ROADS AND THEIR ASSOCIATED USERS AS A THREAT TO WILDLIFE: AN APPROACH TO ASSESSING AMPHIBIAN ROADKILL IN THE VHEMBE BIOSPHERE RESERVE (WESTERN SOUTPANSBERG), LIMPOPO PROVINCE, SOUTH AFRICA

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DECLARATION

By submitting this thesis, I declare that this is my own work, and have not been previously submitted for any degree at this university or any other university. All design, execution and all reference materials contained therein has been duly acknowledged.

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Signature Date

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GLOSSARY OF TERMINOLOGY

Biodiversity - The variety of animal, plant and micro-organism life on earth or a particular habitat or ecosystem.

Biosphere reserves - Large landscapes that are incorporated by the United Nations Educational, Scientific and Cultural Organisation's (UNESCO's) Man and Biosphere programme and recognised internationally as important sites for fostering economic and social-ecological sustainable development.

Citizen science - Collaborative approach of collecting and analysing scientific data by members of the public.

Folklore - Traditional beliefs, customs and stories of a community that are passed from generation to generation through oral transmission.

Herpetology - The branch of zoological science that studies reptiles and amphibians.

Human wildlife conflict - The negative impacts that result from the interactions between humans and wildlife**.**

Road ecologist - A researcher that studies and investigates the complex interactions between roads and the natural environment.

Road ecology - The branch of ecology that studies the interactions of roads and highways and the impacts they have on wildlife.

Special Economic Zones (SEZs) - Geographical regions within which the government facilitates industrial parks through the establishment of fiscal and regulatory incentives and infrastructure.

ABBREVIATIONS

CS – Citizen Science
HWC – Human Wildlife Conflicts
LI – Linear Infrastructure
MMSEZ – Makhado-Musina Special Economic Zone
SEZ – Special Economic Zone
SPA – Soutpansberg Protected Area
VBR – Vhembe Biosphere Reserve

ABSTRACT

Transportation networks are associated with a number of threats that degrade the integrity of wildlife. These threats have been understudied in the Soutpansberg Protected Area (SPA), one of the core areas of the Vhembe Biosphere Reserve (VBR). As part of the Makhado-Musina Special Economic Zone (MMSEZ) plan, road infrastructure upgrades to support the expanding economic activities are proposed within the VBR. This includes the expansion of road lane from single to dual lanes by 2050, which has the potential to accelerate threats to wildlife by creating barriers and cause potential increases in wildlife roadkill for multiple taxonomic groups. One of the most understudied but likely most impacted groups is amphibians.

Globally, many amphibian populations are declining at a rapid rate due to growing anthropogenic threats (for example, habitat loss and degradation, as well as climate change). Road upgrades in the VBR will potentially further increase negative impacts on smaller vertebrates, such as amphibians and reptiles, as they easily cross the barriers (that is, fencing) surrounding protected areas and other properties. Amphibian mortality due to direct roadkill incidents has gradually become one of the contributing factors that affects the persistence of amphibians, thus influencing their population decline. However, the ecological impacts of roads on African amphibians during seasonal migrations are poorly studied. Therefore, using driven surveys at a speed of 20 to 30 km/h, this study recorded amphibian roadkill on regional road networks that surround the western Soutpansberg mountain range.

South African folklore regarding amphibians can cause people to disregard their value in the ecosystem, which may influence human persecution, consequently contributing to their further decline. To examine this belief, a questionnaire-photo survey was administered to 246 households in Ha-Kutama village, in the SPA. This was to determine whether attitudes, knowledge and cultural beliefs have an influence on the participation of local members of the public in citizen science campaigns to raise awareness, encourage them to report roadkill sightings, which could ultimately provide valuable data. These data would identify which amphibian species are most at risk in which areas (hotspots), resulting in mitigation measures being proposed and adopted, and consequently, assisting in the conservation of amphibian species, particularly from roadkill.

The outcomes of the study established a baseline amphibian roadkill inventory comprising a total of 248 individuals belonging to eight known species. The average amphibian roadkill rate for the monitored roads was 0.09 roadkill·km^{-1}·day^{-1}. The distribution of amphibian roadkill along the

monitored roads was non-random, which demonstrated that amphibian roadkill in the study area was spatially clustered at specific road locations (hotspots). Amphibian roadkill was significantly influenced by roadside habitat characteristics (x^2 = 17.091; df = 5; N = 248; $p < 0.05$). Road sections that were adjacent to open savannah bushland had a higher incidence of roadkill (Jacob's Index of 0.17) than road sections closer to waterbodies (Jacob's index of 0.08). This was despite amphibian breeding being associated with wet habitats.

The study findings provide baseline data that confirm the potential threat of roads and their users on the survival of amphibians in South Africa. Although the study indicates positive attitudes towards amphibians in the studied village, negative cultural beliefs, attitudes and a lack of knowledge about amphibians may reduce the effectiveness of developing and implementing citizen science campaigns (amongst specific demographic groups) to obtain amphibian roadkill data in the future. Consequently, more awareness around the value and importance of amphibians, including as an indicator of ecosystem health, is required.

Keywords: *Amphibian, Citizen science, Human-wildlife-conflict, Road ecology, Road impacts, Wildlife conservation*, *Wildlife roadkill*

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

South Africa's biological diversity is critical for sustaining livelihoods through ecosystem services (Gann & Lamb, 2006; Persha *et al.,* 2011; Vira & Kontoleon, 2012; Chaminuka *et al.,* 2014). The country is well known for sustaining favourable breeding sites for diverse populations of wildlife, with approximately 8% of its surface area being terrestrial protected areas (Skowno *et al.,* 2019).

The southern African region has a diversity of climates, landscapes and ecosystems that play an important role in the heterogeneous distribution of its wildlife (Phaka *et al.,* 2017). South African protected areas, private and public game or nature reserves, conservancies and biosphere reserves, provide habitable ecosystems to numerous species of flora and fauna. However, loss of terrestrial biodiversity is accelerating at an alarming rate, due to the alteration of natural ecosystems, primarily for human development (Bradshaw, 2012; Hundera *et al.,* 2013; Soh *et al.,* 2019; Pinto *et al.,* 2020). A growing human population has led to increased infrastructure development which has resulted in the conversion and fragmentation of natural habitats (Craven *et al.,* 2014; Walsh *et al.,* 2015). Increasing threats to wildlife continue to leave many populations of fauna and flora vulnerable, impeding sustainable biodiversity conservation (Wong, 2011).

Linear infrastructure (LI) comprises part of this development, and includes structures such as, roads, railways, power lines and pipelines, which play a vital role in the transportation of goods and services, primarily for economic sustainability (Maciulis *et al.,* 2009). Africa is amongst the most rapidly developing continents in the world in terms of infrastructure development (Laurance *et al.,* 2009; Cote-Roy & Moser, 2019; Kleinschroth *et al.,* 2019), which is also common in many other developing continents and countries, such as South America (Andrade-Nunez & Aide, 2020) and south east Asia (Ng *et al.,* 2020). More specifically, South African road and rail networks, are scheduled for improvement and expansion, thus becoming one of the best state-of-the-art transportation networks in Africa (Manda & Dhaou, 2019). However, despite road development improving the socio-economics of the country, and thus having a positive impact (Mciulis *et al.,* 2009; Collinson *et al.,* 2019a), it is important to explore the negative impacts that development (which not only includes transportation, but the associated infrastructure, such as housing and shopping malls) may have on wildlife (Zeng, 2016), particularly when they are adjacent to or in protected areas, which are often bisected by roads and/or railways (Forman *et al.,* 2003).

Special Economic Zones (SEZs) are geographical regions within which the government facilitates industrial parks through the establishment of fiscal and regulatory incentives and infrastructure

(Zeng, 2016). SEZs and industries, such as mining (and the associated infrastructure to support this), play an important role in improving human livelihoods (Zeng, 2016). However, it coincides with road construction and upgrades, which cause road-induced impacts on biodiversity to increase (Petrovan & Schmidt, 2019). This often results in a barrier effect whereby wildlife populations are unable to migrate, feed and mate and causes poor habitat connectivity (Teixeira *et al.,* 2020). Moreover, this may cause humans and wildlife to use the same road systems, which will likely increase human-wildlife-conflict (Glista *et al*., 2008; de Souza *et al.,* 2014; Seiler & Bhardwaj, 2020). Understanding the complex relationships between linear infrastructure and the natural ecosystems they bisect, is the aim of transportation ecology, and for this study, the focus was on roads.

In the recent five decades, research emerging from the scientific discipline of road ecology has identified roads and their associated users as a threat to amphibians and biodiversity as a whole (Glista *et al.,* 2008; Brzezinski *et al.,* 2012; Arevalo *et al.,* 2017; Zhang *et al.,* 2018). Globally, many road ecology studies focus on mammals (Langen *et al.,* 2007) and birds (Gomes *et al.,* 2009; da Rosa & Bager, 2012) even though amphibians and reptiles appear more susceptible to roadkill than mammals (Ashley & Robinson, 1996; Smith & Dodd, 2003; Stuart *et al.,* 2004; Glista *et al.,* 2008; Heigl & Zaller, 2016). Although there are few data to support that amphibians are more susceptible, it seems logical to assume that they are, due to their small body size and breeding migrations (usually in high volumes).

Amphibians, which include toads and frogs, salamanders and caecilians, are ectothermic vertebrates (du Preez & Carruthers, 2009). As with all taxonomic groups, amphibians face numerous anthropogenic threats, including habitat destruction (Wake, 1991; Beebee & Griffiths, 2005; Whitfield *et al.,* 2007), human persecution (Jensen & Camp, 2003) and climate change (Beebee & Griffiths, 2005).

Despite a growing body of road ecological research in Africa (Collinson *et al*., 2019a), there is a paucity of research that investigate the impacts of roads on amphibians and possible mitigation efforts. Even though amphibians are experiencing severe population declines globally (Stuart *et al.,* 2004; Phaka *et al.,* 2017), there are limited amphibian roadkill studies worldwide, and very few in Africa. In addition, threats to amphibians may be more severe due to amphibians often being less favoured and more misunderstood by the general public globally (Tarrant *et al.,* 2016; Phaka *et al.,* 2017).

Negative mythologies and folklore concerning wildlife may cause negative attitudes and perceptions towards wildlife species (Ceriaco, 2012), leading to persecution, especially if not properly addressed (Ceriaco *et al.,* 2011). For example, cultural beliefs about owls (*Stringiformes*) have resulted in their persecution in many parts of the world (Enriquez & Mikkola, 1997). In many African countries owls are perceived to symbolise misfortune (Ogada & Kibuthu, 2008) and are often associated with witchcraft (Munroe & Gauvain, 2018). Similarly, in Europe, the Iberian wolf (*Canis lupus signatus*) was perceived as a demonic, man-eating creature (Crawford, 1995; Dobkowks-Kubacka, 2018). According to Tarrant *et al.* (2016), poor acceptance of amphibians by members of the public negatively impacts conservation efforts for this taxonomic group.

In recent decades, a citizen science approach has been adopted as a new method of collecting scientific data in the conservation discipline, and also a way of educating and raising awareness of specific species or taxonomic groups (Kobori *et al.,* 2016; Frigerio *et al.,* 2018). Citizen science uses volunteers and members of the public to collect, sort or analyse scientific data (Bonney *et al.,* 2014; Kobori *et al.,* 2016). For example, Trumbull *et al.* (2000) stated that many bird watchers, who actively participate in citizen science projects, often develop a liking and deeper understanding of birds, through participating in these projects. Participating in citizen science projects can lead to local people developing a fondness for nature and improving their scientific knowledge. Moreover, the National Science Board (1996) reported that United States citizens appeared to be more scientifically literate through participating in such projects.

For example, the Noordhoek Unpaid Toad Savers (Toad NUTS) is a conservation group that comprises dedicated community members from Noordhoek, Western Cape Province, South Africa, who voluntarily work together to save the Western Leopard Toad (*Sclerophrys pantherina*) from roadkill during their annual migration to breeding ponds (Van Wyk, 2015). This citizen science campaign has successfully reduced roadkill rates of *Sclerophrys pantherina* from 27% (19 roadkill reported from 51 individuals which migrated in 2012) to 0% (zero roadkill recorded from 61 individuals which migrated in 2013). This project has contributed to our knowledge of the species mortality data as well as in the application of mitigation measures (Toad NUTs, 2013; Van Wyk, 2015). The success of this approach largely relies upon how people feel about the taxonomic group in question. It may be difficult to implement such projects in rural areas, where amphibians are largely misunderstood, and perceived to cause warts on the hands when handled. Such mythologies may preclude active participation of local community members in projects aimed at curbing amphibian roadkill.

