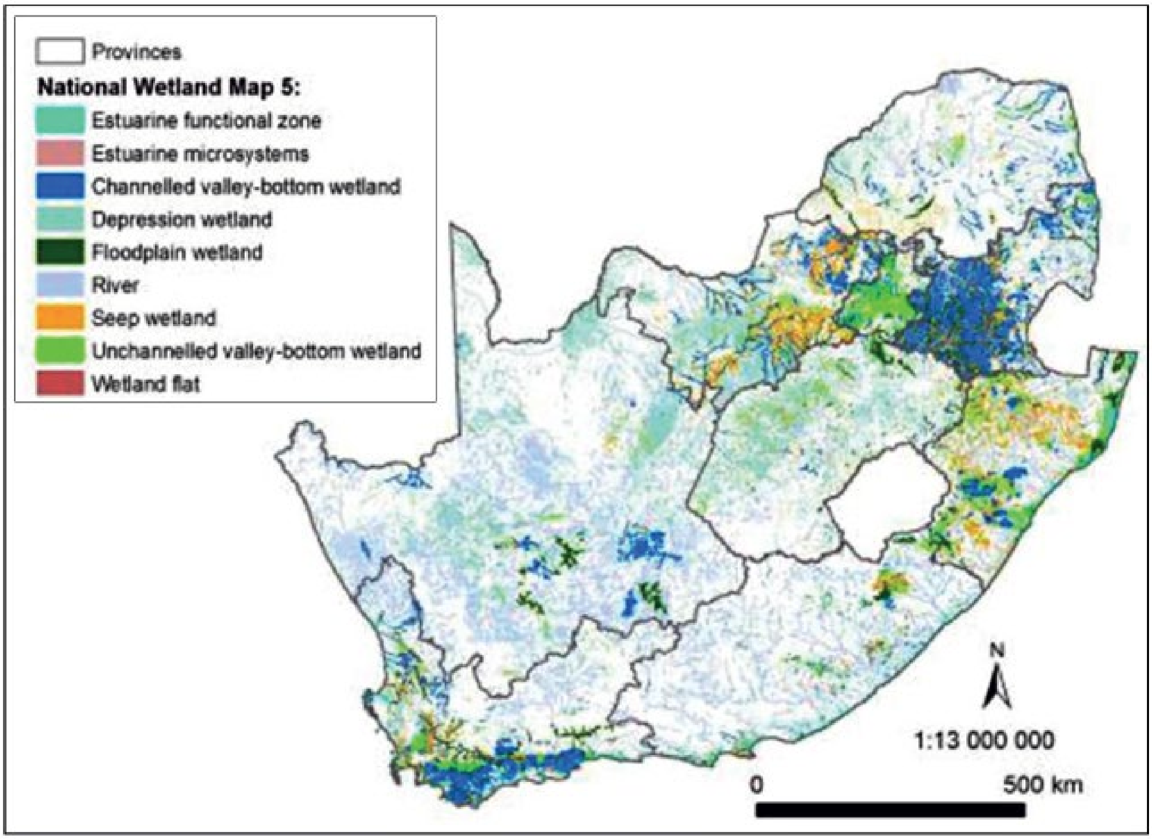

Figure 4: National Wetland Map 5 showing types of wetlands in South Africa (Van Deventer *et al*., 2019).

Wetland types can be described on a broad scale according to the hydrogeomorphic setting. These classifications are supported by soil, fauna and flora diversity (Ollis *et al.,* 2051; Dickens *et al*., 2003; Edwards *et al*., 2018). Based on this classification system the different types of wetlands have been illustrated in Figure 11.

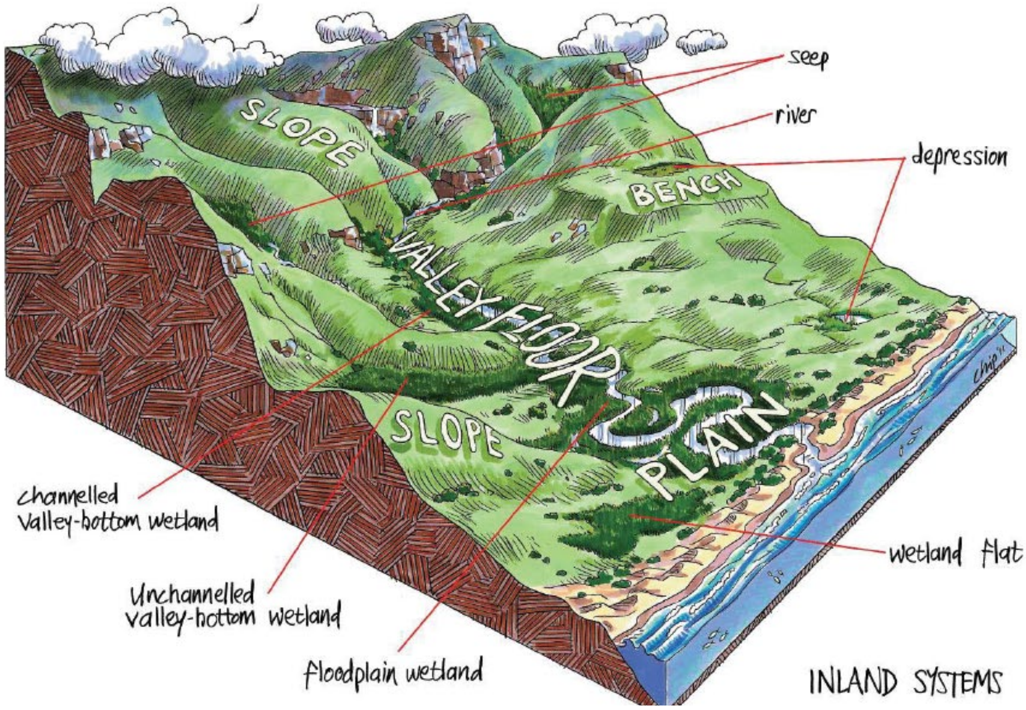

Figure 5: Illustration of the seven primary Hydrogeomorphological and landscape settings (Ollis *et al*., 2015).

3.3 FUNCTION OF WETLANDS

Wetlands, depending on their size, type and structure, provide essential goods and services to all life on earth, including people (Schuyt & Brander, 2004). Specifically, they support essential water services (Millennium Ecosystem Assessment, 2005), provide the habitat for key biodiversity, provide a variety of services that maintain human and ecosystem well-being and play a key role in economic stability both directly and indirectly (Schuyt & Brander, 2004). Wetlands also prevent flooding and store carbon which contributes to climate control and mitigates climate change (Edwards, *et al*., 2018).

3.3.1 Provision of water services

Water is critical to the survival of all life on earth and, without it, there would be no life. Wetlands are important because they store water, recharge groundwater aquifers and purify water (Millennium Ecosystem Assessment, 2005). Since wetlands are often found in flat areas and valleys, the water flowing from the upper catchment spreads across these flat or valley landscapes where the wetland vegetation traps water, enabling water storage, filtration and groundwater recharge (Dickens *et al*., 2003; Edwards *et al.,* 2018). Water is often harvested from wetlands for various uses including domestic and agricultural purposes (Hay *et al*., 2014). Groundwater resources can supply water to many people who live directly downstream from wetlands and who can access these water resources from a well or borehole (Hay *et al.,* 2014).

Wetlands improve water quality by removing sediment from surface waters (Hay *et al*., 2014). The reduced flow of water allows suspended material to settle while vegetation binds accumulated sediments (Hay *et al*., 2014). Heavy metals and other toxicants, attached to the soil, are also bound by wetland vegetation, effectively removing these from the water and improving water quality (Sun *et al*., 2022). Nutrients such as nitrogen and inorganic phosphorus may be stored in sediment and absorbed by wetland vegetation or transformed by chemical and biological processes (Yousaf *et al*., 2021). This prevents eutrophication and improves water quality (Yousaf *et al.,* 2021).

3.3.2 Biodiversity

Wetlands cover only 6% of the earth's land surface but they support 40% of the plants and animals of the world (Schuyt & Brander, 2004). Wetlands are highly productive and capable of supporting complex food webs. Wetlands also allow animals with complex lifecycles such as metamorphosising amphibians, spawning fish and migratory birds to thrive (Darwall *et al*., 2011). It is no wonder that the World Conservation Strategy (1980) determined that wetlands are the third most important life support system on the planet. A decline in biodiversity, including fish or plant species, leads to a decline in the natural resources available to people in the form of food for sustainable household or commercial use (Kumar & Kanaujia, 2014). A decline in resource availability, such as fish, contributes to an increase in poverty and a decline in the quality of livelihoods (Kumar & Kanaujia, 2014).

3.3.3 Goods and service provision to support well-being

Wetlands play an integral role in flood prevention through the control of water from upper catchments during periods of heavy rainfall (Edwards *et al.,* 2018). These systems slow water flow, reducing velocity and absorbing floodwaters to reduce the effects of flooding downstream. Wetlands contribute significantly to the nutrient cycle through the capture, retention and decomposition of harmful concentrations of toxicants using anaerobic processes (Acreman & Holden, 2013). Wetlands are also important carbon sinks and accumulate large amounts of plant material because it takes longer to decompose this material under anaerobic soil conditions since they are mostly saturated with water (Foster *et al*., 2013). This prevents carbon from being released and assists in maintaining a stable climate (Foster *et al.,* 2013).

Food and natural resources received from wetlands support communities either through subsistence, commercial or recreational use (Hay *et al.,* 2014). All these forms of use contribute to the health and well-being of over one billion people (Convention on Biological Diversity, 2016).

Wetlands also contribute to mental and social well-being, which has a positive impact on human health (Whitehead & Rose, 2009). Recreation and outdoor activities contribute not only to mental well-being but such activities assist in building physical strength which promotes health and, in turn, well-being (Abraham *et al*., 2010). Group activities such as recreational fishing, for example, support health thus promoting mental well-being and increased physical health (Abraham *et al*., 2010).

3.3.4 Economic stability

Almost two decades ago, African wetlands had an estimated total economic value of US$256 687 000 or over R4 billion per annum (Schuyt & Brander, 2004). Such economic value is based on the variety of goods produced such as the supply of food and materials to produce crafts and medicine or services such as flood attenuation. Owing to the high nutrient content of wetland soils and related productivity, wetlands are valuable for supporting livestock grazing and the production of crops (Sonnier *et al*., 2020). Although these products can be used directly by communities surrounding wetland systems, wetland products are also distributed to other areas to support commercial enterprises (Zungu *et al.,* 2016).

Recreational, tourism and cultural practices attract people to wetlands, which supports local industries and livelihoods. Schuyt and Brander (2004) estimate the annual economic value of the recreational activity of wetlands at US$492 per hectare while recreational fishing is valued at an annual US$374 per hectare (Brander & Schuyt, 2010).

Furthermore, wetlands supply free ecological services in the form of flood prevention, estimated at US$464 per hectare per year (Schuyt & Brander, 2004), and climate control, because wetlands store approximately 35% of global terrestrial carbon (Ramsar, Scientific and Technical Review Panel and the Secretariat of the Convention on Biological Diversity, 2007), which are important in maintaining a stable economy. A loss of one hectare of wetland can cost society an average of US$1900 per year in flood damage (Taylor & Druckenmiller, 2021), placing pressure on government institutions to divert and expend financial resources to support recovery.

3.4 STATE OF AND THREATS TO WETLANDS

In South Africa, 79% of inland wetlands are threatened (Skowno *et al.,* 2019). Approximately 2.6 million hectares of wetland area remain in South Africa, of which 61% are considered critically endangered, 9% are listed as endangered and 9% are vulnerable which collectively equate to more than 2.3 million hectares (Skowno *et al*., 2019). Despite this, only 6% of inland wetlands are protected (Skowno *et al.,* 2019). Adeeyo *et al*. (2022) and Mitchell (2013) mention some of the main threats to wetlands, which are discussed in the following sections.

3.4.1 Poor land management practice

Poor livestock management through poor grazing and stocking strategies results in trampled wetlands, hardening the ground surface which negatively affects the structure and function of wetlands (Morris & Reich, 2013). In addition, the drainage of wetlands for agricultural, silviculture and pasture crops results in a change in the hydrology of the wetland and affects the functionality of downstream systems (Partington *et al*., 2016). Poor burning practices can decrease biodiversity and negatively affect the ability of a wetland to store carbon, which decreases the ability of a wetland to contribute to climate control (McElwee, 2021).

3.4.2 Poor spatial planning and management

The complete removal of wetlands for the construction of dams and the infilling of wetlands to build houses, factories and roads affect the water flow and the biodiversity of an area (Mantel *et al.,* 2010). Reduced water-flow downstream by a dam can negatively affect the functionality of the ecological infrastructure downstream while infilling wetlands can increase the risk of flooding (Mantel *et al*., 2010). The absence of wetlands and the restriction of land use by local communities negatively affect the well-being of those communities (Hay *et al*., 2014).

3.4.3 Mining

Mining can completely remove or disturb wetland functionality which negatively affects the hydrology and substrate of wetlands, increasing the risk of flooding and erosion of the area, in turn affecting onsite and downstream systems (Macfarlane *et al*., 2016). Through these changes, the biodiversity of the wetland is negatively affected, ultimately resulting in the decreased ability of a wetland to provide essential goods and services to surrounding and downstream communities (Macfarlane *et al*., 2016).

3.4.4 Pollution

Pollution of wetlands can negatively affect the survival of the complex flora and fauna which inhabit the wetland, resulting in a decrease in the functionality of the wetland. High concentrations of pollutants can also negatively affect surrounding and downstream communities that use wetland resources directly.

3.4.5 Invasive alien species

Invasive alien species displace indigenous species which disturb wetland functionality and displace indigenous species thereby reducing biodiversity (Martens *et al*., 2021). Invasive alien plants increase the siltation of wetlands through accelerated soil erosion, reduce water storage capacity and negatively influence the hydrology of wetlands (Martens *et al*., 2021). In addition, they increase the risk of wildfires and this together with effects on water and soil, negatively affect the supply of ecological goods and services (Martens *et al*., 2021).

3.4.6 Poor compliance and enforcement

Poor governance, enforcement and application of environmental legislation to protect wetlands are major contributing factors to the loss and degradation of wetlands (Kidd, 2011). The removal of wetlands in favour of residential developments and agriculture, for example, despite the value of wetlands, has resulted in wetlands being degraded (Kidd, 2011).

In the eThekwini Municipality, owing to a combination of the above threats, only 6 200 ha of wetland habitat remains and, of that, 90% is rated as degraded with only 10% considered to be in good or intermediate condition (World Bank, 2016). The impacts caused by the loss of wetlands and related functionality are being increasingly realised in the region, in particular during the extreme flood events that occurred between 2016 and 2021, in which over 100 people lost their lives and almost 2000 people were displaced by floodwaters. Most recently, floods in April and May 2022 resulted in over 440 deaths with an estimation that over 40 000 people were displaced (The Presidency, 2022).

3.5 ECONOMIC REALITY OF WETLAND LOSS

According to Schuyt and Brander (2004), a functional wetland can equate to over US$2260 or R40 000 per hectare per year based on the ecological goods and services the wetland infrastructure provides (Table 4). However, wetlands have varied functionality based on the type and geographic location. As such, Schuyt and Brander (2010) state that the economic value of wetlands covering approximately 12.8 million km² globally could be as much as US$70 billion per year.

Table 1: Medium wetland economic values by wetland function (Schuyt & Brander, 2004).

Wetland function	Median wetland economic value (US$ per hectare per year, 2000)
Flood control	464
Recreational fishing	374
Amenity/recreation	492
Water filtering	288
Biodiversity	214
Habitat nursery	201
Recreational hunting	123
Water supply	45
Materials	45
Fuelwood	14

In the eThekwini Municipal District, based on the median overall value of R40 000 per hectare per year, the current functional portion of wetlands within the eThekwini Municipality is contributing R24 767 539 per year. This is as opposed to a potential contribution of R247 675 391 per year if all 6 200 ha of wetland remaining were functional (as calculated from Schuyt & Brander, 2004). Although realistically, this amount is less, this estimated value demonstrates the current and potential contribution wetlands could provide to the eThekwini Municipality's local economy.