1.2. PROBLEM STATEMENT

The study area (western Soutpansberg; SPA) lies within one of South Africa's poorest economic regions, with an unemployment rate of 53.9% (Ramarumo & Maroyi, 2020). To address the lack of opportunities in the area, the government has proposed the establishment of the Makhado-Mucina Special Economic Zone (MMSEZ) in the Vhembe Biosphere Reserve (VBR); which includes the SPA and Soutpansberg Mountain range. The MMSEZ comprises four projects envisioned for the Musina-Makhado area, and these include i) a coal-powered power-plant, ii) a coking plant, iii) an alloy factory, and iv) a steel plant (Retief, 2019). While these developments may bring opportunities for improving the local economy, their impacts on biodiversity within the VBR, is of major concern (Hahn, 2018). To date, a potential threat has been identified in the VBR through the development of coalfields, an example of which is the Makhado coal mine in the northern Soutpansberg established by Coal of Africa Limited (CoAL) in 2012 (Groenewald, 2012; Cornish, 2013).

Often where there are mines, other forms of LI are needed for transportation. Consequently, the South African National Roads Agency Limited (SANRAL) has developed a transport plan to upgrade provincial road networks within the VBR (Government Tender Bulletin, 2019), to support the growing economy in the area (specifically mining). One of these projects aims to upgrade two single-lane roads which surround the western Soutpansberg in the VBR (the R521 and R523) to dual-lane roads by 2050 (Government Tender Bulletin, 2019), in order to improve the flow of goods and services (primarily related to mining). However, the expansion of road networks may result in increased traffic volumes and speed (Eloff & van Niekerk, 2005; Collinson *et al.,* 2015; Yue *et al.,* 2019), in addition to the associated negative impacts of coal transport on ecosystem health (Erickson & Jennings, 2017).

The above mentioned road network surrounds the western Soutpansberg, which was declared a priority area for wildlife conservation by the South African National Biodiversity Institute (SANBI) (Rouget *et al.,* 2004). Besides *ad hoc* roadkill data reported within the VBR, there are few scientific studies that quantify road impacts on wildlife within this region. Thus, the VBR remains understudied for wildlife roadkill. This provides a challenge for scientists who advise road planners and engineers on where to prioritise appropriate mitigation structures to minimise roadkill (Lesbarrieres & Fahrig, 2012). If sustainable road infrastructure is not implemented, road impacts on wildlife (e.g. barriers for wildlife movement, genetic isolation and wildlife roadkill) (Collinson *et al.,* 2014; Kioko *et al.,* 2015 Teixeira *et al.,* 2020) will likely increase, especially for smaller vertebrates such as herpetofauna (Ashley & Robinson 1996; Glista *et al*., 2008).

Heigl and Zaller (2016) state that through citizen science initiatives, community members have made a significant contribution to improving wildlife roadkill data. Nevertheless, folklore associated with certain animal groups may influence anti-conservation attitudes, causing them to exclude roadkill of certain taxonomic groups (such as amphibians) that are often less valued or feared (Ceriaco, 2011). Ceriaco (2012), Tarrant *et al.* (2016) and Phaka *et al*. (2017) state that citizen science efforts for amphibian projects are few, due to folklore impairing effective conservation efforts for various species. Persecution of amphibians by humans (Ceriaco, 2012; Tarrant *et al.,* 2016; Tarrant & Armstrong 2017; Phaka *et al.,* 2017), can lead to increased amphibian roadkill since they are not regarded as valuable by many members of the public.

Although a citizen science approach was successful with the Toad NUTS group protecting *Sclerophrys pantherina* in an urban, more affluent, area of the country, few studies support it as an effective tool for reporting amphibian roadkill in the rural areas of South Africa (Matthews, 2014). Therefore, understanding the perceptions, beliefs and misconceptions towards indigenous species (from a different demographic group to the Noordhoek community, Toad NUTS), will provide information that may be essential for solving the conservation concerns arising around human perspectives (Ceriaco, 2012).

1.3. SIGNIFICANCE OF THE STUDY

Currently, South African road agencies rely only on the Environmental Impact Assessments (EIAs) when planning road development projects (the scoping report), and road ecologists have yet to be involved at this early stage in the process (Lesbarrieres & Fahrig, 2012). This is likely because of road ecology being a new scientific discipline in Africa (Collinson *et al.,* 2019a). This excludes road ecologists from the critical planning phase, disregarding their expertise in the design of eco-friendly road infrastructure. Through monitoring amphibian roadkill occurrence on roads around the western Soutpansberg, this study will provide baseline data that can be used to guide future, informed decision-making that will ensure improved habitat quality for wildlife through planning for effective conservation strategies – specifically during the EIA process (Beaudry *et al.,* 2008).

This study will also assist in identifying habitat characteristics where amphibian roadkill occurrence is highest and guide existing roadkill-modelling and predictor studies, which may be applied elsewhere in the country. Monitoring allows for a cost-and-time effective monitoring approach and may serve as a useful tool for roadkill predictions (Shilling *et al.,* 2015).

Furthermore, improving participation of local people in community-based conservation projects may alter their existing negative attitudes towards wildlife. To support this, du Toit (2002) stressed the active participation of members of the public in citizen science as a key factor in ensuring success or failure for any conservation project; therefore, reporting wildlife roadkill sightings through a citizen science approach can be applied in the VBR.

Community members, through the Endangered Wildlife Trust's (EWT) Road Watch smartphone Application (http://www.prismsw.com/roadwatch/android/RoadWatchSouthAfrica.apk) (Periquet *et al.,* 2018) regularly submit roadkill data from across the country, with almost 25,000 data points being submitted since 2013 (EWT, 2021). However, the EWT roadkill database has a significant lack of data for amphibian roadkill from across the country (< 3%), which may either be due to the disappearance of the roadkill due to scavengers (Coelho *et al* 2012), driven over too many times to be recognisable (their small size) (Glista *et al.,* 2008), or underreporting due to existing negative mythologies and folklore contributing to widespread negative perceptions of amphibians (Ghimire *et al.,* 2014; Tomazic & Sorgo, 2017).

If effective conservation strategies and research are not undertaken to alter human attitudes towards amphibians, several amphibian species may soon become extinct (Tarrant *et al.,* 2016). The importance of emphasising citizen science input in developing strategies for amphibian conservation research in South Africa was emphasised by Measey *et a*l. (2019). The lack of amphibian roadkill studies is responsible for the insufficient roadkill data and poor awareness concerning amphibian roadkill as a conservation threat. This study is significant in that it advocates for sustainable road infrastructure for smaller vertebrates such as herpetological fauna. It attempts to create and motivate for a platform where communities in, and adjacent to, protected areas, actively participate in collecting wildlife roadkill data for all species, including amphibians.

1.4. AIMS AND OBJECTIVES

The first aim of this study was to examine the negative impacts posed by roads and their users on amphibian biodiversity around the western Soutpansberg Mountain range, within the VBR.

The second aim was to investigate the perceptions of people from of the Ha-Kutama Tribal Authority in the SPA and determine how their attitudes, knowledge and folklore of amphibians influence their willingness to actively participate in amphibian roadkill citizen science projects.

The aims were achieved through the following objectives:

- To establish an inventory of amphibian roadkill for the western Soutpansberg through driven surveys during the hot/dry and hot/wet breeding seasons over a 70-day monitoring period.
- To assess the influence of roadside habitat and land-use structures on the occurrence of amphibian roadkill in the western Soutpansberg.
- To investigate whether public perceptions and folklore of amphibians influence the participation of local people in amphibian roadkill citizen science projects in Ha-Kutama (Midoroni and Maebane villages).

1.5. STUDY AREA

1.5.1. THE VHEMBE BIOSPHERE RESERVE AS A CONSERVATION AREA

Biosphere reserves are large landscapes recognised internationally as important sites for fostering economic and social-ecological, sustainable development, inclusive governance of natural assets and ecosystems, as well as proper monitoring through environmental education, research and international networking (SEF, 2016; Barclay & Gifford, 2017; Carruthers, 2020). These sites are designated within the framework of the United Nations Educational, Scientific and Cultural Organisation's (UNESCO) Man and Biosphere (MAB) Program. The guidelines of UNESCO biosphere reserves are underpinned by three elements (Spool-Stanvliet *et al.,* 2018) (Table 1 and Figure 1), and these elements are critical for establishing differential usage of ecosystem services as well as forming diversified management regimes within each biosphere reserve (Huge *et al.,* 2020).

Table 1: The elements of biosphere reserves according to UNESCO (Pool-Stanvliet *et al*., 2018)

#	Biosphere reserve element	Description
1	Core areas	Sites that are statutory protected for biological diversity conservation
2	Buffer zones	Sites that adjoins and surround the core areas; used for cooperative activities; and are associated with sound ecological practises (ecotourism and environmental education)
3	Transitional areas	Flexible areas that contain a variety of uses (agriculture, settlements and others) and are underpinned by cooperative management among stakeholders (communities, scientists, non-governmental organisations and cultural groups)

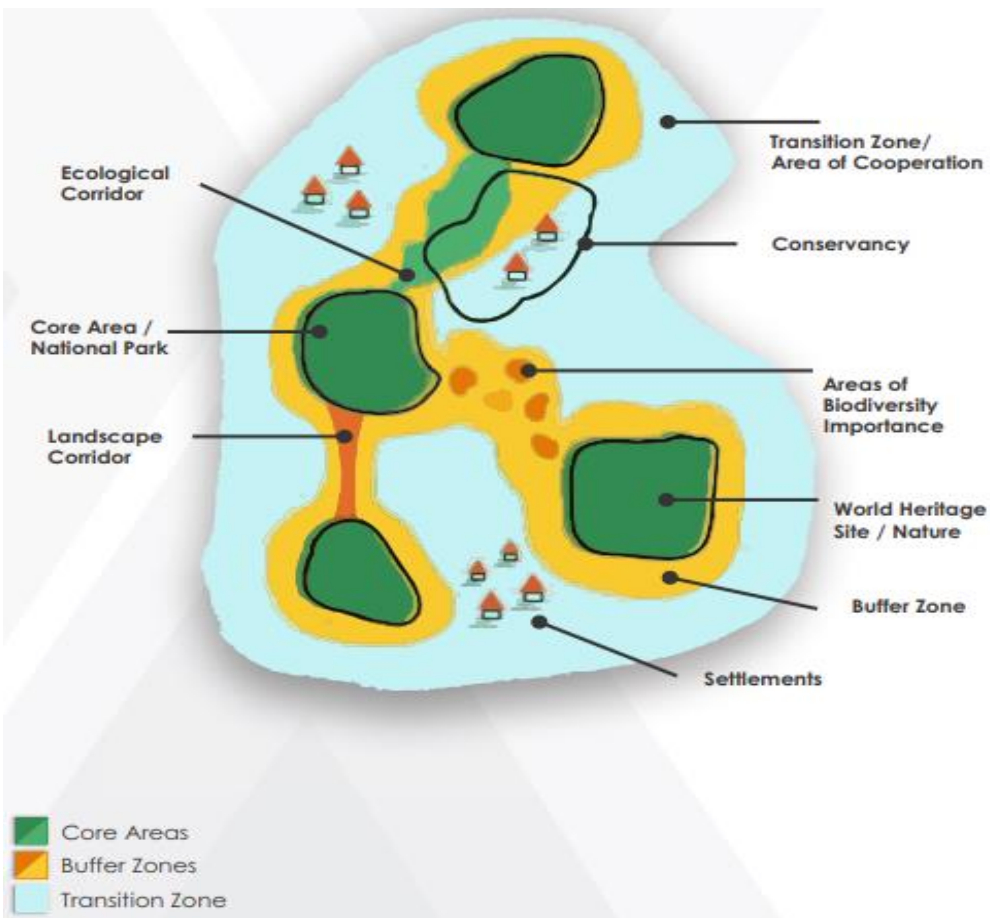

Figure 1: Elements of biosphere reserves according to UNESCO (The UNESCO Man and Biosphere Programme in South Africa, 2019)

South Africa has 10 biosphere reserves (Figure 2 and Table 2). The Limpopo Province has three Biosphere Reserves (the VBR, Kruger-to-Canyon and Waterberg) (Figure 2 and Table 2), of which the focus of this study is the VBR, with the Soutpansberg forming part of this core area. The VBR was designated a biosphere reserve in 2009 to form part of the World Networks of biosphere reserves (Jauro *et al.,* 2019), and is the second largest biosphere reserve in South Africa, with a total area of 3 070 000 ha. The VBR is largely rural and home to approximately 1.4 million people (Jauro *et al.,* 2019), with the majority reliant on natural resources for sustaining their livelihoods. Moreover, over 66% of households directly rely on harvesting firewood for meeting their basic fuel needs, particularly for cooking and heating (Linden *et al.,* 2016). The Soutpansberg mountain region of the VBR is rated amongst the most biodiverse areas of South Africa, which makes it a focal area of the VBR (Lima Action Plan for UNESCO, 2016).

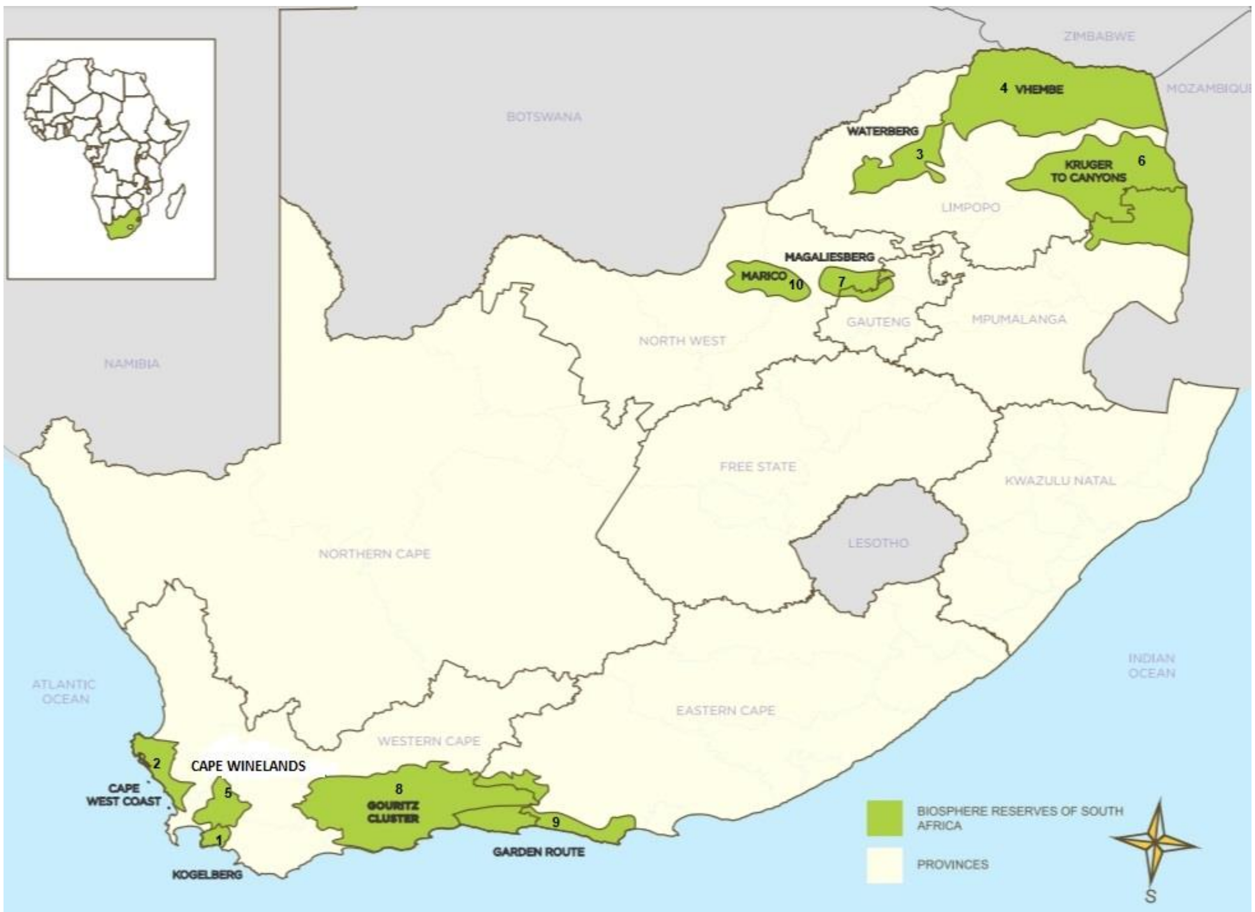

Figure 2: The biosphere reserves of South Africa (The UNESCO MAB Programme, 2019)

Table 2: The location, size, and year of proclamation of biosphere reserves in South Africa

Biosphere reserve		Province	Year of proclamation	Size (ha)
1.	Kogelberg	Western Cape	1998	100 000
2.	Cape West Coast	Western Cape	2000	378 000
3.	Waterberg	Limpopo	2001	417 000
4.	Vhembe	Limpopo	2009	3 070 000
5.	Cape Winelands	Western Cape	2007	322 000
6.	Kruger-to-Canyon	Mpumalanga and Limpopo	2001	2 474 700
7.	Magaliesberg	Gauteng and North West	2015	230 846
8.	Gouritz Cluster	Western Cape	2015	3 269 000
9.	Garden Route	Western Cape	2017	698 363
10.	Groot Marico	North West	2018	447 269

1.5.2. STUDY LOCALITY

The Soutpansberg is the most northern mountain range in South Africa, and is bisected by the N1 road, effectively creating two distinct areas, the eastern (6 800 km^2) and western Soutpansberg (2 800 km^2) (Hahn, 2010). The Soutpansberg extends approximately 210 km from Vivo in the west to Pafuri in the east (Hahn, 2010) and it forms part of the VBR, a priority area for biodiversity. Roads surrounding the western Soutpansberg formed one part of the study locality (for the roadkill surveys), with the communities in the SPA, forming the other part of the study locality. The region is in the arid, northern part of the Limpopo Province (Hahn, 2002; Mostert, 2006), South Africa (23°05'S, 29°17'E and 22°25'S, 31°20'E) (Figure 2), which is recognised as an important centre for biodiversity and endemism with diverse habitats as well as floral and faunal diversity (van Wyk & Smith, 2001; Pool-Stanvliet, 2013; Petford *et al.,* 2019).

1.5.3. ECOLOGY OF THE SOUTPANSBERG

The Soutpansberg is known for its rich complex vegetation (Hahn, 2002), and Mucina and Rutherford (2006) identified three vegetation types that significantly contribute to its intrinsic biodiversity: Soutpansberg Summit Sourveld, Soutpansberg Mountain Bushveld and Northern Mistbelt Forest (Figure 3). According to van Huyssteen (2018) the Northern Mistbelt Forest, Soutpansberg Summit Sourveld and Lowveld Riverine Forest are critical areas for amphibians in the VBR. Stuart and Stuart (2018) state that the Soutpansberg has approximately 600 tree species and in excess of 2 500 plant species. Several indigenous plant species are used by local people for traditional medicine and to sustain their livelihoods (Berger *et al.,* 2003). The Soutpansberg is represented by 56% of the bird species (n=298) and 60% of the mammals of southern Africa (n= 95) (Hahn, 2006), and is rich at the generic level too (Linden *et al.,* 2014). Stuart and Stuart (2018) further state that the area provides habitat to 93 reptile, 130 spider, 17 fish and 28 amphibian species.

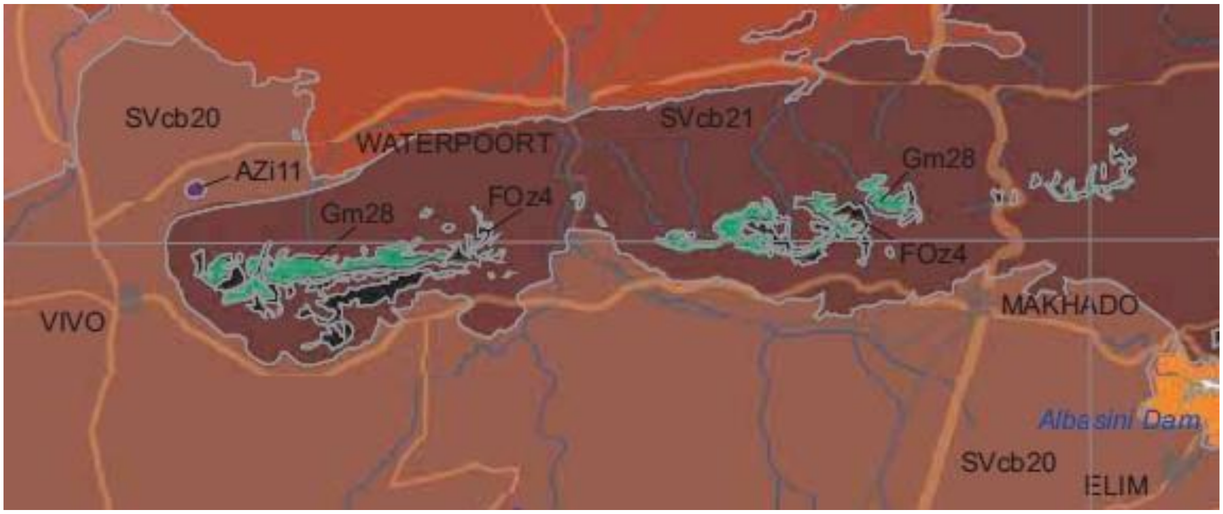

Figure 3: Vegetation map of the western Soutpansberg. GM28 - Soutpansberg Summit Sourveld, SVcb21 - Soutpansberg Mountain Bushveld, FOz4 - Northern Mistbelt Forest, SVcb20 - Makhado Sweet Bushveld, AZi11 - Subtropical Salt Pans (Mucina & Rutherford, 2006)

1.5.4. AMPHIBIANS OF THE SOUTPANSBERG

According to van Huyssteen (2018) the most significant areas for conserving amphibians in the VBR are the major rivers (Sand River, Mogolakwena River and Limpopo River and its tributaries) of the western Soutpansberg, the far eastern Vhembe region (Pafuri) and the Limpopo valley. During herpetological surveys in the western Soutpansberg, van Huyssteen (2018) listed 38 amphibian species, including two endemic species: *Breviceps sylvestris taeniatus* (Near Threatened) and *Breviceps mossambicus* (Least Concern) (IUCN, 2020), both of which are found in the SPA. Herpetological surveys undertaken on the Medike Nature Reserve (a property in the SPA) during the current study recorded 14 species of amphibians during the wet November 2019 season (Appendix A).

1.5.5. CLIMATE, TOPOGRAPHY AND HYDROLOGY OF THE SOUTPANSBERG

The altitude of the Soutpansberg ranges from 200 m asl, to 1 719m at Hanglip (central Soutpansberg, second highest peak), and 1 748 m at Mount Lajuma, the highest point in the Soutpansberg (Kirchhof *et al.,* 2010). Climatically, the northern slopes of the Soutpansberg receives an average annual rainfall of approximately 300 mm (Linden *et al.,* 2014), whilst the southern slopes receive more than double that, with an average annual rainfall of approximately 750 mm (Foord *et al.,* 2015), the location of highest precipitation being Entabeni with an annual rainfall of 1 874 mm (Mpandeli, 2014; Hahn, 2018). Most of the rain falls during the hot summer season from October to April. During the hot / wet season temperature ranges from 16 to 40 °C and during the cold / dry season temperature ranges between 12 and 22 °C (Kephe *et al.,* 2016).

1.5.6. ROAD INFRASTRUCTURE IN THE SPA

Data from the Limpopo Department of Roads and Transport shows that in the Vhembe District Municipality (VDM; which also forms part of the VBR buffer and transitional zones), roads comprise the National road (N1; 159 km), provincial roads (762.2 km) and unpaved roads (1 145.47 km) (VDM, 2013). The VBR is situated in an area wherein agriculture and ecotourism form the core drivers of economic growth (Statistics South Africa, 2018). In addition, Mudau *et al.* (2014) found that public transport, as well as light and heavy delivery vehicles, form the main modes of transportation for humans and freight around the VBR.

Currently, the western Soutpansberg is surrounded by three regional roads and one national road. On the southern boundary is the R522 that runs from Makhado in the east to Vivo in the west, and the western boundary is the R521 from Kalkheuwel in the north to Vivo in the south (Mostert, 2008). The northern boundary is the R523 from Wyllies Poort in the east to Kalkheuwel in the west, and the N1 lies on the eastern side from Makhado in the south to Wyllies Poort in the north (Mostert *et al.,* 2008) (Figure 4). All four roads are paved, and the three regional roads single-lane, with plans to upgrade the R521 and R523 to dual carriageways to address the anticipated increase in traffic as a result of growing economic activities in the area (Makhado Municipality IDP Review, 2019).