The impact of floods can be devastating. The April 2022 floods in the eThekwini Municipality resulted in the death of 448 people, displaced 40 000 people, and destroyed 12 000 homes (European Civil Protection and Humanitarian Aid Operations, 2022). The economic costs of the April 2022 floods alone were estimated at R17 billion for one flood event, much of which could have been avoided with improved catchment and wetland management such as wetland and riparian protection and conservation interventions (Mboto, 2022).

3.6 CONCLUSION

Wetlands are diverse in type and located across South Africa, making them a national asset that provides a wealth of goods and services that support human well-being. Considering the contribution of wetlands to the well-being of people, not only in the goods and services they provide but in relation to economic stability and risk aversion through flood prevention, for example, wetlands should be prioritised for protection, rehabilitation and restoration.

CHAPTER 4
THEORETICAL FRAMEWORK: SOCIO-ECOLOGICAL RESTORATION

4.1 INTRODUCTION

Socio-ecological restoration (SER) can be considered a restoration process that has a positive impact on both the ecological and social environments (Fernandez-Manjarres *et al*., 2018). Although SER follows the same principles as ecological restoration, three main concepts make it different (Fernandez-Manjarres *et al*., 2018). Firstly, SER recognises the need to recover the minimum living standards of local community members (Fernandez-Manjarres *et al*., 2018). Secondly, it recognises the relationship between people and their environment (Fernandez-Manjarres *et al*., 2018). Lastly, it accepts that external support is required to initiate and enable restoration, as resources may be absent within the target community (Fernandez-Manjarres *et al*., 2018). According to Fischer *et al*. (2021), this approach is complex as it requires interlinking social and environmental processes and consists of various components including the following:

Resilience and adaptability. Restoration needs to promote resilience and systems need to be able to adapt to change, both socially and ecologically.

Stewardship. Stewardship towards caring for and managing the natural environment for improved resilience needs to be promoted within local communities.

Relational values. A positive relationship needs to be promoted between people and their environment to improve values.

Coevolution of human and ecological systems. Positive coevolution between people and ecological systems needs to be promoted to foster sustainable systems.

Long-range socio-ecological connections. Knowledge systems need to be mapped and built to show the local and global connections of human actions and impact.

Leverage points for transformation. Local and global leverage points need to be understood and incorporated to promote transformation.

4.2 PRINCIPLES OF SOCIO-ECOLOGICAL RESTORATION

Restoration requires time, resources, knowledge, enabling policies, and governance to bring about a positive change for improved socio-ecological resilience (UNEP, 2021). To support maximum results to ensure successful restoration, the FAO (2021) has developed nine guiding principles to consider, namely:

Principle 1: Promotes continued and consistent inclusivity and participatory governance, social fairness and equity.

Principle 2: Includes a continuum of restorative activities.

Principle 3: Works towards achieving the highest level of recovery possible to support social and ecological well-being.

Principle 4: Addresses the drivers of degradation.

Principle 5: Incorporates all types and sources of knowledge and encourages knowledge sharing.

Principle 6: Is contextually formulated but understood and included global connectedness.

Principle 7: Support multidisciplinary influences which consider social, ecological, political and economic systems.

Principle 8: Implements a long-term comprehensive monitoring, evaluation and adaptive management process.

Principle 9: Aligns with legislative frameworks and policies, maintaining funding and support systems while seeking opportunities to scale out systems.

4.3 APPROACHES FOR SOCIO-ECOLOGICAL RESTORATION

Many SER interventions have been unsuccessful for a variety of reasons, including, for example, lack of local support and understanding for restoration projects, inappropriate restoration solutions and poor planning (Fisher *et al.,* 2021; O'Higgins *et al*., 2020). Learning from these projects in order to develop approaches to effective SER is key to ensuring better practice. Fisher *et al.* (2021) and O'Higgins *et al*. (2020) identify interconnecting approaches of socio-ecological systems which can improve restoration. These have been summarised in the following sections.

4.3.1 Mixing models and multidisciplinary approaches

A multitude of approaches to SER exist, involving a multitude of intervention types for restoring a system (O'Higgins *et al*., 2020; De Wit *et al.,* 2020). Mixing ecological restoration models such as mapping priority areas based on conservation targets, alien invasive species eradication projects and soil erosion control may be required to restore a system (O'Higgins *et al*., 2020). However, SER interventions involving skills transfer for effective local environmental management, employment and education initiatives may be necessary to promote relational values towards people and their environment (Fisher *et al.,* 2021; O'Higgins *et al*., 2020).

The choice of approach should be carefully considered based on local assessments to determine the state of the ecological and social systems, the degradation drivers and then the related approaches for restoration (O'Higgins *et al.,* 2020; De Wit *et al.,* 2020).

4.3.2 Diverse stakeholder engagement

Interested and affected parties should be identified through stakeholder analysis. The role, authority and influence of each stakeholder should be clearly understood (O'Higgins *et al*., 2020). With this, a stakeholder engagement and communication strategy should be developed and implemented from the outset of project intervention, allowing an opportunity for all to contribute (Fisher *et al.,* 2020; O'Higgins *et al*., 2020).

4.3.3 Recognition of ecosystem goods and services

Ecosystem goods and services should be mapped, and a communication plan should be developed to build local knowledge and appreciation of these goods and services (Alba-Patiño *et al.* 2021; O'Higgins *et al*., 2020).

4.3.4 Contextual solutions

Contextual restoration systems are imperative (O'Higgins *et al*., 2020). Solutions to address degradation are case-specific and local contexts should be fully understood to allow for relevant restoration actions (O'Higgins *et al*., 2020).

4.4 MONITORING SOCIO-ECOLOGICAL RESTORATION

To determine the effectiveness of SER, a monitoring system that includes baseline assessments should be incorporated. This should include both social and ecological variables, depending on the interventions instituted (Okpara *et al*., 2018). According to Okpara *et al*. (2018), indicators should be based on SMART principles:

> **Specific**: indicators to be measured should be explicit and clearly describe what needs to be measured.
> **Measurable**. The metric should be relevant, scientifically sound and repeatable regardless of the user.
> **Attainable**. A collection of data should be simple and resource-efficient.
> **Relevant**. Indicators need to be relevant to the specific outcome.
> **Time-bound**. A timeframe needs to be coupled to the indicator being measured.

The scientific understanding to restore social and ecological systems, and the complex interactions between people, their environment and climate change, are constantly developing (United Nations Environment Programme, 2021). Knowledge of successful restoration initiatives should be shared to help industry practitioners make informed decisions to increase the success of restoration initiatives (United Nations Environment Programme, 2021).

4.5 CONCLUSION

A socio-ecological restoration systems approach to ecological restoration is recommended by the UN Declaration of Ecological Restoration (2021) in recognition that human and natural systems are interconnected. To successfully restore the huge extent of degraded systems by 2030, the human system needs to be restored in conjunction with the natural system. Careful planning and monitoring are therefore essential to demonstrate the effectiveness of SER and improve the understanding of and science behind this approach.

CHAPTER 5
CONTEXT AND STUDY SITES

5.1 INTRODUCTION

The study was conducted under the auspices of the Endangered Wildlife Trust's Threatened Amphibian Programme (TAP) through the Pickersgill's Reed Frog Recovery Project (PRF-RP). The PRF-RP aims to protect the endemic endangered Pickersgill's reed frog which is found in a narrow strip along the KwaZulu-Natal coastline. In the eThekwini Municipal District where the PRF-RP first started, TAP works in four sites (Figure 1), namely, the Mt Moreland Wetland, the Isipingo Wetland, the Adams Rural Wetland and the Widenham Wetland where conservation measures have been implemented to

- secure habitat through formal protection
- manage habitat by clearing alien invasive plants
- capacitate communities to manage habitats where the Pickersgill's reed frog occurs.

Figure 6: Threatened Amphibian Programme project sites within the eThekwini Municipality (Google Earth, 2022).

For this study, two sites were selected, namely, the Adams Rural Wetland and the Isipingo Wetland. These study sites were selected because the most consistent conservation measures have been implemented at these two sites between 2016 and 2022. These sites are described separately below.

5.2 ADAMS RURAL WETLAND (ARW)

Adams Rural Wetland is a semi-rural community under the governance of the Sobonakhona Traditional Authority and is located in the eThekwini municipal area, KwaZulu-Natal. Adams Rural Wetland area is home to a 466-ha wetland system (Figure 2) consisting of a network of Indian Ocean Coastal Belt Wetland and swamp forest (Table 1) located on an undulating plateau in the upper reaches of three different river systems, namely, the Nungwane River, the Manzimtoti River and the Golokodo River.

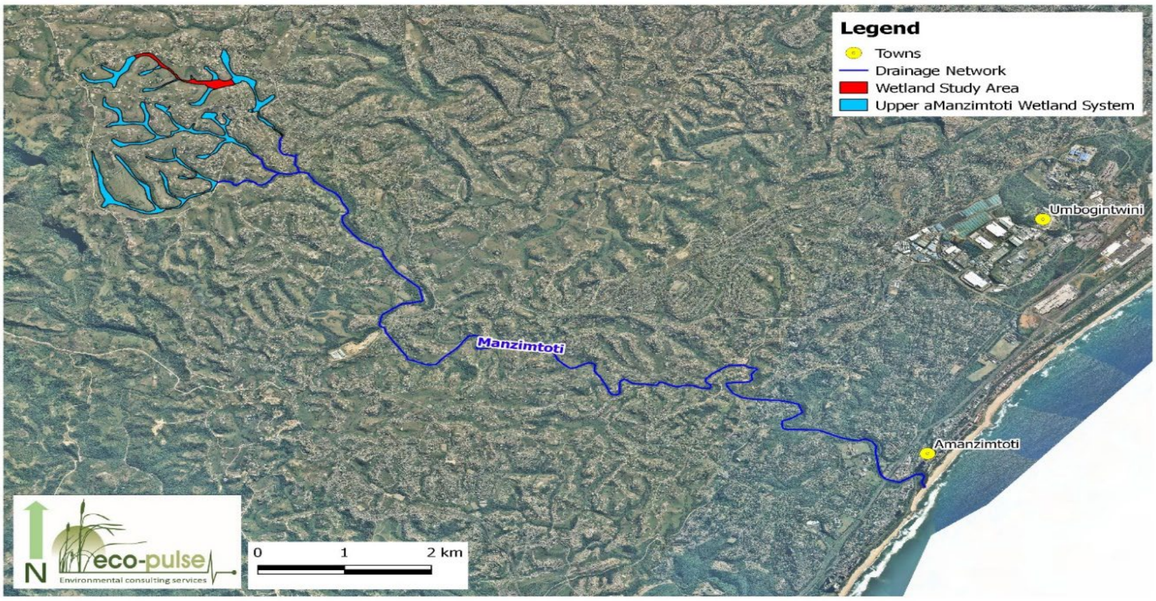

Figure 7: Map showing the wetland system (blue polygon) at the Adams Rural Wetland study site (red polygon) (Eco-Pulse Consulting, 2019a).

5.2.1 Climate

Adams Rural Wetland is situated 173 m above sea level and has a warm and temperate climate (Gabhisa Planning and Investment, 2019). The average annual rainfall for the area is 1 009 mm while the average temperature ranges between 24 °C in summer and 17 °C in winter (World Weather Online, 2021).

5.2.2 Ecological assets

The ecological assets for the ARW are outlined in Table 1.

Table 2: Ecological assets of ARW.

Type	Description
Natural assets	Critically endangered habitats (SANBI, 2014): • Indian Ocean Coastal Belt Wetland • South Coast Grassland • *Voacanga thouarsii* Swamp Forest. Endangered species: • *Hyperolius pickersgilli* (Pickersgill's reed frog) (Figure 3) • *Natalobatrachus bonebergi* (Kloof frog) (Figure 4).
Ecosystem services	The following key ecosystem services are provided: • Fresh water production • Water purification (wetland function) • Medicinal plants • Flood attenuation • Biological adaptations to climate change • Unfragmented catchment system • Provision of important corridors/links to surrounding habitats.
Socio-economic assets	• The site comprises three catchments, Lower Lovu, Manzimtoti and Golokodo, and is therefore important in water provisioning. • The area plays a role in regulating the flow of water through the grassland and wetlands on site. • The site provides pollination services owing to its size, habitat heterogeneity, good condition and connectedness to other natural areas. • The site has a high potential for low-impact ecotourism development, with knock-on benefits for local employment, local markets and the local economy.
Aesthetic assets	• Wetland areas have high scenic beauty value across a variety of ecosystems. • The wetland system provides important green spaces in what is becoming a rapidly urbanised environment.

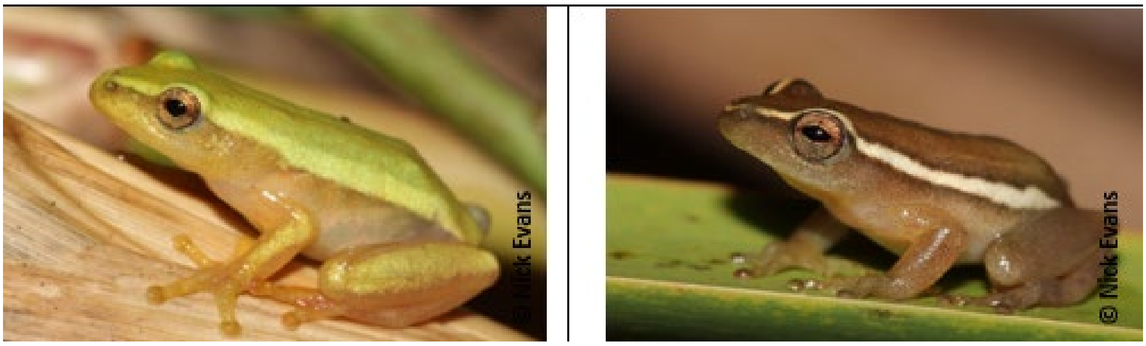

Figure 8: Female (left) and male (right) Pickersgill's reed frog (*Hyperolius pickersgilli*) (Evans, 2013).

Figure 9: The endangered Kloof frog (*Natalobatrachus bonebergi*) present at the Adam's Rural Wetland study site.

5.2.3 Social characteristics

The ARW is found in Ward 96 of the eThekwini Municipality and, according to the 2011 Census, is home to a population of over 31 000 people (Census, 2011a). Over 69% of residents receive water from the municipality, over 31% of residents have access to a chemical or flushing toilet and 8.6% receive waste removal services (Census, 2011a). Approximately 18% of the population is employed and just over 39% of residents have an education level equivalent to Grade 12 or higher (Census, 2011a).

5.3 ISIPINGO WETLAND (IW)

The IW study site falls under the eThekwini Municipality and forms part of the Isipingo River Tributary Wetland (Figure 5). This wetland is a 2.34-hectare herbaceous marsh that borders the Isipingo River Floodplain. The downstream floodplain has been transformed by the Isipingo Wastewater Works, which has canalised the lower portion of the wetland.

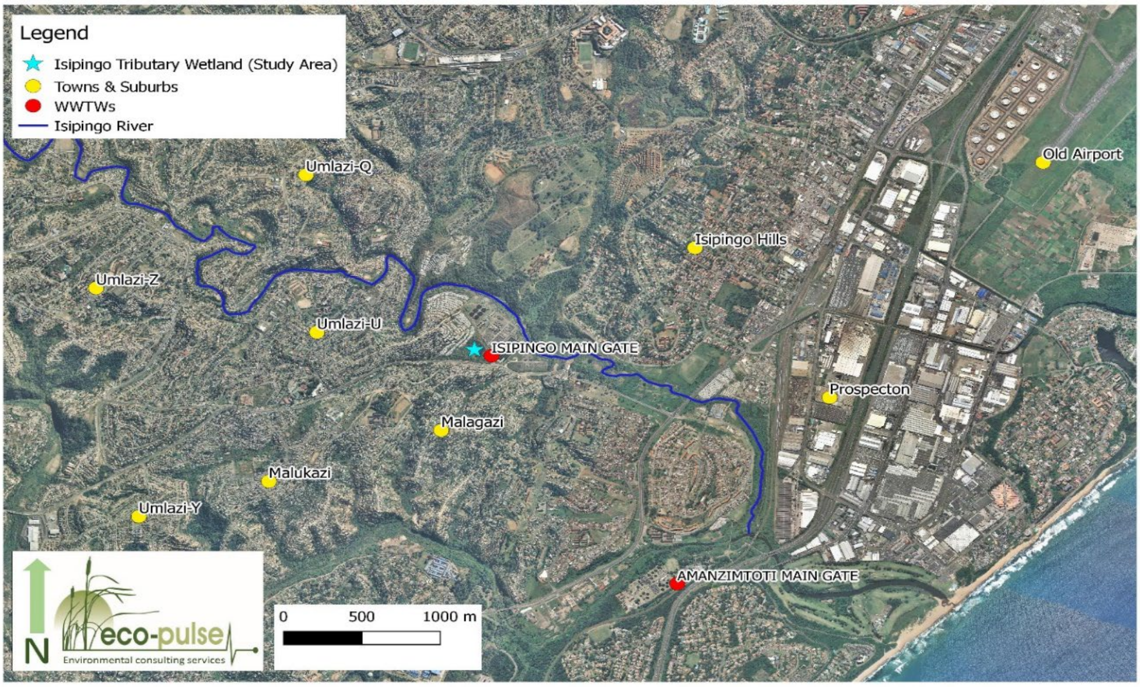

Figure 10: The Isipingo Wetland study site (Edwards, 2016).

5.3.1 Climate

The IW lies 108 m above sea level (Falling Rain Software, 2016). The average annual rainfall for the area is 594 mm, while the average temperature ranges between 26 °C in summer and 21 °C in winter (Weather Atlas, 2022).

5.3.2 Ecological assets

The IW ecological assets are outlined in Table 2.

Table 3: Ecological assets of IW.

Type	Description
Natural assets	Critically endangered habitats (SANBI, 2014): • Indian Ocean Coastal Belt Wetland Endangered species: • *Hyperolius pickersgilli* (Pickersgill's reed frog) (Figure 3)
Ecosystem services	The following key ecosystem services are provided: • Fresh water production • Water purification (wetland function) • Medicinal plants • Flood attenuation • Provision of important corridors/links to surrounding habitats.
Socio-economic assets	• The site provides pollination services. • The site plays an important role in processing grey water from the surrounding community.
Aesthetic assets	• The site has potential to provide an open green space.

5.3.3 Social characteristics

The IW lies in Ward 89 of the eThekwini Municipality. It covers a total area of 4.6 square kilometres and is home to over 24 000 people according to the 2011 census data (Census, 2011b). Over 83% of residents receive water and 65.5% have access to a chemical or flushing toilet (Census, 2011b). Eighty per cent of residents have access to a waste removal service and almost 40% of residents are employed (Census, 2011b). Thirty-eight per cent of residents have a Grade 12 or higher level of education (Census, 2011b).

CHAPTER 6
METHODOLOGY

This study compared two study sites according to the level of land use, the attitude of residents towards the environment and the respective ecological state of the environment. Data on social aspects such as attitude and level of land use were gathered using a qualitative approach, while a qualitative data collection approach was applied to assess the ecological state. Pre and post surveys and assessments were conducted to measure impacts of socio-ecological restoration intevensions. These methods are described below.

6.1 QUALITATIVE ASSESSMENTS

6.1.1 Sample size

A convenience sampling approach was used for the collection of data. The main reason for this approach was to gather data from the population neighbouring the wetland at each study site. Number of questionnaires completed were relative to the number of people within the wetland area i.e. the larger the wetland, the greater the surrounding community resulting in more questionnaires being completed and conversely. Questionnaires were also completed pre and post socio-ecological restoration intereventions to determine any change. Participants were randomly selected within the specific area to complete a questionnaire. No participant was interviewed more than once. Questionnaires were completed until no new information was gained at which point data saturation was reached. According to Creswell (2007), this system uses instances that represent categories of data and continues interviewing until the new information obtained does not provide further insight into the category (Guest *et al*., 2006).

6.1.2 Socio-ecological assessment

Two questionnaires were used, namely:

- Community land engagement surveys (Annexure 1).
- Attitude assessments (Annexure 2).

These questionnaires were conducted in isiZulu and English depending on the preference of the interviewee and the attitude and community land engagement surveys are outlined separately below. Pre and post surveys were conducted to measure impact of socio-ecoligical restoration interventions.

6.1.2.1 Community land engagement survey

Open-ended questionnaires were used to collect data on how community members utilise the land in their area. Land-use practices were determined according to the following:

Local water use – the utilisation of locally sourced water from streams or wetlands as well as water collected through rainwater harvesting.

Flora use – the type of plants used, whether vegetables, crops or indigenous plants, including how these plants are being used.

Fauna use – type and use of animals in terms of domestic, livestock or wildlife/indigenous animals.

Agricultural and livestock practices – whether people utilise the land for the growing of crops or the rearing of livestock.

Waste management – to assess waste management practices in the absence of waste management services from local municipalities.

Service delivery – access to services such as the provision of water and waste management services.

The questionnaires also sought to gauge a person's relationship with the land around them by clarifying the following:

Positivity – whether respondents enjoy living in the area and why.

Perceptions – what perceptions respondents hold regarding the areas in which they live and how they describe these areas.

Threats – identify key issues that threaten the positivity and perceptions of an area.

Challenges – identify the main challenges around waste, water and natural resources experienced by people in the area in which they live.

Finally, the questionnaire sought to determine the living knowledge about an area by examining the changes people have noticed in local water sources from wetlands and rivers.

Qualitative data in the form of individual responses were grouped and categorised and converted to quantitative data in relation to the total number of respondents that specified the category in their responses. Categories were standardised across the two sites.

6.1.2.2 Attitude assessments

A functionalist approach was used to determine the attitudes of people towards their environment (Drews, 2002). A questionnaire was compiled comprising 42 questions intended to rate five attitude dimensions (strongly agree to strongly disagree) of people towards their environment (adapted from Tarrant *et al*., 2016). Three different scales were developed, assessing a person's liking, knowledge and cultural beliefs and these were incorporated into the questionnaire (Tarrant *et al*., 2016). Depending on the response, the scale was allocated a numerical value of -1 (strongly disagree), -0.5 (disagree), 0 (unsure), 0.5 (agree) or +1 (strongly agree). The values attributed to the responses to the 42 questions were added together and an attitude score was determined. The average attitude scores of all the respondents were calculated for each site.

6.2 QUANTITATIVE SAMPLING

6.2.1 WET Health Assessment

A standardised tool, the WET Health Assessment, was used to assess the health of the two wetland sites, combining indicators of three components, namely *hydrology, geomorphology* and *vegetation,* which make up an overall impact score (Macfarlane *et al*., 2009).

Table 4: Wetland present ecological state (PES) categories (Macfarlane *et al*., 2009).

Impact score	Ecological category	Description
0–0.9	A	Natural state
1–1.9	B	Largely natural with a few alterations
2–3.9	C	Moderately modified but the basic ecosystem functions are still unchanged
4–5.9	D	Largely modified. A large loss and change in the habitat, biota and basic ecosystem functions
6–7.9	E	Seriously modified. The loss and change of habitat, biota and basic ecosystem functions are extensive.
8–10	F	Critically modified. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota.

All the components add up to a total score of 10; where a score of 0 indicates that the wetland has not been modified and is in a natural state, and an impact score of 10 means the total opposite, i.e. that the wetland has been completely modified. These impact scores were then used to assign the wetland to an ecological category or present ecological state (PES), as shown in Table 3.

6.2.2 Amphibian species diversity

Amphibian diversity was used as an indicator of biodiversity owing to the significant role amphibians play as bioindicators of environmental health (Saber et al., 2017). Frog calls are species-specific, and observers can use calls to locate and identify different species of frogs easily and reliably within a study area (Tarrant, 2021). Most species of frogs use calls to attract mates and establish breeding habitats (Du Preez & Carruthers, 2009). Passive acoustic monitoring (PAM) allows for the automated recording of the soundscape using equipment designed for biodiversity monitoring (Browning *et al*., 2017). Using song meters (SM) for frog monitoring provides long-term data without needing to visit the site as regularly and is therefore more cost-effective (Browning *et al*., 2017). Recordings were set to be taken from sunset to sunrise at each of the placement sites which were most representative of the area (Tarrant, 2021). Recordings were listened to manually to confirm the presence of *H. pickersgilli* as well as other frog species. The data were stored digitally and analysed statistically using Audiocity® (Tarrant, 2021).

In addition, the expected amphibian species diversity was determined using the mobile application *Frogs of Southern Africa* (Du Preez & Carruthers, 2015) for each area. The expected number of amphibians for each area was then compared to the actual number of amphibian species observed to provide as an indication of habitat health impact on amphibian species diversity.

6.2.3 Socio-ecological rehabilitation

Through the TAP PRF-RP, rehabilitation was used to improve the state of the socio-ecological system (Figure 6). The following interventions were included:

Social

Environmental education. Environmental education programmes were implemented at schools in the study areas.

Conservation conversations. Conversations were held with community members to build knowledge and understanding of the importance of wetlands and related biodiversity.

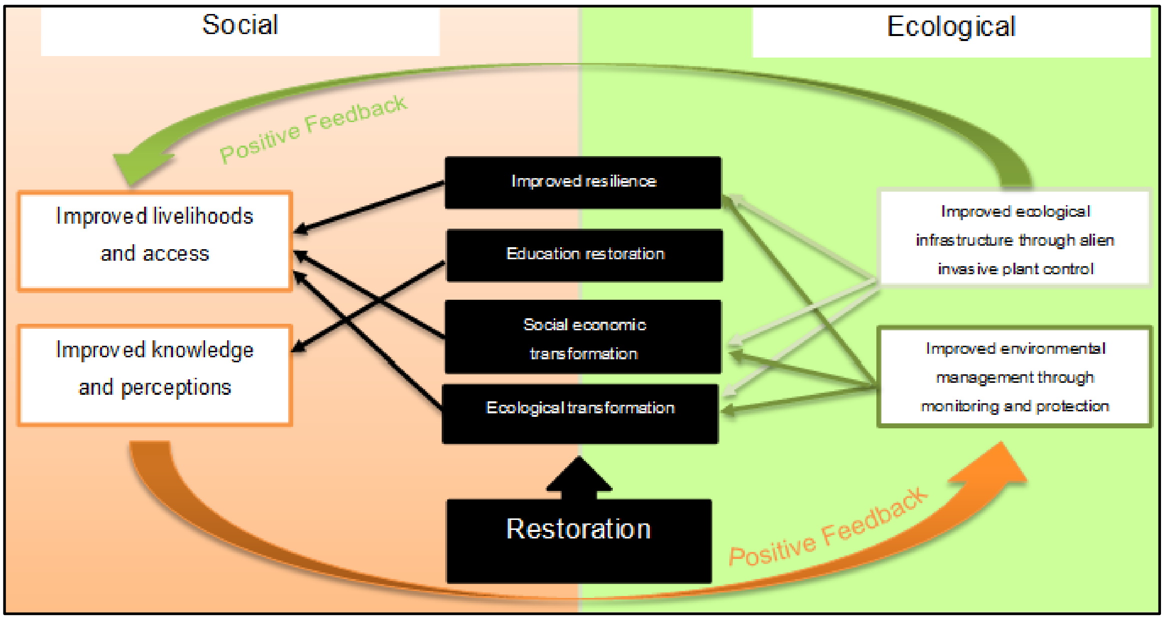

Figure 11: Socio-ecological restoration model (adapted from Kibler *et al.*, 2018).

Skills and capacity development. Selected community members were upskilled through formal learning programmes to provide essential skills for performing specific functions to support restoration activities.

Employment. Selected community members were employed by the Endangered Wildlife Trust TAP as biodiversity protection officers and environmental compliance officers at the project sites to perform specific ecological restorative functions such as alien invasive plant eradication and environmental monitoring.

Ecological

Alien invasive plant control. Alien invasive plants were eradicated and managed within the wetland and riparian areas of the study sites. This work was implemented by the Endangered Wildlife Trust TAP with funding from the Department of Forestry, Fisheries and Environment between 2016 and 2021.

Environmental monitoring. Environmental monitoring was implemented by EWT biodiversity protection officers to determine changes in the ecological infrastructure.

Environmental compliance. Environmental compliance situational assessments were conducted by environmental compliance officers and response systems were put in place to address non-compliance issues.

To compare the two sites, the socio-ecological restoration effort was calculated as follows:

$$\text{Socio-ecological restoration effort} = \frac{\text{(social intervention outputs/number of active years)+(ecological intervention outputs/number of active years)}}{2}$$

6.3 STATISTICAL ANALYSIS

An explanatory sequential mixed methods approach was used to analyse the data (Bowen *et al*., 2017). Qualitative data were converted to quantitative data to merge the data sets and facilitate the analysis of the data. Attitude data from the two sites were compared using analysis of variance (ANOVA). ANOVA is a test to determine whether data from two independent groups are statistically different from each other. A one-way ANOVA test is used to compare two means from two unrelated or independent groups using an F-distribution. An F-distribution is a function of the ratio of two independent variables, each of which has a chi-square distribution and is divided by its number of degrees of freedom (Merriam-Webster, 2022), resulting in an F-value. The F-value also determines the P-value (Statistics How To, 2022). The P-value is the probability of a result being the same or different between groups (Statistics How To, 2022). A null hypothesis for a test would indicate that the two means from the two groups are equal, while a significant result would mean that the two means from the two groups are unequal (Statistics How To, 2022). The formula for ANOVA is $F = \frac{MSE}{MST}$

Where F = ANOVA coefficient

MST = Mean sum of squares due to treatment

MSE = Mean sum of squares due to error

The software used included R statistic software and the following packages: car (Fox & Weisberg, 2019), ggplot2 (Wickham, 2016) and Rmisc (Hope, 2022).

The chi-square statistic (Chi-square Test Calculator, 2022) was used to test relationships between categorical variables within the community-based land engagement surveys and amphibian surveys. A null hypothesis outcome of the chi-square test indicates that there is no association between the categorical variables in a population and that they are independent. The formula for the chi-square statistic is as follows:

$$x^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

Where f_o = the observed frequency (the observed counts in the cells)

and f_e = the expected frequency if NO relationship existed between the variables

6.4 VALIDITY AND RELIABILITY

In quantitative research, reliability and validity are often used to describe quality assurance, whereas, in qualitative research, the term trustworthiness is used (Maree, 2016). Because this was a mixed method study, reliability and validity are discussed for the quantitative data and the trustworthiness dimensions are discussed for the qualitative data.

Quantitative

The reliability and validity measures refer to the questionnaires and surveys used in this study. However, it is essential to note that when measuring social or psychological characteristics like attitudes, for example, reliability may be lower (Leedy & Ormrod, 2015; Maree, 2016).

According to Leedy and Ormrod (2015), reliability refers to the consistency of the results obtained using a specific measurement instrument within a system or context that has not changed. The data were processed into “yes”, “neutral” and “no” categorical data so that Cronbach’s alpha coefficients could be used to check the reliability of the data. Based on Cronbach’s alpha coefficients, the reliability of data collected from questionnaires was calculated at 0.77, indicating that the data were reliable (Maree, 2016).

Validity looks at the level at which the instrument used measures what it is required to measure (Leedy & Ormrod, 2015). The validity of an instrument can take several forms (Leedy & Ormrod, 2015; Maree, 2016):

Face validity – the data collection instruments used in this study were reviewed and assured by peers at the Endangered Wildlife Trust and experts in the field.

Content validity – content was assured through a study proposal which was approved by peers and experts in the field.

Construct validity – was assured through the standardisation of the instrument using exploratory factor analysis.