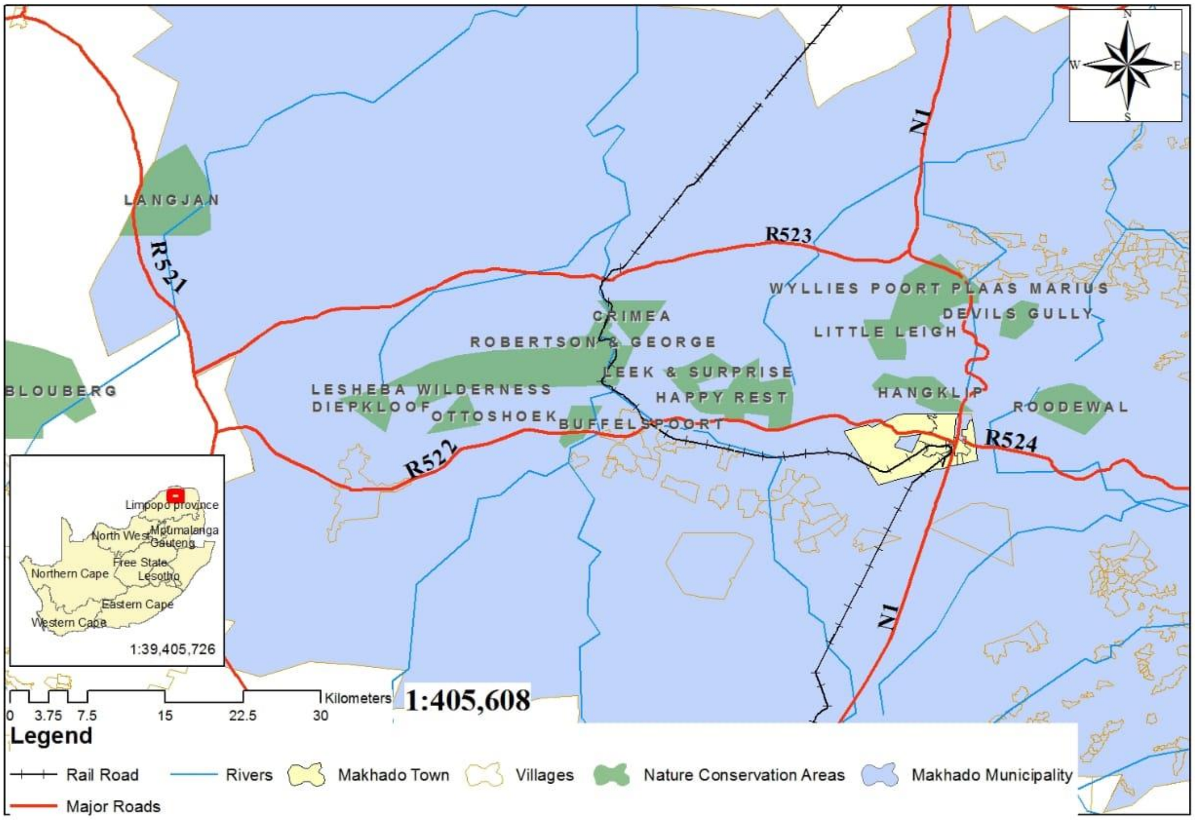

Figure 4: A map of the study area showing the network of roads that surround the western Soutpansberg

CHAPTER 2: LITERATURE REVIEW

2.1. ROAD ECOLOGY

Globally, over 64 million kilometres of road traverse the earth's landscapes (Central Intelligence Agency (CIA), 2014), with the United States having the longest complex of road networks estimated at 11 028 873 km (National Research Council, 2005). South Africa's transportation system comprises road, rail, sea and air (National Treasury Provincial database, 2010), with the country's road network being approximately 750 000 km in length (SANRAL, 2014). Of the 750 000 km, roughly 163 472 km are paved, 454 609 km unpaved and the remaining 131 919 km have not been formally recorded in road inventories (unproclaimed) and are situated predominantly in rural areas (Ross & Townshend, 2019). Road systems consist of unpaved and paved hard surfaces, with some made of concrete (paved roads) to ensure the smooth transportation of goods and people (National Research Council, 2005; Decky *et al.,* 2016).

Roads form linear networks that have positive benefits as they transport both people and goods from one place to another, but they also have negative impacts on biodiversity through fragmenting natural habitats, as well as altering landscapes (Zimmermann *et al.,* 2014; Collinson *et al.,* 2015), and impacting on wildlife movement patterns (Nathan *et al.,* 2008). The increased ecological impacts of linear infrastructure led to the evolution of the discipline of road ecology (Fahrig & Rytwinski, 2009). Van der Ree *et al.* (2015) defines road ecology as "the science of the quantification and mitigation of road impacts on wildlife", while according to Balkenhol and Waits (2009) "the goal for this discipline is to gather sufficient data to enable scientists to advise road engineers and planners on how to design transportation infrastructures that are socio-economically and ecologically sustainable to enhance road safety for both humans and wildlife".

Road infrastructure contributes to the degradation of natural ecosystems and biodiversity, and road ecology research has been active and well-developed since the 1980s in Europe and the USA (Forman & Alexander, 1998; Cabrera-Casus *et al.,* 2020). In comparison, although it has not been widely investigated on the African continent, the concept of road ecology has gained momentum in Africa in the last decade (Collinson *et al.,* 2019b). In many developing countries, private vehicle ownership and consequent demand for more roads are expected to escalate, which may cause further habitat fragmentation and accelerate roadkill occurrence (Seiler, 2005; Teixeira *et al.,* 2020). Consequently, in the absence of enough budget allocated by the state to minimise road impacts on wildlife when planning for roads, transportation systems will continue to be a threat to biodiversity (van der Ree *et al.,* 2011).

2.2. MOVEMENT ECOLOGY AND ROAD ECOLOGY

According to Nathan *et al.* (2008) the ability of fauna to move around in their wilderness forms a fundamental aspect of their survival. Animals move in response to local physical, environmental, and biological conditions (Armsworth & Roughgarden, 2005). Movement is important for fauna because it enables them to reach their natal sites, promotes successful spatial distribution of populations and species as well as improving gene flow within meta-populations (Clobert *et al.,* 2001). Furthermore, different species move in response to their surrounding environment, resource availability (food and water) and in relation to changing ecological seasons (Nathan *et al.,* 2008).

As wildlife habitats are increasingly disturbed by extensive road networks, wild fauna become disconnected from their natural landscapes (Ashley & Robinson, 1996). Animal movement becomes more effective when the spatial arrangement of landscape structures has adequate connectivity among habitat patches (Merriam, 1991; Taylor *et al.,* 1993; Forman, 1998; Nathan *et al.,* 2008). In the absence of proper habitat linkage structures, animals are forced to traverse roads for movement. This highlights the need for expertise from road ecologists (alongside road planners and engineers) in the planning, design and construction stages of transportation infrastructure (Lesbarrieres & Fahrig, 2012).

2.3. WHY SHOULD WE MONITOR WILDLIFE ROADKILL?

When wild fauna attempt to cross the road, they become vulnerable to vehicles, which often results in a negative ecological and conservation consequence (e.g. a wildlife vehicle-collision (WVC) commonly known as roadkill) (Penteriani & Delgado, 2009; Whitfield *et al.,* 2009). It is thus imperative to have a monitoring plan that quantifies wildlife roadkill, not just on regional and national roads but also roads in protected areas, where roadkill is presumably less likely to occur (Kline & Swann, 1998; Garriga *et al.,* 2012). Accurate monitoring of roadkill is critical for determining roadkill rates and identifying roadkill risk areas (i.e. roadkill hotspots) (Pinto *et al.,* 2020). It also enables ecologists to study animal movement, as well as determine and map environmental factors that can improve our understanding of the causes of roadkill (Schwartz *et al.,* 2020). Having reliable baseline data for roadkill can influence the implementation of safe crossing structures for wildlife at a later stage (on the mitigation hierarchy) and raise awareness of the potential threats resulting from roads (Coelho *et al*., 2014). This is critical for making decisions concerning the safety of wildlife on all roads (as well as human beings when involved in a WVC). Lastly, effective monitoring of wildlife roadkill may generate data about the distribution of specific species in an ecosystem including new, rare and/or threatened species (Schwartz *et al.,* 2020).

2.4. ECOLOGICAL IMPACTS OF ROADS ON WILDLIFE

As outlined in sections 2.1 and 2.2 above, roads have negative consequences for biodiversity. In normal circumstances, construction or the expansion of road corridors, requires the land to be cleared to transform the existing land cover into a well-constructed road. By clearing the vegetation cover, the habitat is reduced which can cause loss of biodiversity connectivity and fragmentation of habitat (Forman *et al.,* 2003). On the other hand, the road verges form potential habitat that fosters diverse vegetation (or micro-habitats) that attracts grazing animals (Hensen & Jensen, 1972; Oxley *et al.,* 1974; Milton *et al.,* 2015), often causing them to wander onto the road, directly accelerating the risk of becoming roadkill (Figure 5). Furthermore, trees and bushes on road verges are nesting habitats for many bird species and provide shade and shelter to many faunal species, also putting them at risk of becoming roadkill (Seiler, 2005).

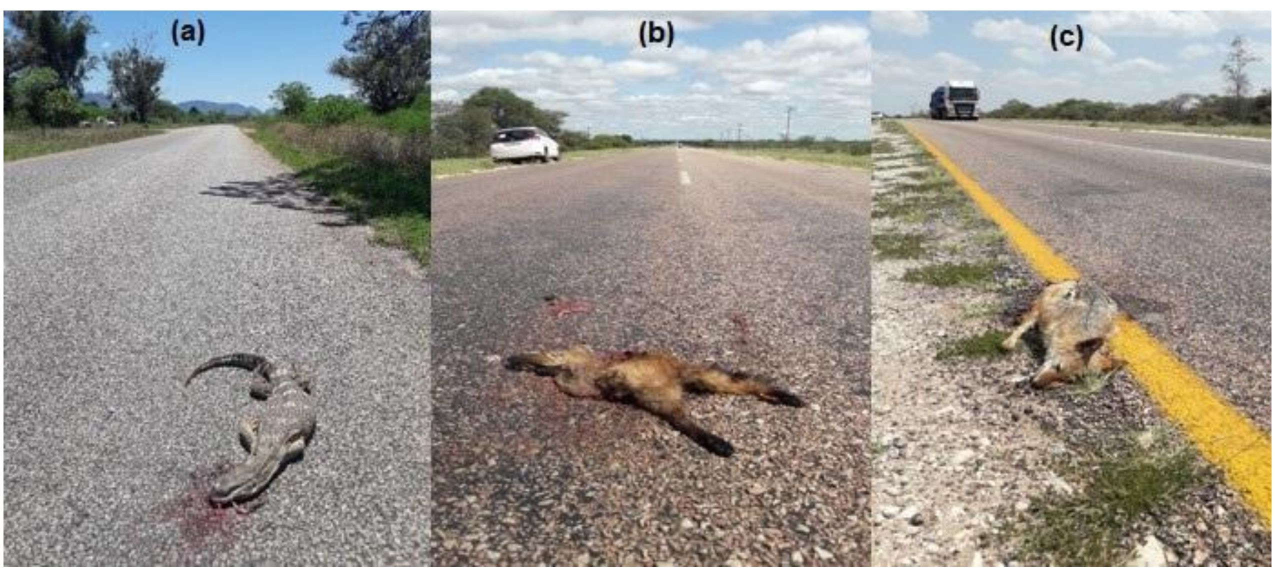

Figure 5: Images of roadkill, illustrating the direct ecological impact of a road in the study area depicting (a) *Varanus albigulsris* (rock monitor), (b) *Otocyon megalotis* (bat-eared fox) and (c) *Canis mesomelas* (black-backed jackal)

In many areas of the country, road infrastructure is not only associated with negatively impacting wildlife but can also cause economic loss for locals residing in the area, due to livestock roadkill. Livestock grazing and production play a significant role in the livelihood of smallholder farmers from many rural and communal areas (Shackleton *et al.*, 2005; Roy & Singh, 2013; Turner *et al.,* 2014). Livestock such as cattle (*Bos taurus*), goats (*Capra aegagrus hircus*) and sheep (*Ovis aries*) are regarded as assets and symbols of wealth in many African cultures and are valued for their contribution to food production and nutrition as well as enhancing food security (Smith *et al.,* 2013).

Livestock grazing forms one of the economic activities within the VBR. However, the roadkill of livestock has become a concern to many rural farmers in the region, who often appear to act irresponsibly by allowing their animals to graze on roadside verges, thus roaming on roads, freely and illegally. This may result in many human road fatalities, vehicle damage, and puts the livestock in danger of becoming roadkill as observed in the study area (Figure 6). Furthermore, adjacent landscapes to roadside verges are often disturbed or damaged to allow development to occur (for example, shopping malls and households), leaving roadside vegetation the only available palatable grazing meadow for livestock.

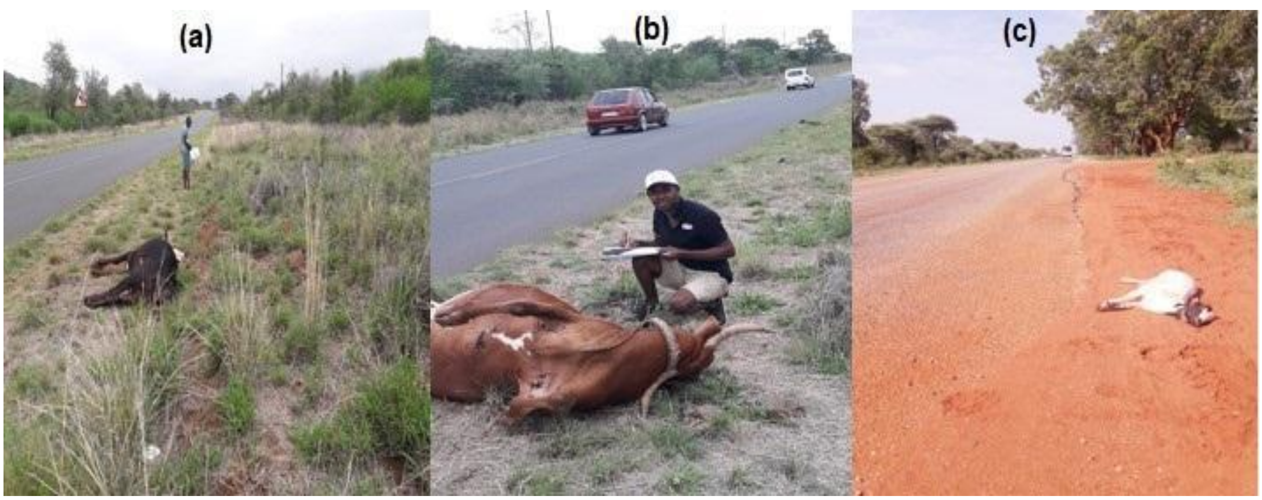

Figure 6: Livestock roadkill in the study area showing (a) and (b) cattle and (c) a domestic goat

2.5. ECOLOGY OF AND THREATS TO AMPHIBIANS

A terrestrial vertebrate taxon that is particularly vulnerable to roadkill is amphibians. Amphibians are ectothermic, meaning that environmental temperatures determine their body temperatures (du Preez & Curruthers, 2009). They are found in almost all terrestrial and freshwater habitats except for distant oceanic islands and Antarctica (Wells, 2007; Stuart *et al.,* 2008). They inhabit ecosystems adjacent to water bodies and all terrestrial and freshwater habitats (Stuart *et al*., 2008), such as freshwater swamps, marshlands, ponds, lakes and streams (Wells, 2007). Globally, amphibians are experiencing population declines due to accelerating threats, such as loss of habitat (International Union for Conservation of Nature (IUCN), 2010). For example, in South Africa, the Critically Endangered Pickersgill's Reed Frog (*Hyperolius pickersgilli)* has declined as a result of human development in the KwaZulu-Natal Province (Tarrant & Armstrong, 2017) while in the Western Cape Province, the Endangered Western Leopard Toad (*Sclerophrys pantherina)* suffers high road mortality during breeding migration periods (IUCN, 2016) and in the Gauteng Province, the Least Concern African Bullfrog (*Pyxicephalus adspersus*) is reported to be negatively impacted by urban development and roadkill (Yetman *et al.,* 2012; Thomas *et al.,* 2014).

2.6. THE AMPHIBIANS OF SOUTHERN AFRICA

Worldwide, there are more than 8 282 species of amphibians, with 7 301 species in the order *Anura* (Stuart *et al.,* 2008), 767 species in the order *Caudata* (salamanders) and 214 species in the order *Gymnophiona* (caecilians) (Frost, 2021). Southern Africa has 171 described species of amphibians (Frost, 2021) with approximately one third of these categorised as Threatened due to increasing threats (Tarrant & Armstrong, 2017; IUCN, 2018).

South Africa has 131 anuran species (Measey *et al*., 2019; Frost, 2021) and the KwaZulu-Natal Province accounts for the highest amphibian species richness (Underhill *et al.,* 2013) (Figure 7). This is due to the favourable environmental conditions and subtropical climate of this region, which comprises the coastal dune forest, montane grassland, and moist, savanna biome (Drinkrow & Cherry, 1995). The Cape Floristic Region has the highest amphibian endemism in the country due to its different micro-habitats and is a centre of endemism (Drinkrow & Cherry, 1995).

Similarly, the VBR, with its unique landscapes that comprise channels of rivers and wetland areas within the northern Limpopo valley, accounts for over a quarter (n=38) of the amphibian species in the province (van Huyssteen, 2018). Here, *Breviceps sylvestris taeniatus* (Near Threatened due to severely fragmented distribution) (IUCN 2010) and *Breviceps mossambicus* (Least Concern) (Minter *et al.,* 2004) are reported to be locally abundant along the Soutpansberg Summit Sourveld in the VBR (van Huyssteen, 2018).

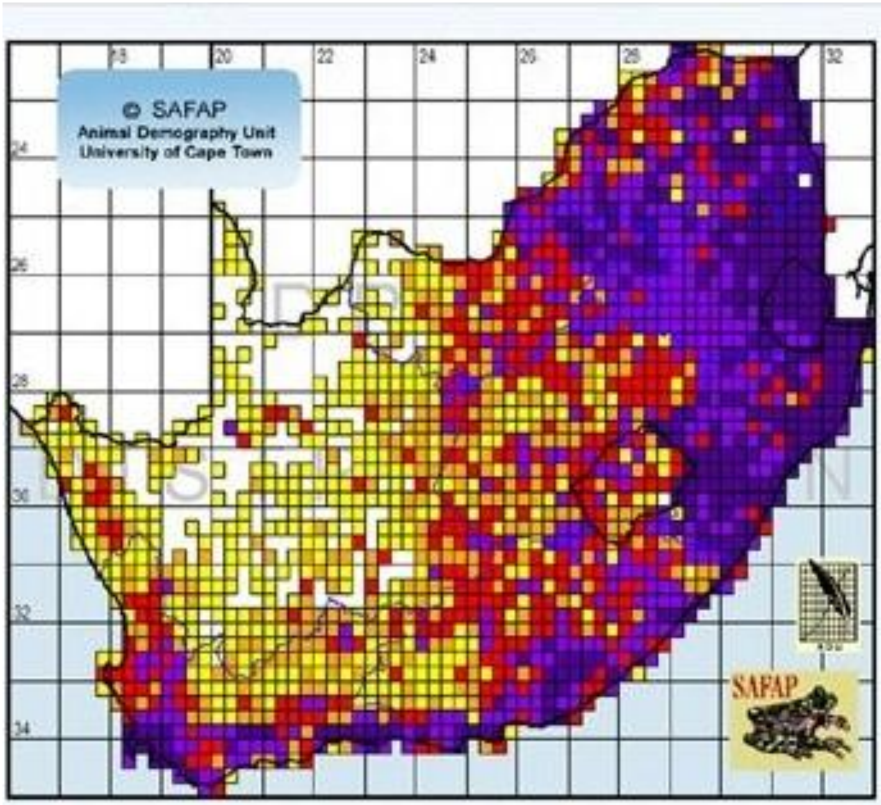

Figure 7: The distribution and diversity of amphibians in South Africa with legend below (Animal Demography Unit (2018). FrogMap database)

Text box 1: Legend

Number of species*	Symbol	No. QDSs	% QDSs
1 - 3	■ (yellow)	414	20.44
4 - 5	■ (orange)	293	14.47
6 - 8	■ (red)	350	17.28
9 - 13	■ (purple)	365	18.02
14 - 50	■ (dark purple)	327	16.15

QDS-Quarter Degree Square

2.7. WHY MUST WE CONSERVE AMPHIBIANS?

Despite efforts made by scientists to address global amphibian decline (Pounds, 1999; Young *et al.,* 2001; Stuart *et al*., 2004), many people do not understand why we should care for amphibians. As a result, persecution of amphibians by humans is continuing to be a critical factor that leads to amphibian population decline globally (Tarrant *et al.,* 2016; Martinez-Abrain & Galan, 2018), despite them providing ecosystem services that directly and indirectly sustain our natural environment and human livelihoods (Valencia-Aguilar *et al*., 2013; Hocking & Babbitt, 2014).

According to the Millennium Ecosystem Assessment, there are four classifications of ecosystem services:

i). Provisioning (useable products such as food, genetic resources, fibre, fresh water and medicinal value);

ii). Regulating (water purification, erosion control, disease control, pest species control, climate regulation, pollination and seed dispersal);

iii). Supporting services (soil formation and primary production); and

iv). Cultural (recreation, religion, spiritual and aesthetic services) (MEA, 2005).

2.7.1 Provisioning

Amphibians serve provisioning services by providing dietary and medicinal needs for humans (MEA, 2005). For example, *Pyxicephalus* species are harvested for food consumption in parts of Mozambique, Botswana, and the Limpopo and KwaZulu-Natal provinces of South Africa (Phaka *et al.,* 2017). Other amphibian species such as the South American giant leaf frog (*Phyllomedusa bicolor*) and african clawed frog (*Xenopus laevis*) naturally secrete toxins, and it has been recognised that such toxins are used for producing antibiotics that may help with depression and heart stimulants (Govender *et al.,* 2012; Hocking & Babbitt, 2014). According to Phaka *et al.* (2017) some traditional healers in the KwaZulu-Natal region burn specimens of *Phrynomantis bifasciatus* and mix them with herbs to treat asthma.

2.7.2 Regulating

According to Wager (1986), amphibians serve a critical role in regulating and nurturing important symbiotic associations in the ecosystem that they occupy (MEA, 2005). Through their predator-prey role, they feed in the middle of the food web eating both smaller vertebrates such as reptiles and small mammals; as well as invertebrates such as worms and anthropods (Carruthers & du Preez, 2011; Phaka *et al*., 2017). This connects amphibians with the feeding interactions of many animal species in the food web. Being insectivores, they control insect pest, and disease-vector populations (Hocking & Babbitt, 2014), which ultimately improves human health (MEA, 2005). At the nymph stage, most amphibians exist as tadpoles that feed on algae (Wager, 1986; du Preez & Carruthers, 2009; Schmidt *et al.,* 2017). Thus, tadpoles regulate algal populations (MEA, 2005), which improves stream quality (Schmidt *et al.,* 2017).

2.7.3 Supporting

The biphasic life cycle and porous skin of amphibians make them highly sensitive to pollution and thus important bio-indicators of ecosystem health (du Preez & Carruthers, 2009; Phaka *et al.,* 2017). Hence, their presence in an ecosystem may help assess the health status of the area.

2.7.4 Cultural

In parts of the world amphibians are perceived as useful charms for good luck and even used for rituals (Roy, 1996). Some species are traded as pets in Europe (Kopecky *et al.,* 2016). In many parts of the African continent, amphibians are perceived as callers of rainfall signalling to people the start of the wet season which is vital for cultivating the land (Mokuku & Mokuku, 2004; MEA, 2005).

2.8. FEATURES OF AMPHIBIAN BIOLOGY THAT MAKE THEM SUSCEPTIBLE TO ECOLOGICAL DEGRADATION

There are several attributes that influence amphibian susceptibility to ecological degradation. Firstly, amphibian skin serves various functions including respiration, protection against pathogens, and assisting with thermoregulation and water balance (Clarke, 1997; du Preez & Carruthers, 2009). To perform these functions the amphibian skin has to be moist and semi-permeable (Hussain & Pandit, 2012), often allowing pollutants and toxins to easily infiltrate. Secondly, many amphibians have a biphasic life cycle that makes them reliant on both aquatic and terrestrial environments (Wells, 2007; du Preez & Carruthers, 2009). Thirdly, *Anura* migrate to different habitat patches in search of resources and for breeding. Both these movement patterns often involve traversing roads, which increases their risk of becoming roadkill (Glista *et al.,* 2008; Rassati, 2016).

2.9. AMPHIBIAN ROADKILL AND FACTORS THAT INFLUENCE THEIR OCCURRENCE

Roads, and their associated users, affect amphibians in the same way that they pose ecological threats to other vertebrate classes (Collinson *et al.,* 2015). Moreover, there are several drivers of wildlife-road-mortalities and these can be classified into environmental, physical, and biophysical factors.