Qualitative

Trustworthiness refers to scientific inquiry that can "demonstrate truth value, provides the basis for applying it, and allows for external judgements to be made about the consistency of its procedures and the neutrality of its findings or decisions" (Erlandson *et al*., 1993; Janesick, 2000). Several authors (Denzin & Lincoln, 2005; Lincoln & Guba, 1985; Maree, 2016; Shenton, 2004) recommend including the following elements to increase trustworthiness (reliability) in a qualitative study:

Credibility (internal validity). This study used questionnaires based on existing frameworks and utilised independent fieldworkers to conduct interviews and transcribe data.

Transferability (external validity). In this study, a random sampling method was used in two target communities. Fieldworkers conducted data collection using questionnaires and methods as described by the researcher and approved by the Departmental Research and Innovation Committee, the UNISA-CAES Health Research Ethics Committee and the Endangered Wildlife Trust to ensure rigour. All documents of processes followed and the data captured represent an audit trail that enables the transferability of the study.

Dependability (reliability). All data capture followed a predetermined and approved process. All interviews were documented and processes were reported and reviewed by applicable authorities.

Confirmability. Questionnaires were used to collect qualitative data on social aspects of the research. These were administered by field staff independent of the researcher.

The trustworthiness of this research was also ensured through triangulation involving different methods and sources to check the integrity of or extend inferences drawn from the result of the data collected (Ritchie, 2003). Triangulation is an accepted approach when using mixed methods (Denzin, 1994) and, as such, the following triangulation methods were used (Decrop, 2004):

Data triangulation involves the use of a variety of data sources. In the current study, the data collected and the inferences made were corroborated by similar studies to support inferences and conclusions (Carter *et al.*, 2014; Lincoln & Guba, 1985).

Method triangulation involves using multiple methods to study a single problem – thus, a combination of qualitative and quantitative methods was used. These included qualitative data on ecological factors and quantitative data from questionnaires completed with the use of fieldworkers who might have related differently to the participants than the researcher.

6.5 STUDY LIMITATIONS

Certain limitations to this study were identified, which include the following:

Sample size: Only two study sites were included in this study, which limited statistical correlation to conclusively validate findings.

Study site variability: The two study sites differ in terms of area (hectares) which limits statistical correlation to conclusively validate findings.

Variables: Multiple variables affect the socio-ecological contexts within communities. Such variables included in this study were selected within the scope and frame of the study, but it is recognised that there may be other variables that have an impact on socio-ecological contexts.

6.6 ETHICS

Ethical approval was granted by two authorities, UNISA and the Endangered Wildlife Trust. Details of these approvals are outlined below:

6.6.1 UNISA

Committee:	UNISA-CAES Health Research Ethics Committee
Date granted:	20 January 2022
Reference number:	2022/CAES_HREC/010 (Annexure 3)

6.6.2 Endangered Wildlife Trust

Committee:	Endangered Wildlife Trusts Ethics Committee (EWTECH)
Date granted:	31 July 2021
Reference:	EWTEC2021_008 (Annexure 4)

CHAPTER 7
RESULTS AND DISCUSSION

7.1 INTRODUCTION

The results of this study are presented according to the outcomes of the community land engagement surveys, attitude assessments and wetland health assessments. The outcomes of the community land engagement surveys were processed according to demographics, sense of place, perceived threats to sense of place (including sense of positivity and living memory of the area), natural resource use, service delivery and observed biodiversity.

In terms of the attitude surveys, data were processed according to average attitude score and habitat health as a wetland health score represented as a percentage. The total number of amphibian species present at each site was recorded and all data sets for each site were compared statistically using ANOVA and the chi-square statistic to determine statistical significance between sites.

Following the results, a discussion section has been formulated to deliberate the results to determine whether there is a link between the ecological state and biodiversity of the environment and a community's land use and attitude towards the environment.

7.2 RESULTS

7.2.1 Community land engagement surveys

7.2.1.1 Demographics

A total of 223 (n) community land engagement surveys were completed at the ARW. Fifty-four per cent of the respondents were female. The average age of respondents was 40, and 31% of the respondents were born in the ARW. In terms of employment, 30% of ARW participants were employed or self-employed, while 70% were unemployed. The average number of people per household was six.

In the IW area, a total of 98 (n) pre and post community land engagement surveys were completed. Sixty-two per cent of these respondents were female. The average age of respondents was 33 and only 3% of respondents were born in the IW area.

Twenty per cent of IW participants were employed or self-employed while 80% were unemployed. The average number of people per household was four (4).

Demographically, ARW and IW are similar in that most respondents were female and there was a high percentage of respondents who were unemployed. The average age of respondents was slightly higher in the ARW than in the IW.

7.2.1.2 Sense of place

The community land engagement surveys showed that 85% of respondents from the ARW area enjoyed the place where they lived, while only 16% of respondents from IW felt they enjoyed where they lived. Figures 12 and 13 show the frequencies for the various positive reasons given by participants from ARW and IW, respectively.

A chi-square test was used to determine a statistical association between site and positivity. The null and alternative hypotheses were:

> $\mathbf{H_0}$ = there is **no association** between the study site and positivity.
> $\mathbf{H_a}$ = there **is an association** between the study site and positivity.

Table 5 shows *p* = *<0.0001* demonstrating that there is a significant association between the study site and positivity.

Table 5: Number of respondents who felt positive about the area they live in.

	Positivity			Descriptives		
	No	**Neutral**	**Yes**	x^2	df	p
ARW	27	7	189	155.68	2	**< 0.0001**
IW	82	0	16			

Source: Chi-square Test Calculator (2022)

Positivity towards the environment on the part of ARW respondents is much greater than that of their IW counterparts, with the reasons for positivity differing greatly between the two sites. For example, the respondents from the ARW indicated that one of the reasons they enjoy where they live is because it is quiet and peaceful. With regard to the IW, accessibility and savings are cited as reasons why they enjoy living there. The diversity of reasons is also far greater regarding the ARW than the IW, indicating that there are more benefits to living in the ARW than in the IW.

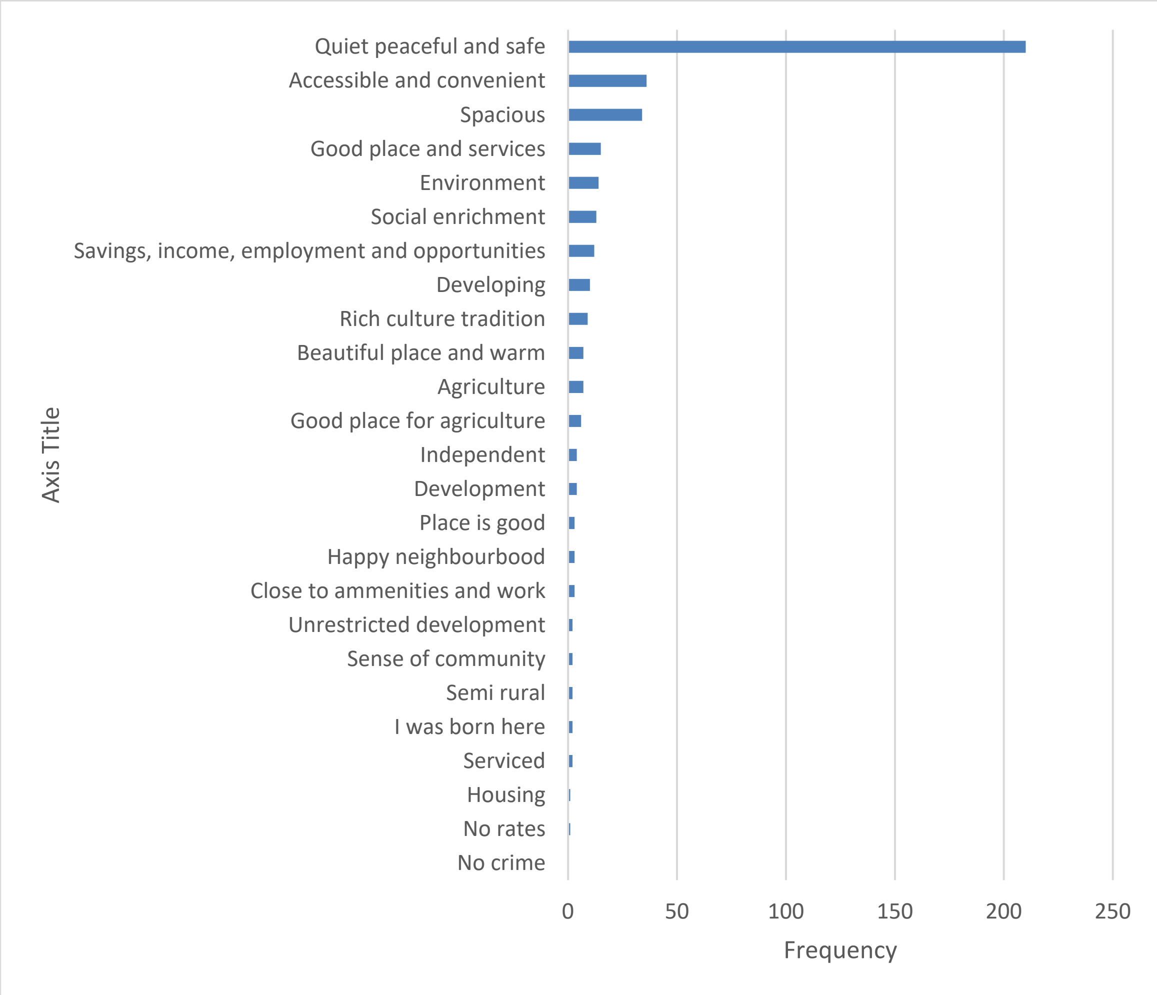

Figure 12: Positivity frequencies for ARW.

In the ARW, 75% of respondents stated that they noticed a change in the local water sources, while 93% of respondents from the IW stated that they had observed a change in the local water source. Respondents in the ARW cite changes relating to deteriorating water quality (15%) and quantity (10%), while those in the IW stated that the quality of water (21%) in their local water sources had deteriorated. Only 1% of IW respondents stated that the quantity of water in their local water source had changed.

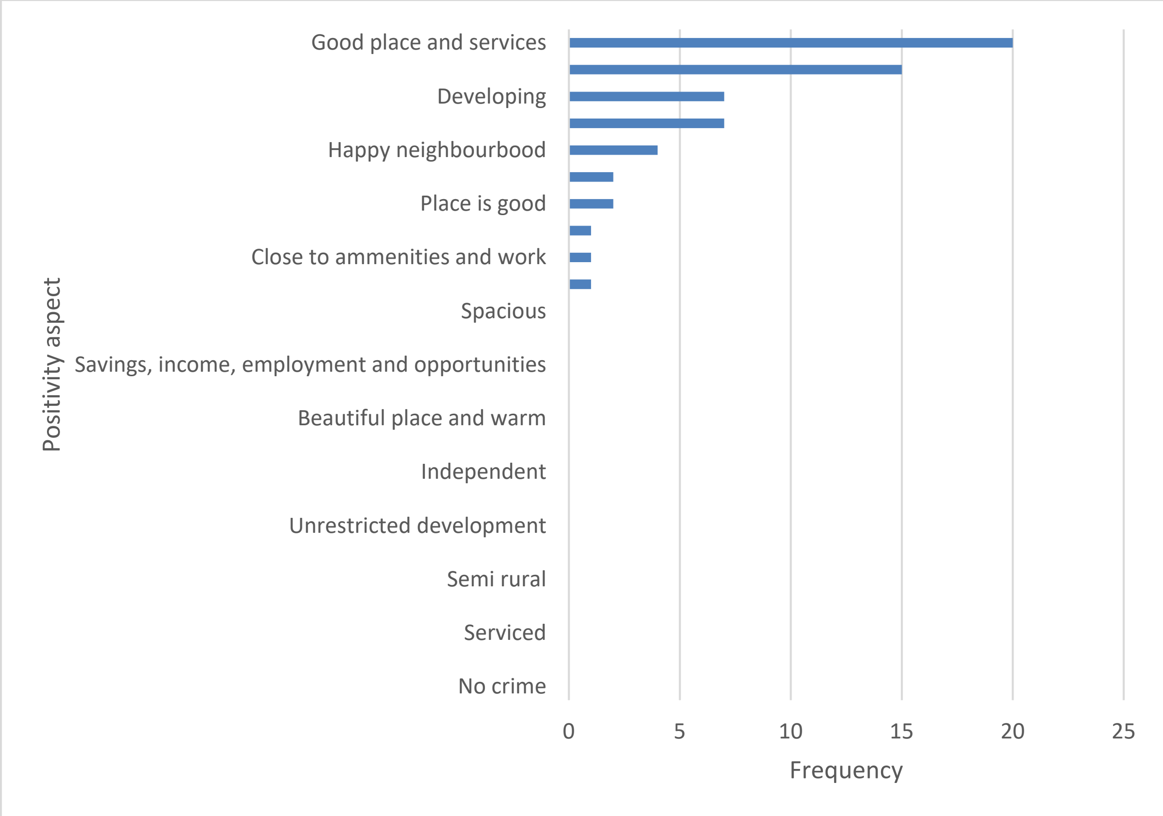

Figure 13: Positivity frequencies for IW.

Statistically, a chi-squared test was used to determine whether there was an association between the study site and a change in the local water resources. The following hypotheses were formulated:

> **H_0 =** there is **no association** between the study site and an observed change in local water**.**
>
> **H_a** = there **is an association** between the study site and an observed change in local water.

Table 6 shows *p* = < *0.0001* demonstrating a significant association between site and changes in local water sources.

Table 6: Number of respondents who observed a change in their local water resources.

	Change in Local Water			Descriptives		
	No	Neutral	Yes	x^2	df	p
ARW	14	41	168	18.739	2	**< 0.000085**
IW	5	1	92			

Source: Chi-square Test Calculator (2022)

7.2.1.3 Threats

The main threats perceived by the respondents to their site appear to be similar for both sites. In the ARW, crime (29%) was cited as the biggest threat by respondents followed by no threat (23%) and then poor service delivery (22%) (Figure 14). In the IW, crime was also ranked as the biggest threat (30%), followed by service delivery (15%), while 13% of respondents did not respond to the question (Figure 15).

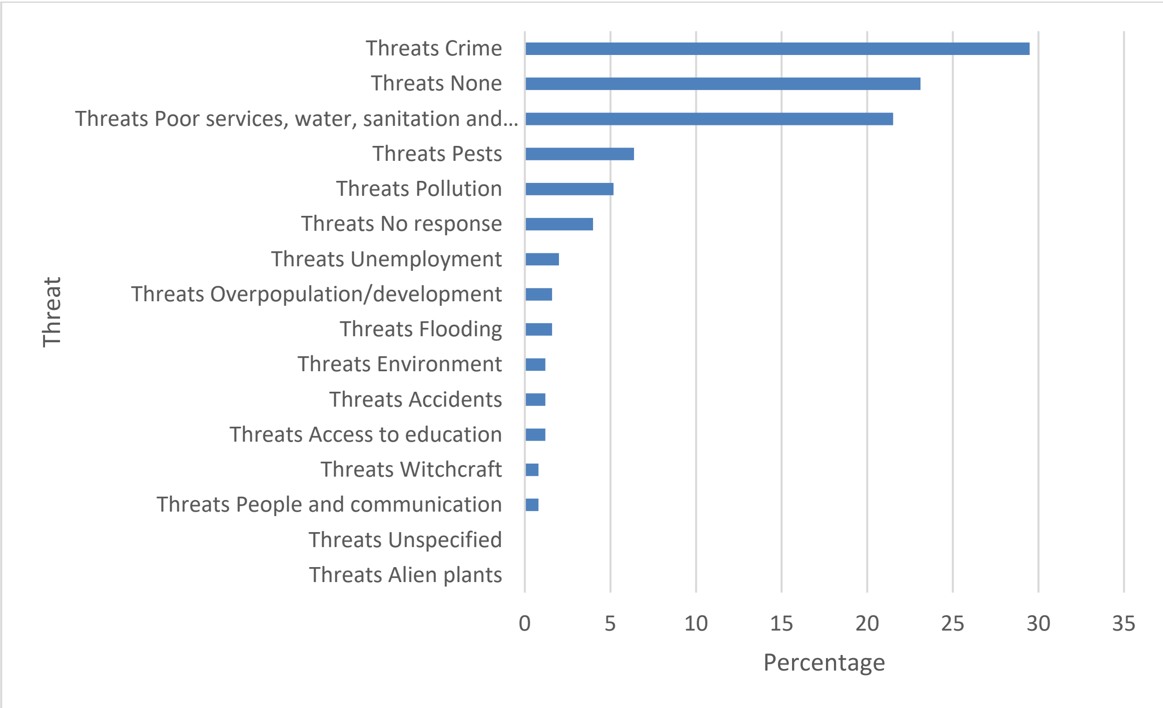

Figure 14: Factors that threaten the ARW site as perceived by respondents.

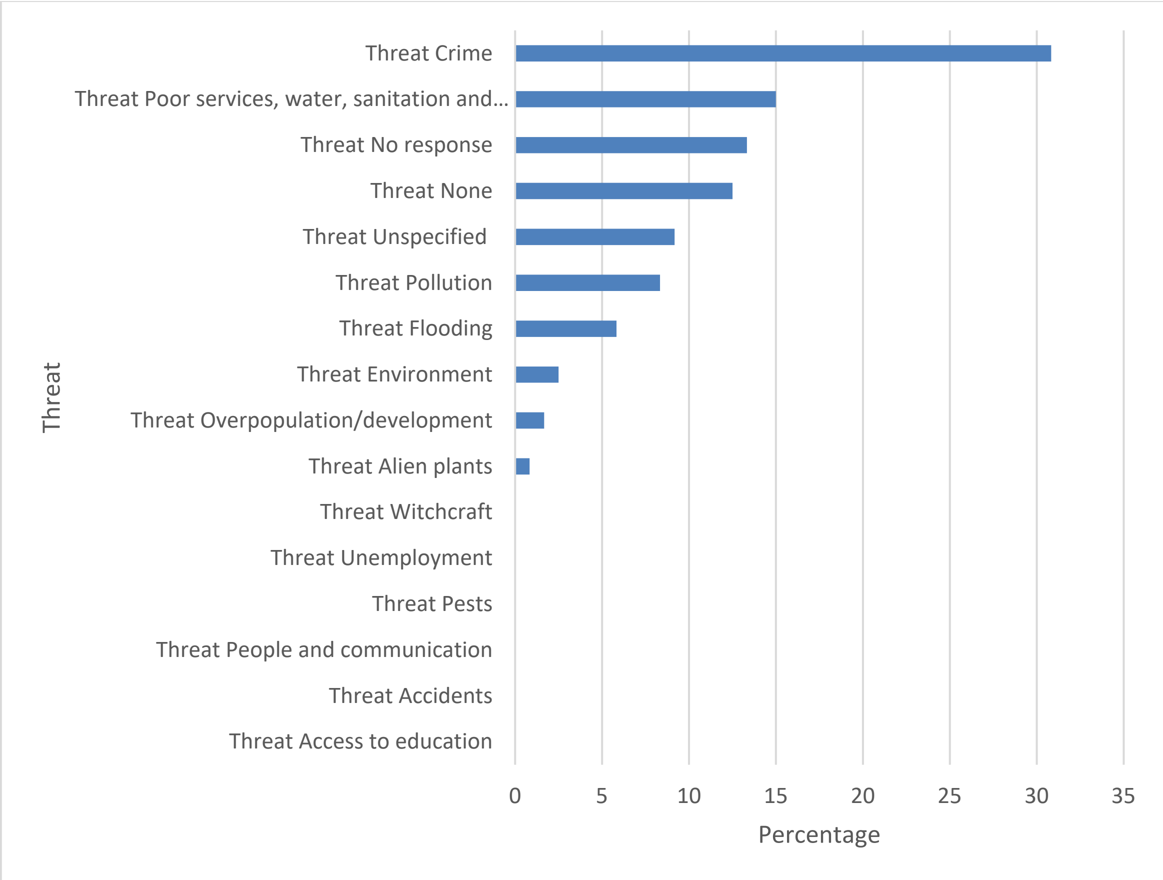

Figure 15: Factors that threaten the IW site as perceived by respondents.

A chi-square test was used to statistically determine a relationship between the study site and the perceived threat. The null and alternative hypotheses were formulated as follows:

H_0 = there is **no association** between the study site and perceived threat.

H_a = there **is an association** between the study site and perceived threat.

The results showed *p* = *>0.05* concluding that there is no association between the study site and perceived threat, as outlined in Table 7.

Table 7: Number of respondents who stated that the area in which they live is threatened.

	Perceived Threat		Descriptives		
	No	**Yes**	x^2	df	p
ARW	68	183	0.0657	1	**< 0.79**
IW	31	89			

Source: Chi-square Test Calculator (2022)

7.2.1.4 Service delivery

All respondents (100%) in the IW receive municipal water compared to 97% of respondents in the ARW. In the ARW, 35% of respondents stated that the municipality collects their waste in comparison to 25% of IW respondents. Figure 16 shows the different methods of waste management at each site. In ARW, 56% of respondents burn their waste, followed by 35% of respondents stating that waste is removed through municipal collection.

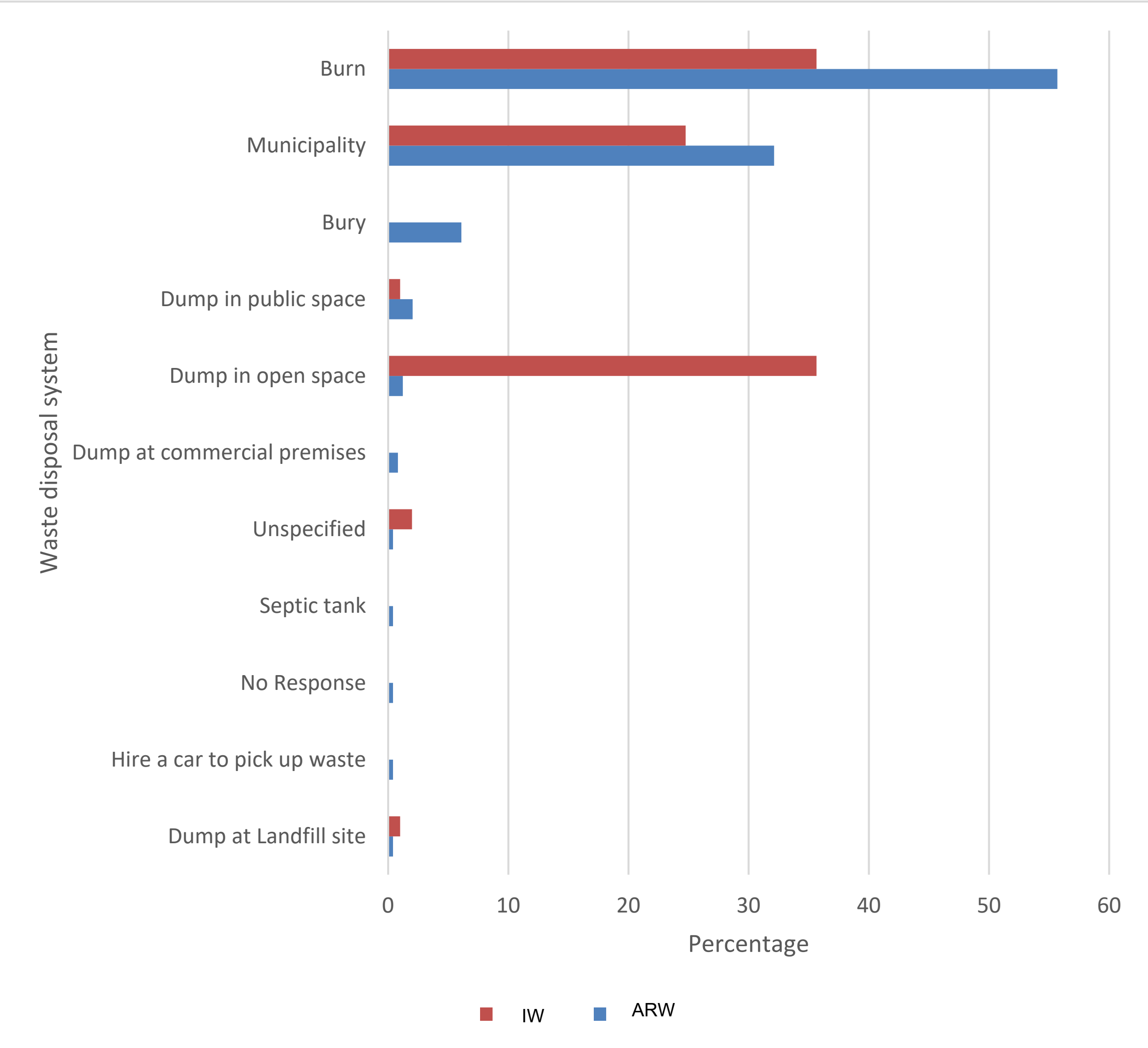

Figure 16: Methods of waste management for ARW and IW.

In the IW, 36% of respondents burn waste and 36% of respondents dump waste in an open space.

A chi-squared test was used to determine an association between the study site and waste and water service. For waste service, the following null and alternative hypotheses were formulated:

H_0 = there is **no association** between the study site and municipal waste service.

H_a = there **is an association** between the study site and municipal waste service.

Table 8 shows *p = >0.05* demonstrating that there is no association between the study site and waste service.

Table 8: Number of respondents who received municipal service.

	Waste Service		Descriptives		
	No	**Yes**	x^2	df	p
ARW	144	79	2.6204	1	**< 0.7445**
IW	73	25			

Source: Chi-square Test Calculator (2022)

In terms of municipal water service, the following null and alternative hypotheses were formulated:

H_0 = there is **no association** between the study site and municipal water service.

H_a = there is **an association** between the study site and municipal water service.

Table 9 *shows p = >0.05* indicating that there is no association between site and municipal water service provision.

Table 9: Number of respondents who receive municipal water service.

	Water Service		Descriptives		
	No	**Yes**	x^2	df	p
ARW	6	217	2.6204	1	**< 0.1005**
IW	0	98			

Source: Chi-square Test Calculator (2022)

7.2.1.5 Natural resource use

On average, 36% of ARW respondents reported using locally sourced resources (excluding alien species) for various uses, while only 8% of IW respondents reported using local resources (excluding alien species). Figure 17 shows the various resource use components, indicating that 56% of ARW respondents practise farming in their community while only 6% of respondents in IW do so. In the ARW, 36% of respondents use local water sources while only 5% of IW respondents used water from a local source.

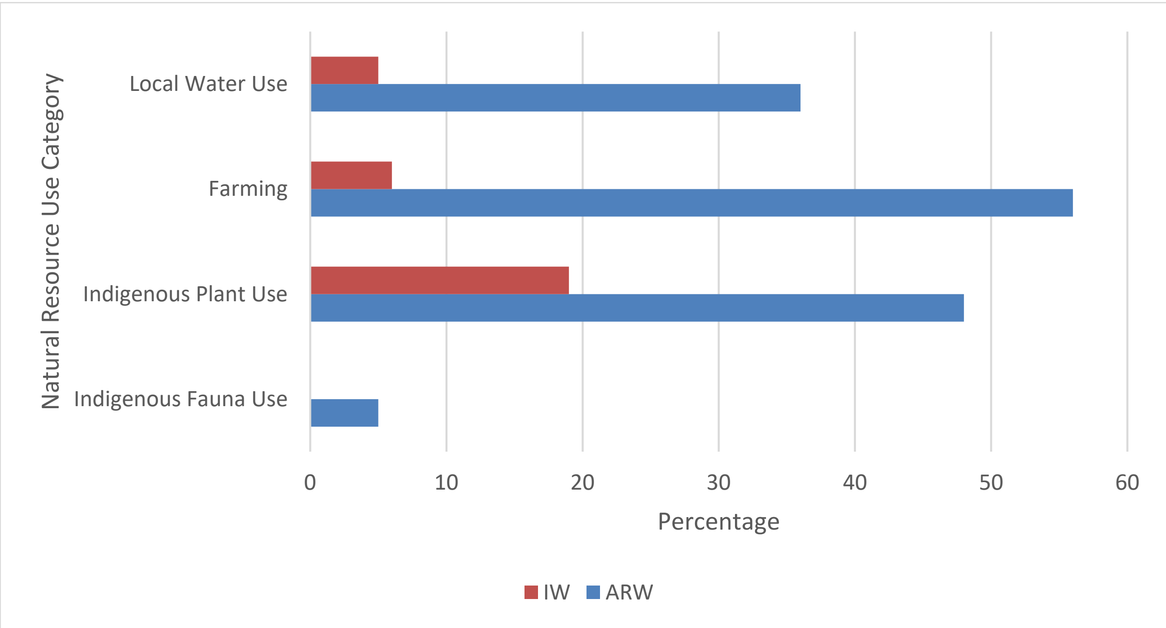

Figure 17: Percentage of respondents who use natural resources from ARW and IW

A chi-squared test was used to determine an association between the study site and natural resource use categories. The results show that there is an association between the study site and indigenous animal use (Table 9), indigenous plant use (Table 10), farming (Table 11) and local water use (Table 12).

Indigenous animal use

The null and alternative hypotheses formulated include:

> **H_0** = there is **no association** between the study site and indigenous animal use.
>
> **H_a** = there is **an association** between the study site and indigenous animal use.

Table 10 shows *p = <0.0001* indicating that there is a significant association between the study site and indigenous animal use.

Table 10: Number of respondents who use indigenous animals in ARW and IW.

	Resource Use: Indigenous Animals			Descriptives		
	No	No response	Yes	x^2	df	p
ARW	94	117	12	23.81	2	**< 0.0001**
IW	69	29	0			

Source: Chi-square Test Calculator (2022)

In ARW, indigenous animals are mainly being used for food (49%) and ritual (38%) purposes.

Indigenous plant use

Null and alternative hypotheses include:

> **H_0** = there is **no association** between the study site and indigenous plant use.
> **H_a** = there is **an association** between the study site and indigenous plant use.

Table 11 shows *p = <0.0001* concluding that there is a significant association between the study site and indigenous plant use.

Table 11: Number of respondents who use indigenous plants in ARW and IW.

	Resource Use: Indigenous Plants			Descriptives		
	No	No response	Yes	x^2	df	p
ARW	113	3	107	25.703	2	**< 0.0001**
IW	79	0	19			

Source: Chi-square Test Calculator (2022)

In ARW indigenous plants are being used for medicine (63%) and rituals (30%), while in IW indigenous plants are being used for medicinal (52%) and food (30%) purposes.

Farming

The null and alternative hypotheses formulated include:

> **H_0** = there is **no association** between the study site and farming practices.
> **H_a** = there is **an association** between the study site and farming practices.

Table 12 shows p = *<0.0001* concluding that there is a significant association between the study site and farming practices.

Table 12: Number of respondents who farm in the area.

	Farming Practices		Descriptives		
	No	**Yes**	x^2	df	p
ARW	98	125	68.22	1	**< 0.0001**
IW	92	6			

Source: Chi-square Test Calculator (2022)

Water use

The null and alternative hypotheses formulated include:

H_0 = there is **no association** between the study site and local water use.

H_a = there is **an association** between the study site and local water use.

Table 13 shows p = *<0.001* demonstrating that there is a significant association between the study site and local water use.

Table 13: Number of respondents who use local water.

	Local Water Use		Descriptives		
	No	**Yes**	x^2	df	p
ARW	142	81	32.61	1	**< 0.0001**
IW	93	5			

Source: Chi-square Test Calculator (2022)

7.2.1.6 Biodiversity

Overall, observations of indigenous flora and fauna species were higher in the ARW compared to the IW. Most observations made referred to mammals (132) in ARW, followed by reptiles (82) and amphibians (41). In the IW, most observations made referred to reptiles (58), followed by mammals (46) and amphibians (27) (Figure 18). Most notably, the majority of mammals observed in the ARW were vervet monkeys, while rats were the most common mammal observed in the IW.