The variables influencing amphibian roadkill are:

1. Landscape and land-use effects (both on roadside verges and surrounding habitat);

2. Distance to open water;

3. Influence of meteorological conditions; and,

4. Road-related features such as, traffic speed, volumes and vehicle types, width of road, and roadside fencing.

2.9.1. Landscape and land-use effects

Numerous variables at the landscape level may be correlated with the presence or absence of amphibians. According to van Buskirk (2004) and Ficetola *et al. (*2008) landscape features play a vital role in the distribution of individual species and their habitats. For instance, roadside environmental features such as the nature of the habitat (Clevenger *et al.,* 2003) and landscape characteristics (Santos *et al.,* 2013) may attract and facilitate animal activity adjacent to roads. Landscapes and land-use type that are close to roads, may influence amphibian activity, and with the presence of roads, may accelerate the risk of amphibian roadkill. Forest and grass litter (Knutson *et al.,* 1999), and arable farmlands (Hansen *et al.,* 2019) also form favourable dispersal, foraging and overwintering habitats that support the terrestrial life stages of amphibians. Farm dams have proven to be beneficial to amphibians, as they serve as potential breeding sites (Hazell *et al.* 2001). However, if roads bisect such landscapes, they may initiate the occurrence of amphibian roadkill.

2.9.2. Distance to open water

Amphibians require aquatic habitats for successful breeding, and when road networks bisect areas with water courses, they may be forced to traverse roads (Fahrig *et al.,* 1995; Ashley & Robinson, 1996; Philcox *et al.,* 1999; Smith & Dodd, 2003; Ficetola *et al.,* 2008; Glista *et al.,* 2008). In Bulgaria, Kambourova-Ivanova *et al.* (2012) discovered that amphibian roadkill was influenced by characteristics of the roadside habitat, particularly the presence of water courses such as wetlands and ponds, as they provide suitable amphibian breeding sites.

2.9.3. Influence of meteorological conditions (climate and weather)

The ectothermic characteristics of amphibians make them reliant on ambient temperature. This renders weather, predominantly air temperature and precipitation, significant factors in controlling their movement patterns (du Preez & Carruthers, 2009; Grant, 2012). Nocturnal amphibian movements are influenced by a range of factors from meteorological parameters (Corn, 2005; Bickford *et al.,* 2010; Grant *et al.,* 2013) to moonlight effect (Grant *et al.,* 2013; Kronfeld-Schor *et al.,* 2013; Onorati & Vignoli, 2017), which determines when they commence their annual breeding.

The life cycle of amphibians largely begins from water, which makes rainfall events significant for initiating amphibian movement. In the event of enough rainfall, new breeding ponds fill up (Marsh, 2000). This may invite more male *Anura* to occupy the flooded ponds and start their vocal choruses to attract females for mating (Grant, 2012). When road networks bisect landscape structures that are located on valley slopes, rainfall events may create temporal pools of water. These temporal pools on the road verge (Appendix D), often form potential breeding sites for some species of amphibians. In the absence of effective amphibian crossing structures, such landscapes may become hotspot areas for amphibian roadkill.

2.9.4. Road related features, traffic, and fencing influence

Road-related features such as road width, traffic volumes and speed limits affect the incidence of wildlife roadkill (Forman *et al.,* 2003; Bullock *et al.,* 2011). The slithering and leaping motions of most reptiles and amphibians can make them more vulnerable when moving across wider roads than species that can easily escape by running or jumping across the road (e.g. mammals) (Glista *et al.,* 2008).

Fencing is a common practice in the conservation of protected areas on the African continent (Spierenburg & Wels, 2006; Ferguson & Hanks, 2012; Lindsey *et al.,* 2012; Bariyanga *et al.,* 2016), especially in the southern part of the continent, where most conservation land is fenced either by electric, game or cattle fence to mitigate human-wildlife conflict (Snijders, 2012; Bariyanga *et al.,* 2016). Although fencing is associated with fragmenting habitats and creating barriers to animal movement (Patterson, 1977; Massey *et al.,* 2014), numerous studies have assessed their efficiency in deterring animals from crossing roads (Dodd *et al.,* 2004). As a result, this has appeared to be an intervention strategy to reduce roadkill (Lesbarrieres & Fahrig, 2012). However, Ghimire *et al.* (2014) argue that protected areas that are fenced, do not always protect smaller wildlife fauna, such as amphibians. Despite their importance in conserving wildlife, smaller fauna, often cross boundaries where protected areas are fenced to inhabit localities outside of them where they are more vulnerable to many threats (Gaston *et al.,* 2008; Ghimire *et al.,* 2014); this includes roadkill (Forman *et al.,* 1998; Eloff & van Niekerk, 2005; Litvaitis & Tash, 2008; Collinson *et al.,* 2014; Yue *et al.,* 2019) and human persecution (Ceriaco, 2011; Tarrant *et al.,* 2016; Phaka *et al.,* 2017).

2.10. THE IMPORTANCE OF IMPROVING ROADKILL RATES ESTIMATION

Determining the magnitude of wildlife roadkill requires counting roadkill over repeated surveys both temporally and spatially. Numerous studies have outlined the possibility of underestimating roadkill rates (Teixeira *et al.,* 2013; Santos *et al.,* 2016; Cabrera-Casas *et al.,* 2020). According to Santos *et al.* (2016), the correct estimation of wildlife roadkill rates is important for evaluating the full impacts on wildlife conservation and therefore, planning mitigation measures. Understanding correct sampling, monitoring and counts of roadkill are key aspects of road ecology, and despite the effort an observer invests in searching for vertebrate carcasses on roads, it is still unlikely that the observer will detect all the carcasses (Teixeira, 2011; Coelho *et al.,* 2012).

There are two parameters that are critical for estimating road mortality rates: 1. carcass detection capacity (P) and, 2. carcass persistence time (T_R) (Teixeira *et al.,* 2013; Santos *et al.,* 2016; Cabrera-Casas *et al.,* 2020), as outlined below:

1) Carcass detection capacity (P) defines the ability of the searcher to spot carcasses on the road since detection may be significantly affected by factors such as the method (e.g. walks or driven surveys), observer ability, road surface, as well as carcass size (Coelho *et al.,* 2014).
2) Carcass persistence time (T_R), is the period up to which a carcass will remain detectable before it disappears depending on traffic volume, size of the carcass, removal by scavengers and weather conditions (Coelho *et al.,* 2014). Amphibians have low carcass persistence times because of their small body size (Santos *et al.,* 2011; Teixeira, 2011).

Both these two parameters complicate roadkill monitoring of amphibians (Coelho *et al.,* 2014) and may result in false conclusions concerning the impact of road mortality on their populations (Cabrera- Casas *et al.,* 2020). Consequently, these factors must be considered when analysing roadkill rates to avoid under and/or over reporting.

2.11. CULTURAL BELIEFS, VALUES AND FOLKLORE IN BIODIVERSITY CONSERVATION

People's beliefs and perceptions of wildlife correlate with the conservation of species (Ceriaco, 2011; Alves *et al.,* 2013; Ghimire *at al.,* 2014; Tomazic & Sorgo, 2017). Schneider (2018) stated that the integration of cultural beliefs and values into conservation may benefit the conservation of biodiversity through the establishment of sacred landscape elements. African folklore often promotes the conservation of wildlife (Jones *et al.,* 2008; Baker, 2013), which is critical for sustainable wildlife conservation. Folklore has long been recognised as having a positive effect on the conservation of wild species through the establishment of practical indigenous knowledge (Mokuku & Mokuku, 2004). Some examples are given below:

1) The Swati tribe in the Mpumalanga Province, South Africa, and around Swaziland, portrays a strong belief that the knysna turaco (*Turacus corythaix*) is associated with beauty, luck and royalty (Thwala, 2018). Consequently, coming across this species is perceived to symbolise good fortune but killing it is associated with misfortune. This therefore, promotes a liking for the species and improves its conservation by decreasing its risk of persecution.
2) The Pedi tribe in the Limpopo Province, South Africa, believe that the call of the Letlametlu frog or edible bullfrog (*Pyxicephalus edulis*) is associated with rainfall because they often croak when it rains (Mokuku & Mokuku, 2004). This makes the species valued since rainfall is associated with cultivating the land and a good harvest.

The above shows that people have different understandings and relationships with amphibians depending on their location, cultural belief and personal experiences (Alves *et al.,* 2013). Positive folklore towards wildlife not only promotes the conservation of species, but may also improve the way cultural beliefs influence the attitudes and perceptions with which people perceive wildlife (Tarrant *et al.,* 2016). This is significant in promoting positive attitudes towards wildlife and their acceptance by the public and makes it imperative to understand indigenous beliefs that may influence people's attitudes and values pertaining to the conservation of natural assets (Tui, 2007).

Despite the critical role played by folklore in the conservation of wildlife, negative cultural beliefs towards some animal species are responsible for accelerating human-wildlife-conflict in many protected areas. Amphibians are generally less valued by many people, and negative mythological concepts around native amphibians increase negative attitudes, which impacts negatively on their conservation (du Preez & Carruthers, 2009; Ceriaco, 2012; Tarrant *et al.,* 2016; Phaka *et al.,* 2017).

Amphibians are often referred to as ugly creatures and feared by people in many parts of the world with some cultures perceiving them as symbols of evil spirits (Tarrant *et al.,* 2016; Phaka *et al*., 2017). For example, toads, in some places, are associated with witchcraft and demonic magic (Parish, 2019), whilst Tarrant *et al.* (2016) discovered that many people who hate amphibians had a strong belief in the myth that touching a frog or toad causes warts on their hands. Exploring the impacts of negative folklore on wildlife is critical in modifying human attitudes towards wildlife and developing sustainable development plans for the effective conservation of native species.

2.12. REDUCING HARMFUL CULTURAL AMPHIBIAN PERCEPTIONS THROUGH COMMUNITY ENGAGEMENT IN WILDLIFE CONSERVATION

The involvement of indigenous community members in wildlife-conservation-campaigns can establish an effective transfer of skills and knowledge (Borrini-Feyerabend *et al*., 2004). It presents an opportunity for local people to express their thoughts, feelings and concerns regarding the conservation challenges experienced in their conservancy. Community engagement, as a tool for sustainable wildlife conservation, requires that local people be recognised as stakeholders in conservation efforts (Zacharia & Kaihula, 2001). This is critical in creating a more flexible bottom-up conservation approach for the management of wildlife, specifically in protected areas (Ward *et al.,* 2018). This may ultimately improve anti-conservation attitudes that exists in many African societies, through creating a community-based-conservation approach.

Engaging local communities in the conservation of wildlife may also establish a co-management system where the state, local people, private entities, non-governmental organisations (NGOs) and other non-state entities exercise shared management agreement rights to protected areas (Berkes 2010; Borrini-Feyerabend *et al.,* 2013; Ward *et al.,* 2018). Furthermore, it may provide an opportunity to reconcile human livelihoods with biodiversity conservation, resulting in communities where people are optimistic about biodiversity, enabling humans to live in harmony with their natural assets. In South Africa, Measey *et al.,* (2019) stated that a new strategy for amphibian conservation research would emphasise the potential for citizen science input and continue to explore ways of building capacity for conservation research on South Africa's amphibians.

2.13. THE POWER OF CITIZEN SCIENCE IN ROAD ECOLOGY

The use of citizen science (i.e. members of the public) projects to facilitate ecological monitoring and data collection has gained momentum in the last decade (Silvertown, 2009; Dickinson *et al.,* 2012; Kobori *et al.,* 2016), developing as a functional mechanism that enables the participation of interested, indigenous people in scientific studies (Frigerio *et al.,* 2018). Monge-Najera (2018) states that citizen science has been actively used in recording wildlife mortality on roads, hence, data adopted by this approach can be reliable in identifying hotspots for roadkill (Periquet *et al.*, 2018).

To address the negative impacts of roads on wildlife, road ecologists need to identify hotspot areas of roadkill (Forman *et al.,* 2003; Seiler, 2005; Fahrig & Rytwinski, 2009). This will assist in the prioritisation of roadkill mitigation measures, which include the installation of structures during road construction and development. Quantifying road impacts on wildlife through this inclusive approach, may make data collection easier and help cover larger areas (Periquet *et al.*, 2018). Incorporating citizen science into ecological projects is not only favourable to scientists but may also benefit the broader community through increasing stewardship among citizen scientists (Mcaffrey, 2005). Furthermore, results from citizen science projects should be made accessible to the public not only to increase their knowledge but also to motivate people to continue with the submission of data (Nerbonne & Nelson, 2004). It may also provide a platform for the exchange of knowledge between members of the public and scientists, and finally, researchers may learn useful indigenous knowledge.

2.14. ENSURING SUCCESS FOR CITIZEN SCIENCE INITIATIVES

Citizen science initiatives are underpinned by a volunteer approach that stems from pro-social behaviour and does not involve monetary rewards (Akintola, 2011; Vecina & Marzana, 2019). However, for any volunteering initiative to achieve its outcomes, there is a need to consider what motivates people to participate (Clary *et al.,* 1998; Papadakis *et al.,* 2005). Farmer and Fedor (2001) suggested that the motivation that drives people to volunteer may vary, hence exploring these reasons is critical for the performance and sustainability of the initiative (Clary *et al.,* 1998; Clary & Snyder, 2002; Stukas *et al.,* 2009; Vecina & Marzana, 2019). When volunteers are inspired and motivated, the recruitment of more participants increases (Stukas *et al.,* 2009), and in addition, makes the initiative more impact oriented (Rokach & Wanklyn, 2009).