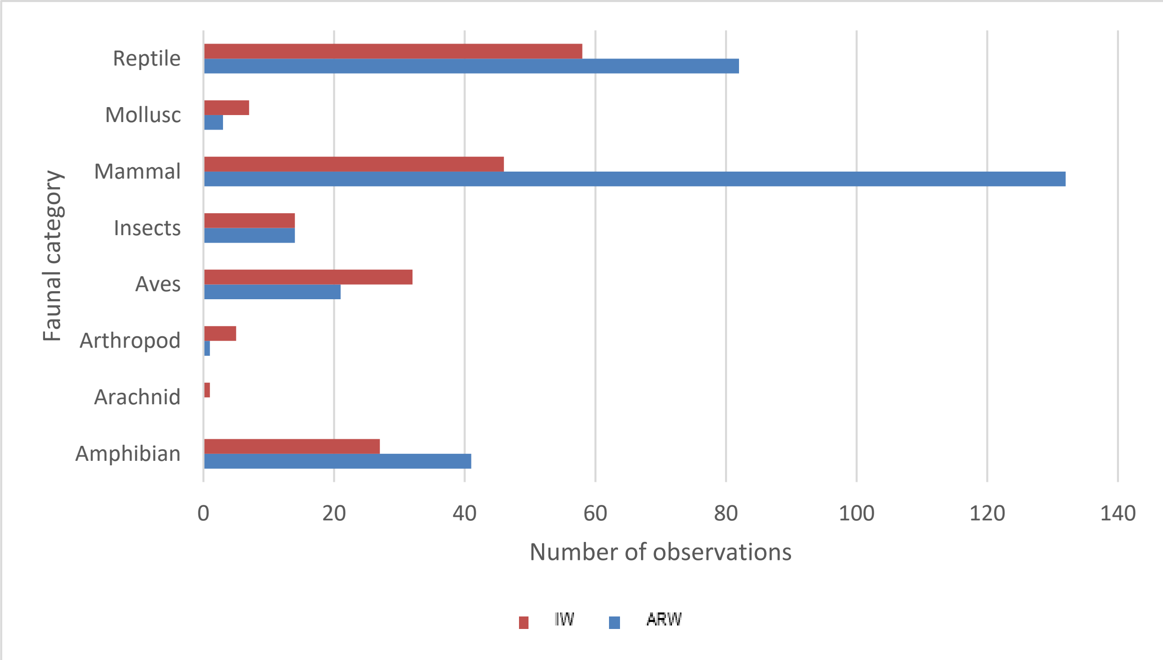

Figure 18: Number of observations based on faunal category compared for ARW and IW.

Overall, the number of indigenous flora and fauna species recorded was higher in the ARW than in the IW (Table 14).

Table 14: Number of indigenous flora and fauna species observed by respondents in ARW and IW.

Site	Indigenous Flora	Indigenous Fauna
ARW	19	21
IW	5	8

Statistically, a chi-squared test was used to determine whether there is an association between indigenous species and alien species observations. The null and alternative hypotheses formulated include:

> H_0 = there is **no association** between the study site and indigenous biodiversity observations.
>
> H_a = there is **an association** between the study site and indigenous biodiversity observations.

Table 15 shows $p = <0.05$ concluding that there is an association between the study site and indigenous biodiversity observations.

Table 15: Number of indigenous species observations by respondents.

	Biodiversity Observations		Descriptives		
	Indigenous Species	**Alien Species**	x^2	df	p
ARW	294	62	4.0103	1	**< 0.045222**
IW	186	59			

Source: Chi-square Test Calculator (2022)

Respondents from the ARW and IW experience problems with animals (Figure 19) of which a third are indigenous animals (Table 16). Twenty per cent of the indigenous problem animals in the ARW are vervet monkeys, while snakes are seen as a problem in the IW according to 18% of the respondents. Coincidentally, rats and frogs are the second and third listed problem animals in IW, which are the main food source for snakes. In the ARW, snakes are also listed as the second-highest problem animal, followed by rats.

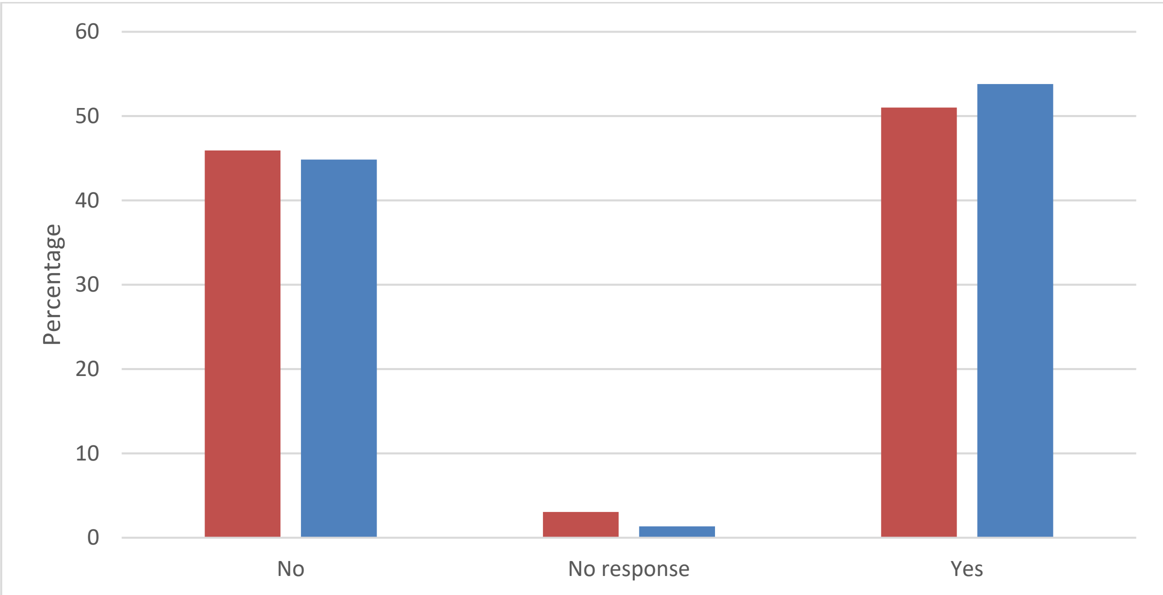

Figure 19: Percentage of respondents who do or do not experience problems with animals in ARW (blue) and IW (red).

Table 16: Percentage of respondents who experience problems with animals based on animal category for ARW and IW.

Site	Amphibians	Birds	Domestic Animals	Insects	Livestock	Mammals	Reptiles	Unspecified
ARW	2	2	7	8	12	43	13	13
IW	9	0	4	5	0	36	23	23

Statically, a chi-squared test was used to determine an association between the study site and problem animals. The null and alternative hypotheses formulated include:

H_0 = there is **no association** between the study site and problem animals.

H_a = there is **an association** between the study site and problem animals.

Table 17 shows *p* = *>0.05* indicating that there is no association between the study site and problem animals.

Table 17: Number of respondents who experience problems with animals

	Problem Animals		Descriptives		
	No	**Yes**	x^2	df	p
ARW	100	120	0.0978	1	**< 0.7445**
IW	45	50			

Source: Chi-square Test Calculator (2022)

7.2.2 Attitude surveys

A total of 147 (n) pre and post attitude surveys were conducted with residents from the ARW, with an average attitude score of 10.8. In the IW, a total of 140 (n) pre and post surveys were conducted with residents, with an average attitude score of 7.5 (Figure 20).

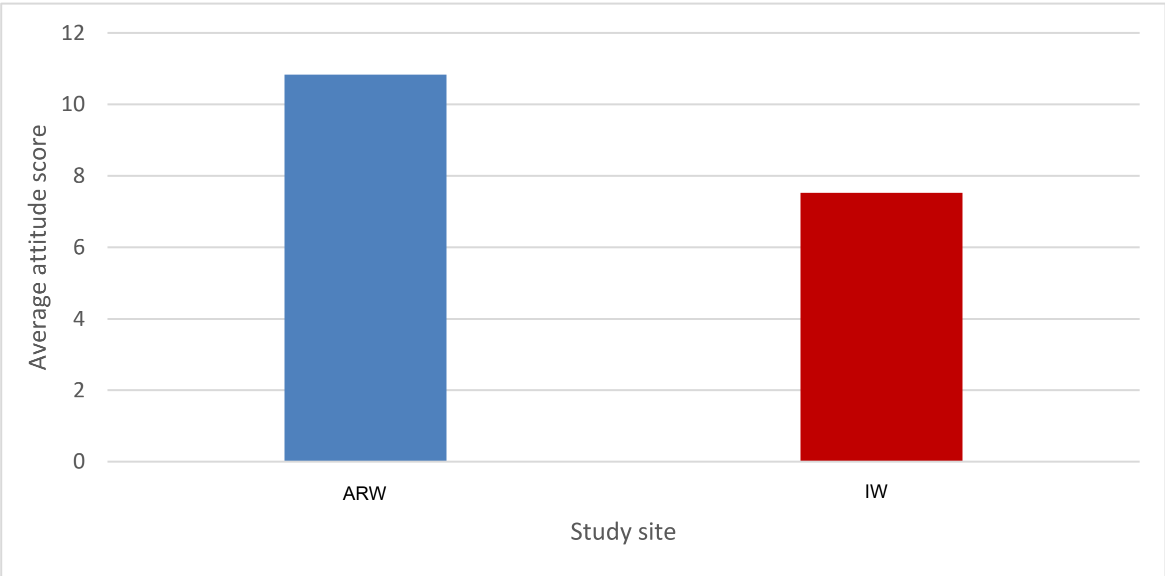

Figure 20: Average attitude scores for ARW and IW.

Fifty-four per cent of respondents from the ARW scored above average in their environmental attitude scores (a score of 10 and above), while 29% of respondents from the IW scored above average.

Compared pre and post socio-ecological intervention environmental attitude scores in terms of location showed an improvement in attitude at both sites (Table 18).

Table 18: Comparison of pre and post socio-ecological restoration intervention environmental attitude scores the two study sites

Site	Pre	Post	Average
ARW	10.54	11.90	10.92
IW	4.66	8.60	7.53

Statistical analysis: assumption checking

Homoscedasticity:

> **H_0**: the variances of attitude scores are equal in each group.
> **H_a**: the variances of attitude scores are unequal in each group.

Results: F = 2.0184; df = 3, 23; p = 0.1115

Therefore, H_0 is accepted with *p = >0.05* and it is assumed that the attitude scores in each group are equal (Figure 21 shows a similar variance).

Normal distribution of attitude scores:

> **H_0**: attitude scores follow a normal distribution.
> **H_a**: attitude scores do not follow a normal distribution.

Results: Figure 21 shows a symmetric distribution with of the attitude scores in each; hence H_0 is accepted as *p = >0.05* and the assumption of the normal distribution can be made in the ANOVA.

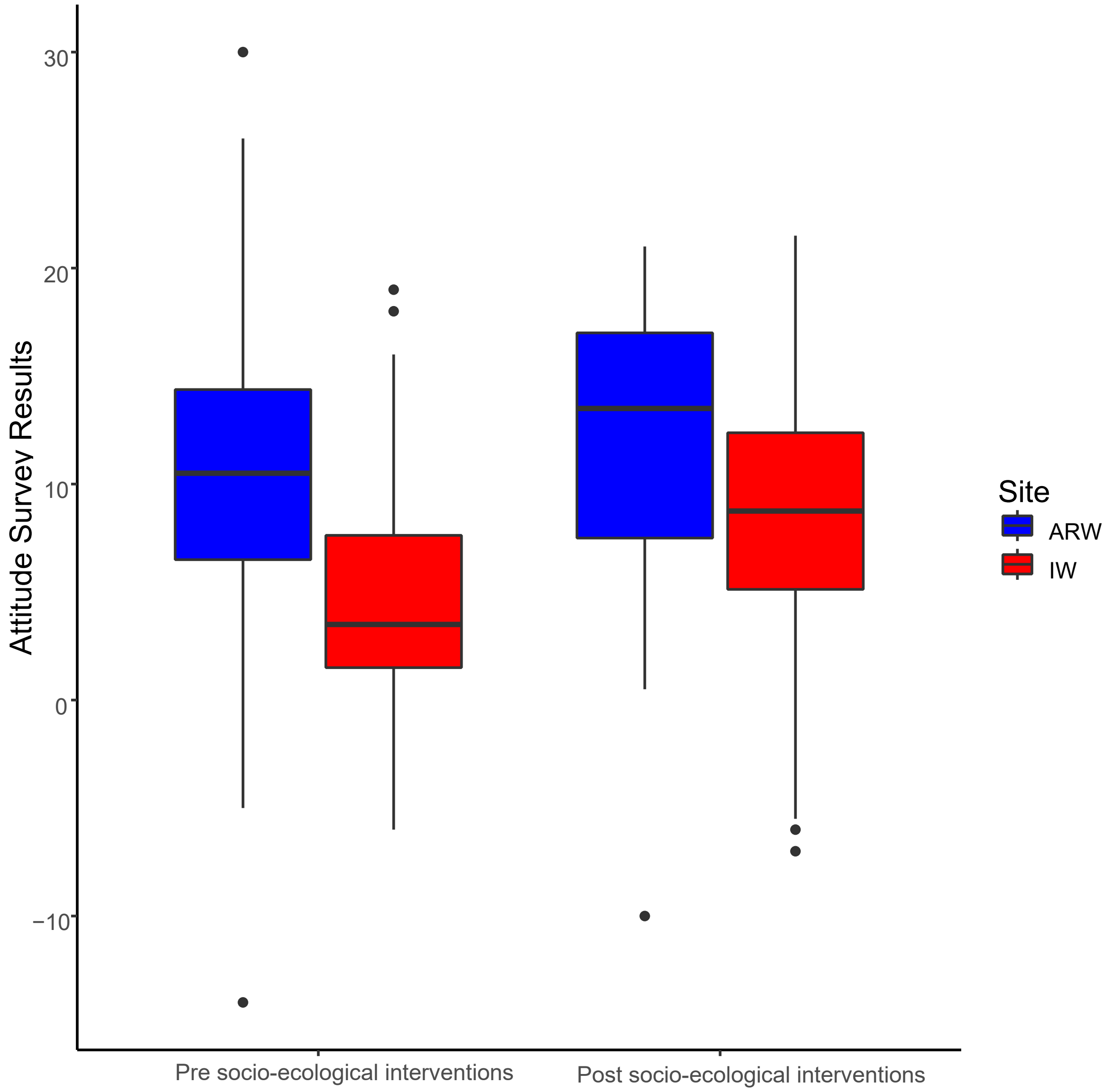

Figure 21: Attitude survey results, ARW and IW, showing equal variance and normal distribution.

Statistical hypotheses

H_0: there is no interaction effect between location and the year.

H_a : there is an interaction effect between site and year.

Results: F = 2.269; df = 1, 283; p = 0.13312. Therefore, H_0 is accepted with a P Value of 0.13312 and it can be concluded that there is no evidence of an interaction effect between location and year. This is illustrated in Figure 22 where ARW has consistently higher attitude scores and both sites show an increase in post socio-ecological interventions.

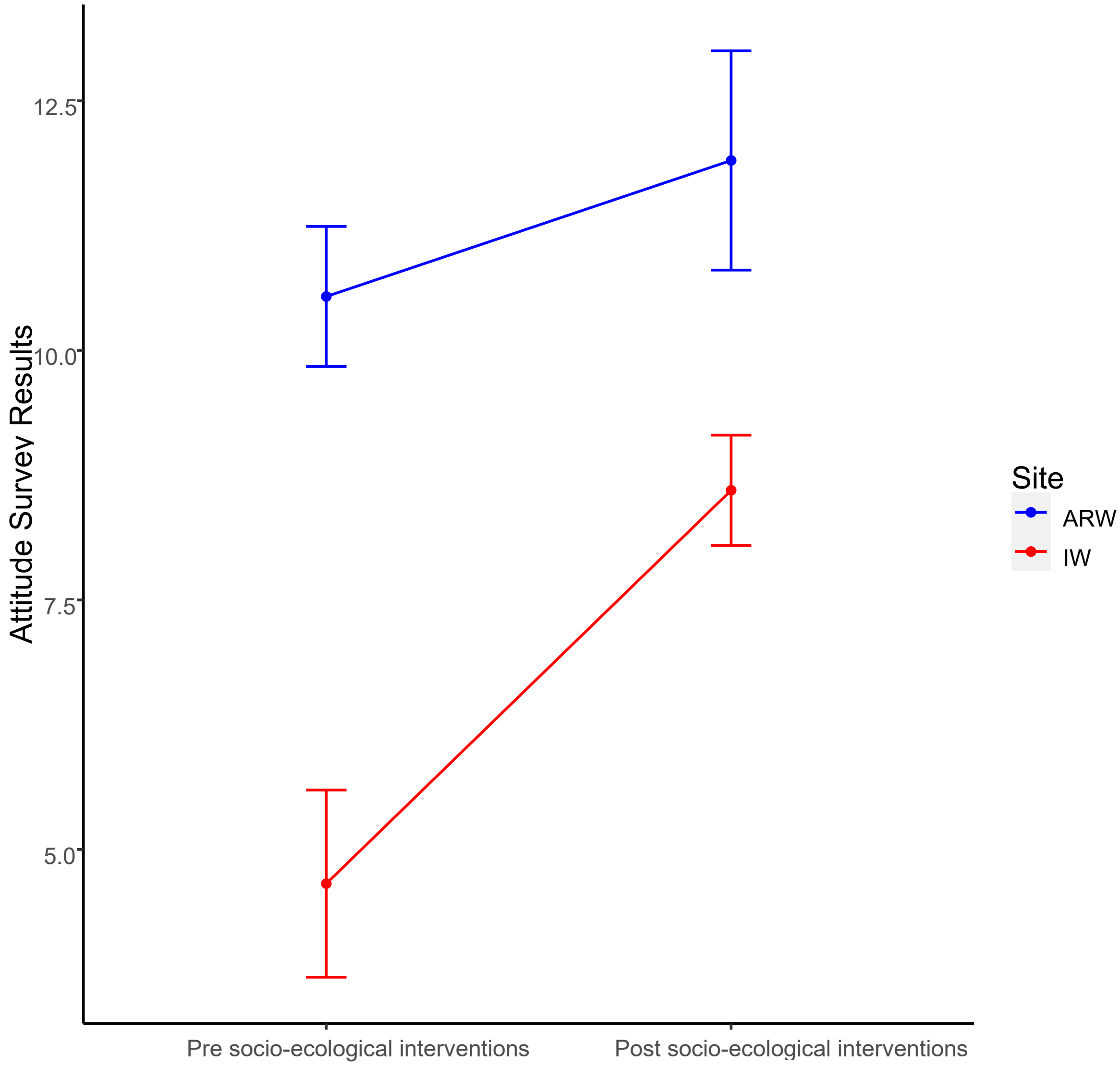

Figure 22: Attitudes scores for ARW showing a consistently higher score than IW pre and post socio-ecological interventions.

Therefore, a model with only location and year but no interaction effect is used:

$$Attitude = Location + Year$$

Null hypothesis: there is no difference in mean attitude scores between ARW and IW. Alternative hypothesis: there is a significant difference in mean attitude scores between ARW and IW. Results: F = 19.612, df = 1, 284; p < 0.001. Therefore, the null hypothesis is rejected concluding that there is a significant difference (*p= <0.001)* in mean attitude scores between ARW and IW.

Null hypothesis: there is no difference in mean attitude scores pre and post socio-ecological intereventions. Alternative hypothesis: there is a significant difference in mean attitude scores pre and post socio-ecological interventions. Results: F = 9.269, df = 1, 284; p = 0.00255. Therefore, the null hypothesis is rejected with p = *<0.01* and it is concluded that there is a significant difference in mean attitude scores pre and post socio-ecological interventions.

7.2.3 Wetland health surveys

Wetland health assessments were conducted in 2016, 2019 and 2022 at both sites, showing an average health score of 81% for the ARW and a present ecological state (PES) category of B, considered to be largely natural with few alterations. In the IW, the overall health score was 22% with a PES category of E, considered to be seriously modified.

In 2019, there was an improvement in the health score of the ARW owing to alien invasive plant clearing (Eco-Pulse Consulting, 2019a), but a decline in health score was observed in 2022 as a result of alien invasive plant clearing being stopped in 2020 (Table 19). At the IW site, a decline in the health score was measured between 2016 and 2022. The wetland health assessment conducted by Eco-Pulse Consulting (2019b) states that the clearing of alien invasive plants exposed soil and that poor hydrology and the limited availability of indigenous plants prevented the wetland system from recovering.

Table 19: Wetland health assessment results between 2016 and 2022 for ARW and IW.

Site	2016			2019				2022				Overall Change (2015–2022)
	Impact Score	Health Score	Health Percentage (%)	Impact Score	Health Score	Health Percentage (%)	Change (%)	Impact Score	Health Score	Health Percentage (%)	Change (%)	
ARW	1.84	8.16	81.60	1.79	8.21	82.10	0.50	2.08	7.92	79.20	-2.90	-2.40%
IW	7.68	2.32	23.20	7.84	2.16	21.60	-1.60	7.97	2.03	20.30	-1.30	-2.90%

A chi-squared test was used to determine an association between the study site and PES. The hypotheses formulated include:

> **H_0** = there is **no association** between the study site and the present ecological state.
>
> **H_a** = there is **an association** between the study site and the present ecological state.

Table 20 shows *p* = *<0.0001* concluding that there is an association between the study site and PES.

Table 20: Wetland health condition in relation to the percentage that is in good and poor condition.

	Wetland Health Condition		Descriptives		
	Good Condition	**Poor Condition**	x^2	df	p
ARW	81	19	69.68	1	**< 0.0001**
IW	22	78			

Source: Chi-square Test Calculator (2022)

7.2.4 Amphibian species diversity and habitat health

The calls of frog species recorded using song meters (SM) identified a total of 15 species at the two sites (Figure 23) between 2016 and 2022. The most common species represented across both sites are *Hyperolius tuberilinguis, Leptopelis natalensis, Hyperolius marmoratus*, *Sclerophrys gutturalis and Hyperolius pickersgilli* (Figure 23).

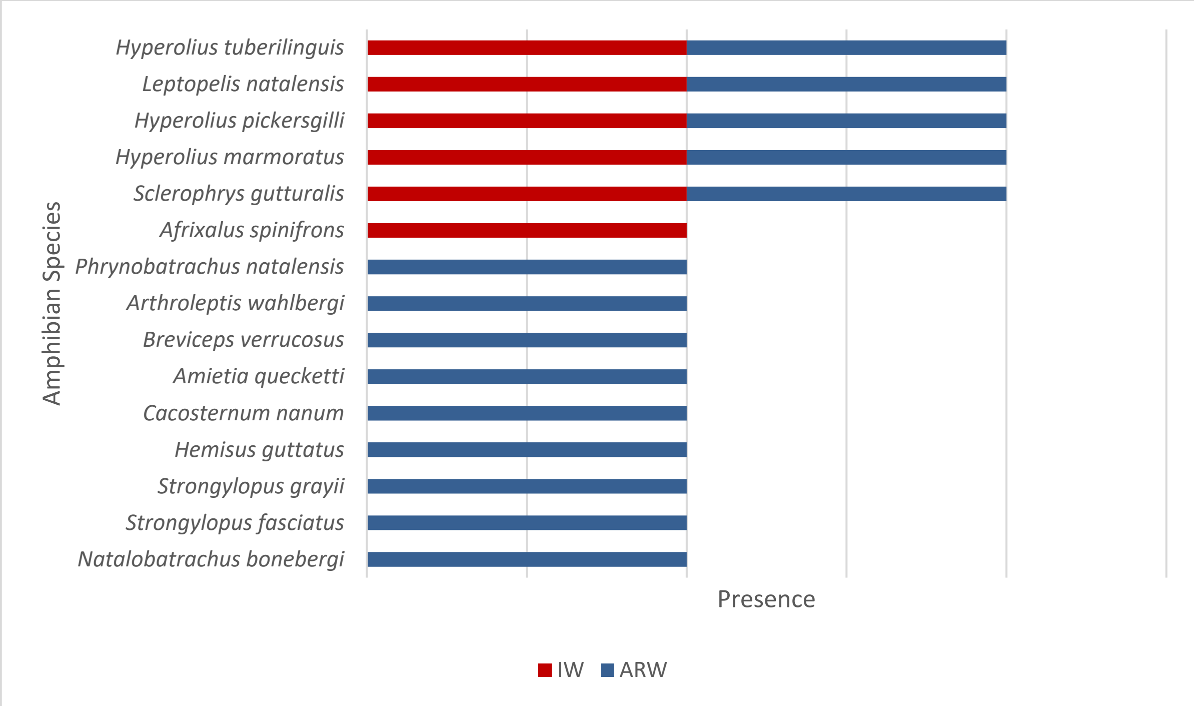

Figure 23: Amphibian species presence in ARW and IW during the total study period.

Overall, the ARW had the highest number of frog species, with a total of 14 species recorded, while six species were recorded at the IW site. To determine the total expected amphibian species diversity per area, data were sourced from the mobile application *Frogs of Southern Africa* (Du Preez & Carruthers, 2015) (Table 21).

Table 21: Expected amphibian species per area

Site	Expected number of amphibian species for the area
ARW	32
IW	38

Source: Du Preez and Carruthers (2015)

To determine a statistical association between the study site and the presence of amphibians, a chi-squared test was used. The null and alternative hypotheses formulated include:

> $\mathbf{H_0}$ = there is **no association** between the study site and the presence of amphibians.
>
> $\mathbf{H_a}$ = there is **an association** between the study site and the presence of amphibians.

Table 22 shows *p* = < 0.01 concluding that there is an association between the study site and the number of amphibians species.

Table 22: Amphibian species present/absent based on the expected number of amphibian species per site.

	Amphibian Presence		Descriptives		
	Present	**Absent**	x^2	df	p
ARW	14	32	6.6546	1	**< 0.00989**
IW	6	38			

Source: Chi-square Test Calculator (2022)

7.2.5 Socio-ecological restoration interventions

Through the TAP PRF-RP between 2016 and 2022, a total of 30 hectares of the IW and the associated riparian area was cleared and maintained free of alien invasive plants. This project was funded by the Department of Forestry, Fisheries and Environment Natural Resource Management Programme. Through this initiative, ten local community members were trained and employed as herbicide operators.

In addition, a local community member was employed as a full-time biodiversity protection officer in 2019 to work in the area in order to support sustainable vegetable gardening practices and conduct environmental education initiatives with schools and community members within the area. To date, four schools in the vicinity of this site have participated in environmental education activities, reaching a total of 711 learners. Conservation conversations, which are open dialogues that work towards building knowledge of wetlands, biodiversity and their importance were held with over 200 community members. The biodiversity protection officer also conducted environmental monitoring assessments, completing nine transects (a line transecting across a habitat along which measurements are taken) during the study period. The biodiversity protection officer also received a bursary to further her studies through the Endangered Wildlife Trust, in addition to ongoing mentorship by the programme staff.

Between 2016 and 2022, a total of approximately 200 hectares in the ARW area was cleared and maintained free from alien invasive plants, employing 20 people. Four local community members were educated and mentored as nature site guides, two of whom have been employed as full-time biodiversity protection and environmental compliance officers since 2017. The biodiversity protection officers monitored the environment completing a total of 2 122 transects.

Between 2016 and 2022, conservation conversations were held with over 360 community members from the ARW area. Learners from one school were engaged, reaching over 100 learners through a targeted environmental education programme.

The average ecological restoration effort (as outlined in section 2.2.3.) was higher in the ARW than in the IW, while the average social restoration effort was higher in the IW than in the ARW (see Figure 24).

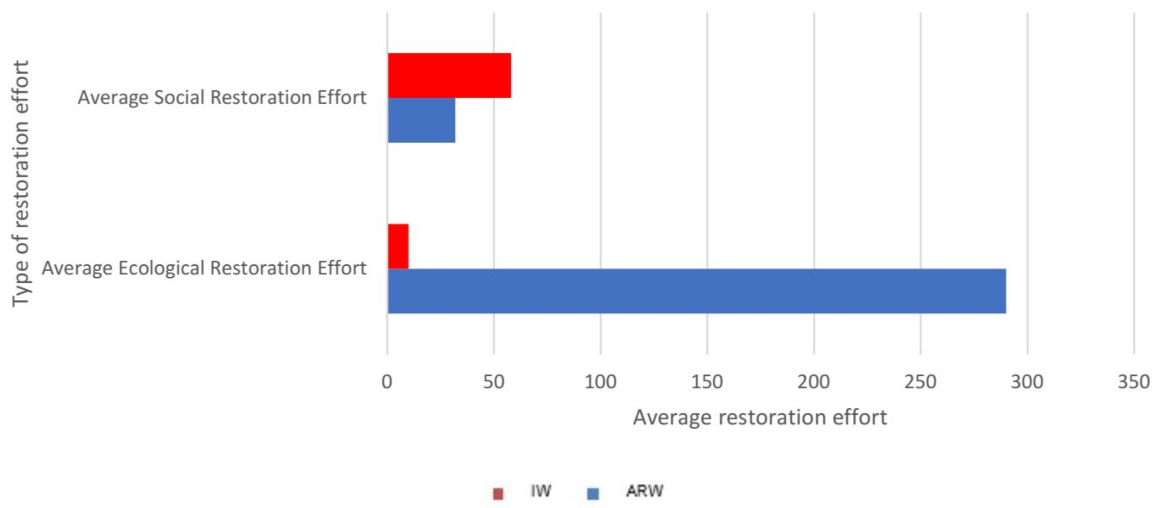

Figure 24: Average SER effort for ARW and IW

7.3 OVERALL SITE COMPARISON

Variables that demonstrated an association with the site were plotted on a radial diagram (Figure 25) which clearly shows that ARW scores are higher than IW scores across biodiversity, habitat health, resource use, positivity and environmental attitude variables.

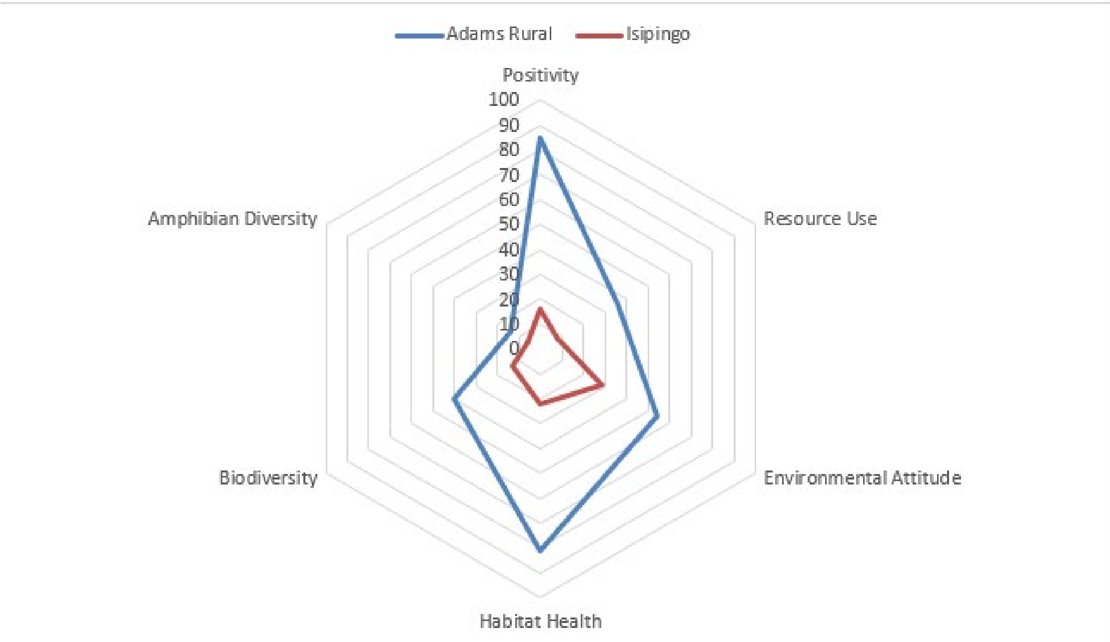

Figure 25: Radial diagram comparing social and ecological factors between ARW and IW.