Establishing citizen science initiatives in areas with dominant negative cultural beliefs and folklore about wildlife is more difficult because of people showing less motivation to participate (Ceriaco, 2012). This, however, provides an opportunity to improve the negative attitudes of members of the public towards wildlife. This can be done through effective educational campaigns where members of the public participate (Tarrant *et al.,* 2016). Such campaigns will improve people's awareness and help change their paradigm on how they perceive wildlife (Ceriaco, 2012; Tarrant *et al.,* 2016). As a result, many environmental organisations have widely adopted two broad strategies to achieve an inclusive conservation approach: i) encouraging citizens to practice sustainable and environmentally friendly lifestyles, and ii) motivate people to look after natural resources and interact with their natural environment (Saunders, 2003).

These two strategies are key in motivating a member of the public's participation in community wildlife conservation initiatives. Clary *et al.* (1998) developed a functional theory of volunteerism that summarises the value functions that drive people to volunteer (Table 3). The functional theory suggests that people are motivated to volunteer because they want to satisfy a value function (either humanitarian or altruistic value). These can be categorised into six functions (Table 3). The functional theory of volunteerism suggest that people do not volunteer because there are no motives that motivate for their participation. The theory further demonstrates that analysing and understanding the functional motives of people may direct approaches to get more people to volunteer (Clary *et al.,* 1998; Papadakis *et al.,* 2005).

Table 3: Functional motive categories for volunteerism (Clary *et al*., 1998)

#	Functional motive	Description
1.	Understanding	It provides a way to enhance learning and acquire knowledge, skills and abilities.
2.	Enhancement	Establish the opportunity to develop and grow one's ego.
3.	Protective	Provides a way of protecting the ego of an individual from the difficulties of life.
4.	Social	Initiate a mechanism to develop and strengthen social ties.
5.	Values	Enables the expression of altruistic and humanitarian values.
6.	Career	Instil the ability for an individual to improve his or her present and future career prospects.

2.15. SUMMARY OF THE LITERATURE REVIEW

In the above literature review, road ecology and the importance of incorporating citizen science into road ecological initiatives were briefly described. Road ecology has been linked with the movement ecology of amphibians to understand how road systems may impact the persistence of amphibians mainly through wildlife roadkill. Moreover, the features that make it imperative to monitor amphibian roadkill were explored. The review further examined how cultural beliefs and folklore about amphibians may influence people's attitudes towards this animal class, which ultimately limit their participation in amphibian roadkill citizen science initiatives. The review discussed ways to ensure success for citizen science initiatives through understanding what motivates people to volunteer.

CHAPTER 3: STUDY DESIGN AND METHODS IN THE STUDY AREA

3.1 AMPHIBIAN ROADKILL IN THE WESTERN SOUTPANSBERG

3.1.1. Monitoring amphibian roadkill on regional buffer roads of the western Soutpansberg

Amphibian roadkill incidences were monitored following the methodology described by Collinson *et al.* (2014) and was conducted on three regional roads that surround the western Soutpansberg Mountains, namely the R522 (50 km), R521 (7 km) and R523 (46 km) totalling 103 km. The N1 road was not surveyed because it is a dual carriageway, hence not comparable with the other regional roads. The three regional roads were monitored using driven surveys for a total of 70 days across two consecutive amphibian migratory seasons (Season 1 = 35 days from 22 December 2018 to 16 February 2019 and Season 2 = 35 days from 15 November 2019 to 19 December 2019). The days were selected by considering the meteorological factors that influence amphibian activity as described in 2.9.3, hence, days that were associated with higher amphibian activity were selected for monitoring.

Roadkill surveys were conducted using a vehicle, driving at a speed of 20 to 30 $km^{-1}h^{-1}$, with one trained observer (the same observer for all surveys) to detect roadkill carcasses on the road (Collinson *et al.,* 2014). The monitoring trips began approximately 1.5 h^{-1} after sunrise and lasted for the time necessary to complete the entire 100km stretch. Upon detection of a roadkill, the vehicle was stopped safely on the roadside with the hazards turned on, the location recorded using a handheld GPS (Garmin-Etrex 10), the specimen identified to species level where possible and photographed for verification purposes. Carcasses were removed from the road to avoid recounting. A heat map for amphibian roadkill was drafted based on the roadkill data collected during the two ecological seasons using ArcGIS software (ESRI, 2011). To estimate risk areas for amphibian roadkill, road sections that had > 10 amphibian roadkill incidences per km per week were identified as potential high risk areas (hotspots). Road sections that had roadkill counts between 5 and 10 per km per week were identified as medium risk areas and sections that had < 5 roadkill incidences per km per week were marked as low risk areas.

3.1.2. Estimating roadkill rates for the monitored regional roads

Amphibian roadkill rates were estimated by dividing the total roadkill found for each monitored road section of a km/day, as described by Garrah *et al.* (2015) and Kummoo *et al.* (2020) .The units for roadkill rates were reported as roadkill magnitude·km^{-1}·day^{-1}. This study could not determine the traffic volumes for each of the studied three regional buffer roads, because of limited resources. Despite the study primarily focusing on amphibian roadkill, data on other vertebrate fauna (e.g. mammals, birds and reptiles) were also collected as it would be useful for establishing an overall baseline roadkill inventory for the study site (Appendix E).

3.1.3. The influence of roadside habitat type characteristics on the occurrence of amphibian roadkill in the western Soutpansberg

Roadside habitat and land-use types along the three road stretches monitored were assessed through driving the monitored road stretches to determine how they influence the occurrence of amphibian roadkill. Following visual observations, the vegetation stratification patterns along the road segments were assessed on both sides of the road (modified from Milton *et al.* (2015)) and divided into six roadside habitat types (Figure 7). These were then recorded for each of the 248 amphibian carcasses observed during the roadkill surveys (as modified from Chase *et al.* (1989) and Wuczynski (2005)).

The number of roadside habitats were assessed for each carcass and allocated a score of 1 if there was one habitat type (for both sides of the road) (Wuczynski, 2005). If more than one roadside habitat type was observed for the same carcass, each habitat type was allocated an equal fraction of the score 1. The scores for each habitat type was obtained by summing the values allocated for each. The proportion for each habitat type was compared with the expected values based on habitat availability in the study area (Makhado Municipality IDP review 2019/2020). The influence of the distinguished roadside habitat types on the amphibian roadkill distribution was determined using Jacobs' index (Jacobs, 1974):

$$D = \frac{r - p}{r + p - 2pr}$$

Where, *r* denotes the proportion of amphibian roadkill specimens in a given habitat type, *p* the proportion of a given habitat type in the study area, and *D* the Jacobs' index score which varies from -1 (complete avoidance-low roadkill occurrences) through 0 (habitat use proportional to habitat availability-moderate roadkill) to 1 (exclusive use-high roadkill occurrences).

A test for goodness-of-fit (Chi-square) was employed to deduce the relationship between landscape, land-use structures and the occurrence of roadkill for amphibians in the SPA.

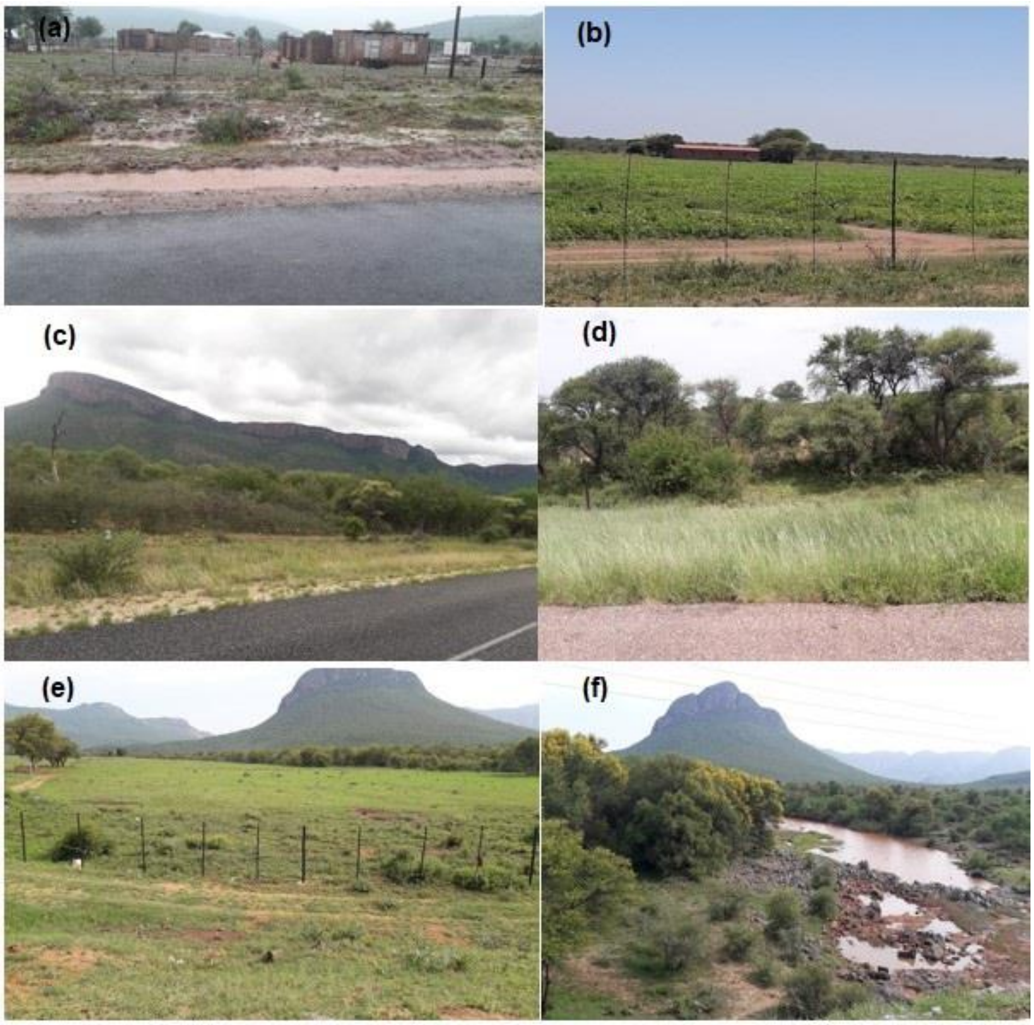

Figure 8: The six roadside habitats identified for describing roadkill occurrence in the VBR: Roadside habitat types (a) residential area, (b) crop cultivation area, (c) area of dense forest, (d) open savannah bushland, (e) livestock grazing meadow and (f) waterbody

3.2. METHODS TO INVESTIGATE IF PUBLIC FOLKLORE, HUMAN ATTITUDES AND LACK OF KNOWLEDGE ABOUT AMPHIBIANS IMPEDE ACTIVE PARTICIPATION OF LOCALS IN AMPHIBIAN ROADKILL CITIZEN SCIENCE PROJECTS IN HA-KUTAMA VILLAGE

3.2.1. Study area

This study was conducted in Ha-Kutama village which lies in the Makhado local municipality, Limpopo Province, with map reference coordinates 23.0704°S, 29.6191°E (Figure 9). To minimise bias in the demographic questionnaires surveys (De Leeuw *et al.,* 2008), we conducted our surveys during the 2018 and 2019 festive season period when the majority of the members of the community (males and females) were on holiday and available to participate during the day on both weekdays and weekends.