7.4 DISCUSSION

The study demonstrated that there is an association between ecological health and the relationship people have with their environment. According to Kudryavtsev *et al.* (2012), sense of place in relation to factors such as access to resources and being surrounded by a healthy environment nurture positivity towards the environment. This is demonstrated by the data analysis which showed that there is a significant association between the site and the community's positivity (Table 5), sense of place (Tables 5 and 6), natural resource use (Tables 10, 11, 12 and 13), biodiversity (Table 15, Figure 18 and Table 22) and attitude (Table 18 and Figure 21) towards the environment. Milfont's (2007) theory of environmental attitudes is supported in that ARW community members displayed a more positive psychological response to the environment based on their positive perceptions (Table 5, Figures 12 and 13). Such perceptions would appear to be since ARW ecological conditions are largely natural (Table 20), providing a more aesthetic environment with access to natural resources (Table 10, 11, 12 and 13), resulting in a more positive experience and connectedness to the environment. This is supported by Rosa and Collado (2019), which demonstrate a positive relationship in relation to positive experiences in nature and related positive environmental attitudes and behaviour. However, Rosa and Collado (2019) conclude that utilitarianism, the use of natural resources in this case, does not necessarily lead to nature connectedness. However, the value of the natural resource use for consumption, medicinal and cultural (rituals) use is high in both AWR and IW supporting human health and spiritual wellbeing. The strong association between the environment or community context in terms of the site in relation to ecological condition, natural resource use, sense of place and biodiversity are directly proportional to attitude and positivity supports Stern's (2000) Attitude-Behaviour-Context (ABC) model. Indicating that an environment in good condition would positively impact a community's perception and attitude towards the environment. Interestingly, there is no site association between other environmental factors such as threats (Table 7), service delivery (Tables 8 and 9) and problem animals (Table 17), indicating that the combination of ecological condition, sense of place, natural resource use and biodiversity have a greater influence on a person's positivity and attitude towards their environment. A study conducted by Cohen (2008) indicates that crime, a threat cited by respondents from both the ARW and he IW, has less impact on life satisfaction because people can exercise control by adapting and protecting themselves from crime and therefore perhaps the threat of crime has a lesser impact on both ARW and IW respondents' environmental attitudes and positivity. Equally, seen through this lens, adaptations to address poor service delivery (such as burning, burying or dumping of waste) and problem animals (such as chasing them away or poisoning them) are being implemented by respondents from both the ARW and the IW. Unfortunately, the continual dumping of waste on the environment negatively impacts environmental conditions over time (Bailey, 2020 & Haywood *et al*., 2021) which could shift a community's perception and attitude towards the environment. Perhaps this shift in attitude and positivity is being realised in IW where dumping of waste within the surrounding environment is more common and concentrated in IW than in ARW (Figure 16). Ultimately, poor environmental conditions often negatively impact mental well-being within communities (South *et al*., 2018 & Hobbs *et al*., 2021) often reflected in negative attitudes.

In terms of the natural environment, each site is strongly associated with the condition of the natural environment (Table 20) since the wetland system in the ARW is classified as largely natural compared to IW which is seriously modified (Table 19). A degraded natural environment and associated low biodiversity, as is the case of the IW site (Table 15, 19 and 22), would naturally reduce and affect the availability of and access to natural resources (WHO, 2021). The effects of poor wetland conditions, resulting from biodiversity loss and reduced access to natural resources, on human well-being, are well documented by Hay *et al*. (2014) and demonstrated in the ARW where the natural environment is in relatively good condition with higher biodiversity (Tables 15, 19 and 22), allowing for greater availability of and access to natural resources than the IW. A study conducted by Acker-Cooper *et al.* (2022) showed that as habitat health decreases so too does amphibian diversity (Table 22). In terms of services such as flood attenuation, the value of a wetland in good condition cannot be disputed; in the April 2022 floods the impact of the floods in the ARW was minimal compared to the devastating effects experienced by the IW (R. Edwards, personal communication, 28 April 2022). Wetland protection and management to mitigate against flooding and other disasters such as drought and veld fires, for instance, have been extensively documented (Belle *et al*., 2018, Rebelo *et al*., 2019 & Turpie, 2010).

However, the size of the wetland systems may also contribute to ecological integrity and resilience (Ramsar Convention on Wetlands, 2018), as the ARW is a much larger system (503 hectares) than the IW which is much smaller (3 hectares). As such, pressure on the IW system from the surrounding community and environmental incidents, such as floods, would have a greater impact on it and its ability to recover. By contrast, the size of the ARW and its associated integrity assists in resilience to pressures and environmental incidents, as was observed during the April 2022 floods (R. Edwards, personal communication, 28 April 2022). To determine the effect of size, it is recommended that the size of wetlands in future studies be included to determine the relationship between size, wetland health and resilience.

Since positivity and attitude towards the environment are closely related to the site and only the environmental factors of condition and biodiversity are site-specific, it can be inferred that positivity about the site and attitude towards the environment is associated with environmental condition and biodiversity. Greater biodiversity and access to natural resources may influence positivity and attitudes towards the environment because there are direct and tangible benefits to the community. The value of biodiversity in attitudes was highlighted in a study conducted by Gunnarsson *et al.* (2017) which demonstrated that people's perception of the environment was proportional to the biodiversity richness of an area. Aesthetics and environment were also two of the top three reasons why respondents in ARW felt positive about where they live (Figure 12). The value of aesthetics in positivity is also supported by a study conducted by Wang and Yu (2018) which demonstrated that aesthetic perception and positive interaction with the surrounding environment can strengthen environmental value. Comparatively, in the IW, two of the top three reasons were that the area that they live in is accessible/convenient and there are economic benefits, such as cheaper cost of living and employment opportunities (Figure 13) – environmental aspects not directly associated with the ecological condition of the environment. According to Bandura (1997), Suresh *et al.* (2006) and LaMorte (2019), SCT, person–environment theory and personal agency support this outcome, as a person's attitude and behaviour are shaped and influenced by their environment and their ability to affect that environment. As such, if the natural environment is in poor condition and a person does not have the personal agency to prevent or improve that environment, then it would probably result in negative perceptions, attitudes and behaviour towards the natural environment. This also supports the outcome of issues related to threats, such as crime or problem animals, which may not have such a great influence on a person's attitude towards the environment as they have the personal agency to mitigate these issues.

Restoration efforts also demonstrate that an increase in ecological restoration efforts, as was the case in the ARW through alien invasive plant clearing and environmental monitoring (Figure 24), results in an improvement in the ecological state (Table 20). This was not the case with the IW, which is far more degraded than the ARW and would require a greater ecological restoration effort to improve ecological integrity. However, the marked improvement in the average attitude towards the environment pre and post socio-ecological interventions among community members at the IW site could be attributed to the greater social restoration effort in the IW (Figure 24). The social restoration effort was not as high in the ARW and there was only a small improvement in environmental attitude post socio-ecological interventions following social restoration efforts. The benefits, such as access to quality natural resources for example, attached to improving the social and ecological environments of a community using a balanced SER effort demonstrate the relationship between these two environments, as recognised by Fernandez-Manjarres *et al*. (2018). Ultimately, the improvement in the social and ecological state within the respective sites indicates that an environment conducive to change can be shaped through social and ecological restoration interventions and contributes to a scientific understanding of the complex interaction between people and their environment, as stated by the United Nations Environment Programme (2021).

The importance of ecological wetland restoration in reducing the risk of loss of life, displacement and infrastructure damage as a result of flooding will restore people's relationship with and attitudes towards their environment, gaining support for conservation and ecological restoration efforts. However, additional factors that influence social resilience, such as the annual number of deaths and displacements because of natural disasters, the incidence of disease and the number of clinic visits, should be considered and related to local environmental conditions. These additional factors would strengthen the understanding of the relationship between people and their environment.

Ultimately, the premise of this study was to demonstrate that the state of the natural environment influences the way a person in that environment engages with and perceives their surroundings. This study has demonstrated that the state of the environment is pivotal to the physical (through access to natural resources) and psychological (through positivity and attitude) well-being of a community. Improved ecological integrity can improve a community's relationship with its environment, contributing to improved socio-ecological resilience. SER efforts can help to create a natural environment conducive to improving perceptions and attitudes towards the environment.

CHAPTER 8
CONCLUSION AND RECOMMENDATIONS

The main aim of this study was to demonstrate that ecosystem health, land use and a community's attitude towards the natural environment are interrelated. The evidence set out by this study demonstrates that despite both habitats at both sites being Critically Endangered Indian Ocean Coastal Wetland Belts, comparatively the ARW and IW sites were strongly associated with opposite ends of the ecological and social well-being spectrum, with the ARW being in better ecological condition, with higher biodiversity, greater access to natural resources and land for agricultural activities. In contrast, the IW was in poor ecological condition with lower biodiversity and less access to resources and land for agricultural activities. Adams Rural Wetland residents also had a better attitude and positivity towards the environment than those from the IW.

However, the IW and ARW do not differ in terms of other environmental factors, such as service delivery, threats or problem animals, leading one to conclude that ecological condition is a more weighted factor influencing a person's relationship with their environment. Although this relationship has been clearly demonstrated, a statistical correlation was not possible because of the limited number of study sites and varying variable metrics. Therefore, the inclusion of more study sites and additional environmental factors to construct a systems dynamics model approach to illustrate the relationship between various socio-ecological factors would improve scientific understanding of the factors of influence. A deeper and broader understanding would contribute to improved planning concerning securing, maintaining and restoring the ecological infrastructure to support more resilient communities. This study also demonstrated how SER can contribute to restoring ecological systems and affects perceptions of and attitudes towards the environment through social restoration interventions. However, socio-ecological efforts need to be implemented with equal effort and in relation to the environmental context.

Finally, this study supports the notion that to effect positive social change in terms of appreciation for the environment, it is imperative that these environments are maintained in a condition that is conducive to supporting positive change. Recognising that if the environments in which people are living are in poor condition, people will not support environmental protection, regardless of whether ecological integrity promotes human well-being, because ecological goods and services such as flood protection and access to natural resources are not realised within these communities.

7.5 RECOMMENDATIONS

The socio-ecological relationship is complex and contextual, influenced by a variety of factors. Therefore, additional variables such as the annual number of deaths and displacements because of natural disasters, the incidence of disease and the number of clinic visits, should be considered and related to local environmental conditions. These additional factors would strengthen the understanding of the relationship between people and their environment. In addition, it is recommended that additional study sites be incorporated in further studies and additional factors of environmental influence such as flooding or droughts be included. Statistically analysing these relationships is complex and it is recommended that a systems dynamic modelling approach be used to statistically correlate influence, effect and impact between social and ecological factors.

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Annexure 1: Community land engagement survey template

Section A: Biographical information			
Survey number		Date	
Physical address			
Contact number		Age	
Number of household residents		Gender (male/female/non-binary/prefer not to disclose)	

Section B: Questionnaire			
Were you born here? (Y/N)		How long have you lived here?	
Do you enjoy living here?			
Why?			
How would you describe the place you live to other people?			
What is the best part of living here?			
Is there anything that threatens this 'best part' for you?			
Are your employed? (Y/N)		Is your work locally, provincially or nationally based?	
Do you farm?		What do you farm? (veg/type of livestock/ etc.)	
Do you have municipal water?		Do you use water locally?	

What do you use the local water for?		How much local water do you use? e.g. number. of buckets?	
Have you noticed any changes with the local water?			
What animals have you seen in your area?			
Are there any animals that cause problems for you?		How do you deal with these problem animals?	
Do you use any of the indigenous animals?		Which ones?	
How do you use these animals?			
Do use any local plants?		Which ones?	
How do you use these plants?			
How do you dispose your waste?		How much waste do you produce?	
Do you experience any problems with waste?			

Annexure 2: Attitude assessment (adapted from Tarrant *et al.*, 2016).

1	Survey Number				
4	What is your age?				
5	What is your gender?	Male	Female	Non-binary	Prefer not to disclose

Rate your answer

		Strongly agree	Agree	Unsure	Disagree	Strongly disagree
1	We should make sure we use plants wisely					
2	Snakes are useful to people					
3	Plants provide people with food					
4	Plants are useful to people					
5	People can generate an income from plants					
6	Nature is dirty					
7	*Imphepho* is important to invoke the goodwill of the ancestors					
8	I would like to look after the animals in my community					
9	I would like to learn more about the plants in my community					
10	I would like to learn more about the animals in my community					
11	I would like to attract animals to my garden					
12	I like to take photos of the plants found in my community					
13	I like to take photos of the animals found in my community					
14	I like to listen to the birds					
15	I like the *umdoni* fruit					
16	I like nature					
17	I like plants					

18	I am scared of birds					
19	I like frogs					
20	I like birds					
21	I know the snakes in my community					
22	I like snakes					
23	I know the frogs in my community					
24	I know the butterflies in my community					
25	I am scared of frogs					
26	I know the names of the birds in my community					
27	I am happy if frogs live near my house					
28	I like butterflies					
29	I do not mind if birds make nests in my garden					
30	I am scared of snakes					
31	I am scared of butterflies					
32	Frogs are useful to people					
33	Frogs and snakes are evil					
34	I am scared of nature					
35	Butterflies are useful to people					
36	I don't like plants					
37	Birds are useful to people					
38	An owl is a bird that belongs to those who perform witchcraft - *'inyoni yabathakathi'*					
39	I use plants for medicine					
40	A healthy environment will keep me healthy					
41	Plants, animals and people need each other					
42	I am a part of nature					
43	I kill snakes					

Annexure 3: UNISA-CAES Health Research Ethics Committee

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 26/01/2022

Dear Ms Acker

Decision: Ethics Approval from 20/01/2022 to 31/01/2025

NHREC Registration # : REC-170616-051
REC Reference # : 2022/CAES_HREC/010
Name : Ms CA Acker
Student #: 34880550

Researcher(s): Ms CA Acker
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Supervisor (s): Ms ME Brand
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Prof EP De Crom
decromep@tut.ac.za; 012-382-4194

Working title of research:

A case study for wetland restoration towards socio-ecological appreciation of natural resources in KwaZulu-Natal (South Africa)

Qualification: MSc Nature Conservation

Thank you for the application for research ethics clearance by the Unisa-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is granted for three years, **subject to submission of yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

The researcher is cautioned to adhere to the Unisa protocols for research during Covid-19.

Due date for progress report: 31 January 2022
The progress report is available on the college ethics webpage: https://w2.unisa.ac.za/www.unisa.ac.za/sites/corporate/default/Colleges/Agriculture-%26-Environmental-Sciences/Research/Research-Ethics.html

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Annexure 4: Endangered Wildlife Trust Ethics Committee Letter

ENDANGERED WILDLIFE TRUST
Protecting forever, together.

Endangered Wildlife Trust Ethics Committee
(EWTEC)

Project title	A case study for wetland restoration towards creating socio-ecological appreciation of natural resources
Ethics clearance number	EWTEC2021_008
EWT programme	Threatened Amphibian Programme
Researcher/Principal Investigator	Cherise Acker-Cooper

Species	Human interviews
Sample size	NA
Approval period	31 July 2021 – 31 July 2022

Kindly take note of the following:

- *The applicant is required to complete a final project report that will be due on 1 September 2022.*
- *Should there be any unexpected adverse effects on individuals, or changes in procedure/s, please submit details to the EWTEC using the respective approved forms.*
- *Please set up a meeting with the EWT Conservation Science Unit regarding the data to be collected and timelines for data submission.*

Application outcome	APPROVED
Date	2021/07/07
EWTEC Chair Signature	[signature]