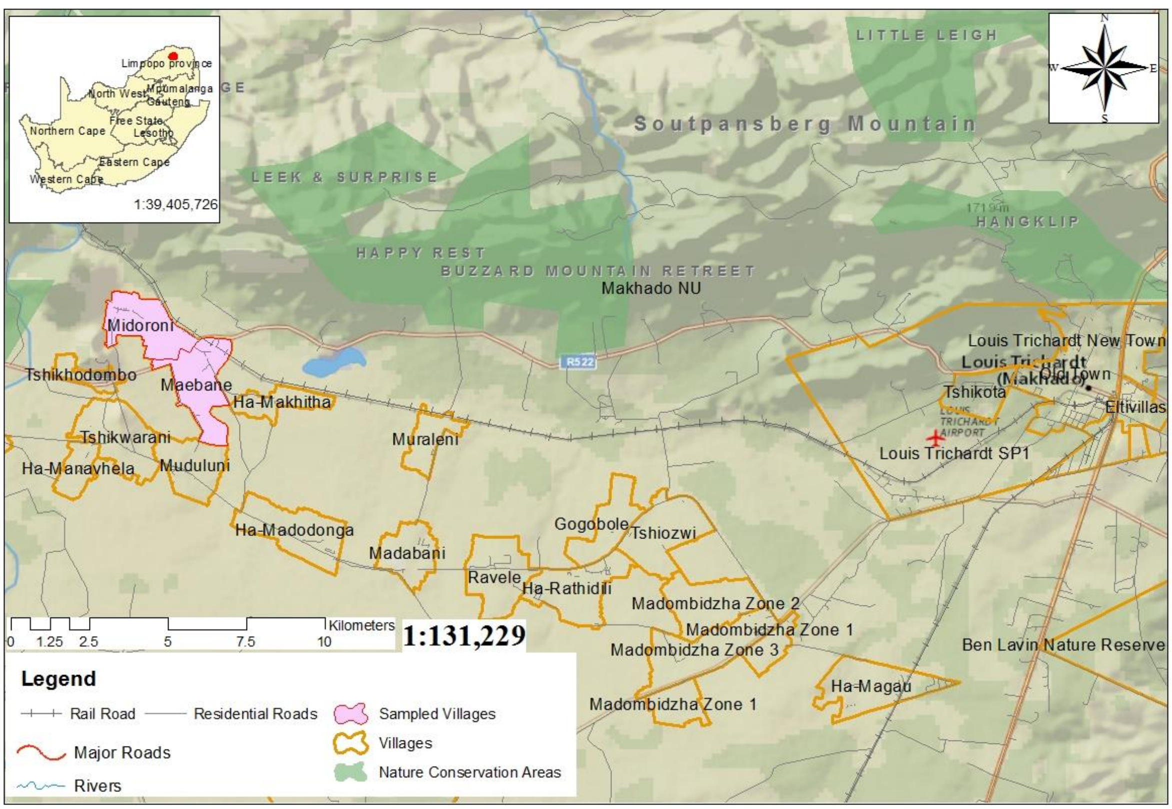

Figure 9: A map showing the Ha-Kutama Tribal Authority and its villages in the Soutpansberg Protected Area with the study site highlighted in pink

The area forms part of the Soutpansberg Protected Area (SPA) and is a tribal village under the tribal leadership of chief Vho-Kutama. Census data by Statistics South Africa (2018) indicate that Ha-Kutama has a population of 1 871, (population density of 1 203 person/km²), with a total household number of 466 and an average household size of four. The population of Ha-Kutama comprises 99.8% Black African, 0.1% Indian / Asian and 0.1% others (Statistics South Africa, 2018). The region is one of the poorest in the country with an unemployment rate of 53.9% (Ramarumo & Maroyi, 2020), a situation aggravated by the low standard of education in 90% of poorly resourced rural schools. Moreover, only 6.5% of the people in this area have acquired tertiary education, with most people traditionally orientated (Figure 10). Many villagers are therefore embedded in their rich cultural beliefs, which is the norm for many rural areas and around the Soutpansberg region (Khorombi, 2007; Mutshinyalo & Siebert, 2010). The local economy in the study area relies largely on farming, tourism in the surrounding holiday resorts and nature reserves on the mountain slopes, as well as government grants (Makhado IDP 2018/19).

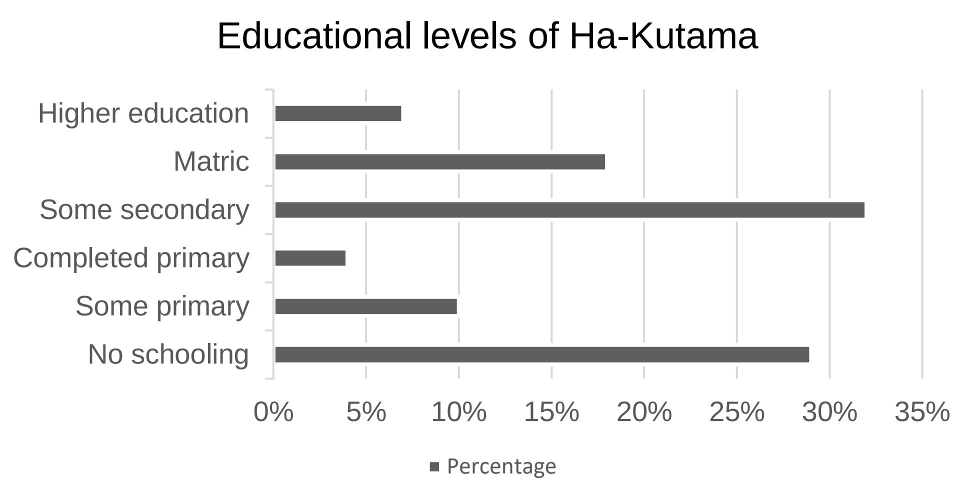

Figure 10: Educational levels in the Ha-Kutama Tribal Authority (Statistic South Africa, 2018)

3.2.2. Questionnaire construction and analysis methods

This study relied on a functionalist approach to explore if attitudes, lack of knowledge, and cultural beliefs towards amphibians have the potential to impede effective participation of locals in amphibian roadkill community volunteering initiatives (method modified from Ceriaco (2012) and Tarrant *et al.* (2016)). Four different constructs (variables) were compiled with each representing different latent variables (namely: Liking, Knowledge, Cultural beliefs and Likeliness to volunteer in amphibian roadkill projects). These were modified to questionnaires which comprised 16 questions that rated the four constructs (Table 7). The four latent constructs formed hypothetical variables that are not directly measured but rather estimated from a set of indicator items that may be directly observed and measured (Byrne, 2001). For this study to develop the four different constructs (scales) on the beliefs and generalised ideas about amphibians throughout the entire South African population, we relied on the questionnaire survey template from the Endangered Wildlife Trust's Threatened Amphibian Programme (EWT-TAP). Their approach involved having conversations about this vertebrate class with different people (e.g. university biologists, ecologists and sociologists) and by reviewing the existing literature (Drews 2002; du Preez & Carruthers, 2009; Ceriaco, 2012).

The scale for measuring the construct 'Liking' was generated on the basis of three item statements which conveyed positive and negative feelings and phobia towards amphibians (e.g. 'I do not mind having frogs in my yard (property)' (Appendix I). Five item statements that defined the ecological characteristics and potential threats to amphibians were generated to measure the 'Knowledge' construct. This enabled the assessment of whether respondents are knowledgeable about the importance and threats concerning amphibians (e.g. 'Roadkill of frogs may reduce their population in South Africa'). The general ideas and concepts that local people often associate with amphibians in South Africa was used to measure the 'Cultural beliefs' construct. It comprised four items that were positively formulated statements (e.g. 'frogs symbolise evil spirits'). The scale for measuring the construct 'volunteering in amphibian roadkill projects', four photo-question statements that were formulated positively were used (e.g. 'I feel sad when I see frogs smashed on the road'). Reliability analyses were conducted for the scales by using the Cronbach's alpha as an indicator of internal consistency (Byrne, 2001). Furthermore, general linear models were used to explore how the dependent variables varied amongst the socio-demographic factors (age group, gender status and educational level) using IBM SPSS Statistics (Version 25).

3.2.3. Data collection processes and sampling

The study primary data were collected from 15 November 2018 to 19 January 2019 and from 18 November 2019 to 18 December 2020 at Ha-Kutama in the Soutpansberg. The Survey Monkey software (Bentley *et al.,* 2017) was used to determine the sample size for this study. As the study focused on households around Ha-Kutama, the total household number was taken as the population size.

Following permission to conduct the research by Musanda Vho-Kutama and his headmen (Vhakoma), 246 questionnaire-photo surveys (Appendix I) were administered throughout the village (Maebane and Midoroni area) (De Leeuw, 2008). Adult participants (>18 years) were selected from each household in the study location following door-to-door surveys, and respondents were selected by randomly requesting consent of participation from any person found in each household. After obtaining the informed consent to participate in the study from the respondents, the purpose and scope for the study were explained and all participants assured that their identities would remain confidential. A total of 246 respondents from 246 households participated in the study, comprising 109 (44%) males and 137 (56%) females. Respondents were categorized into three age groups: youth (18 to 35 years), adults (36 to 59 years) and elderly (≥60 years). Respondents were also categorised into five educational levels (no formal education, primary, secondary, tertiary and graduates). Respondents were asked questions relating to their liking, knowledge, cultural beliefs and probability to volunteer in projects to save amphibians from roadkill. Ethical clearance for conducting this part of the study was obtained from the University of Venda, research ethics committee (Project No: SES/18/ERM/13/1511).

3.3. DATA ANALYSIS

Jacobs' Index (Jacobs, 1974) analysis was used to assess the influence of roadside habitat and land-use structures on the occurrence of amphibian roadkill (as outlined in 3.1.3). Univariate statistics (a reliability test and generalised linear models) were used to investigate if people's attitudes towards amphibians in Ha-Kutama villages influence their willingness to participate in amphibian roadkill citizen science projects. All data were analysed using IBM SPSS (version 25).

CHAPTER 4: RESULTS

4.1. MONITORING AMPHIBIAN ROADKILL IN THE WESTERN SOUTPANSBERG

4.1.1. Amphibian roadkill inventory for the western Soutpansberg

Over a 70-day monitoring period of surveying roadkill, a total of 248 amphibian roadkill specimens were recorded (Table 4), comprising eight species belonging to six amphibian families and one unidentified specimen. The current study reported a 60% (n=148) roadkill for toads although in terms of species representation, frogs were more common comprising six of the eight identified species (Table 4).

Amphibian roadkill occurrence varied significantly between the two ecological seasons, with the hot/wet season representing 72% (n=180) of the total recorded roadkill while the hot/dry season had 28% (n=68). For both seasons, *Schismaderma carens* had the highest roadkill incidences with 37% (n=92 specimens), followed by *Pyxicephalus edulis* (27%; n=68). Most of the amphibian roadkill species had a conservation status of Least Concern (LC) on the IUCN Red List (IUCN, 2013), with one roadkill of *Pyxicephalus adspersus* having a conservation status of Near Threatened (NT) in South Africa (Table 4).

Table 4: Amphibian roadkill inventory for the western Soutpansberg (presenting: scientific names, family, activity (N- Nocturnal and D- Diurnal), IUCN conservation status (LC-Least Concern, NT-Near Threatened), roadkill magnitudes for both seasons

#	Scientific name	Family	Activity	IUCN Status	Number of roadkill		
					Hot / dry	Hot / wet	Total
1.	*Breviceps adspersus*	Brevicipitidae	N	LC	0	2	2
2.	*Kassina senegalensis*	Hyperoliidae	N	LC	0	3	3
3.	*Ptychadena anchietae*	Ptychadenidae	N	LC	0	9	9
4.	*Pyxicephalus adspersus*	Pyxicephalidae	D	NT	1	0	1
5.	*Pyxicephalus edulis*	Pyxicephalidae	N	LC	19	49	68
6.	*Schismaderma carens*	Bufonidae	N	LC	31	61	92
7.	*Sclerophrys garmani*	Bufonidae	N	LC	14	42	56
8.	*Tomopterna natalensis*	Ranidae	N	LC	2	14	16
9.	*Unknown*	Unknown	Unknown	Unknown	1	0	1
TOTAL					**68**	**180**	**248**

4.1.2. Roadkill rates estimate for regional roads surrounding the western Soutpansberg Mountain

Road mortality rates for the combined three roads (100 km segment) (Table 5), was 0.035 roadkill·km^{-1}·day^{-1} (Table 5). Amphibian roadkill rates varied significantly amongst the monitored road tracks, with 0.043 roadkill·km^{-1}·day^{-1} on the R522 being the highest (Table 5). The R523 had 0.029 roadkill·km^{-1}·day^{-1}, whilst the R523 had the lowest roadkill proportions (0.022 roadkill·km^{-1}·day^{-1}). The proportion of roadkill was greatest in the hot/wet season (n = 180 and 0.051 roadkill·km^{-1}·day^{-1}) and lowest in the hot/dry season (n = 68 and 0.019 roadkill·km^{-1}·day^{-1}) (Table 5). Roadkill density for *Schismaderma carens*, *Pyxicephalus edulis* and *Sclerophrys garmani* were highest along the surveyed regional roads.

Table 5: Road track monitored; species recorded; number of roadkill observed during driven surveys (n); mean roadkill (calculated as the number of observed kill divided by the total number of kilometres surveyed (roadkill·km^{-1}·day^{-1})); and the average roadkill rate on regional roads that traverse the western Soutpansberg

#	Road	Species	Hot/dry		Hot/wet		Both seasons average
			n	roadkill·km^{-1}·day^{-1}	n	roadkill·km^{-1}·day^{-1}	
1	R522 (50 km)	*Breviceps adspersus*	0	0.000	1	0.0006	0.0003
		Kassina senegalensis	0	0.000	3	0.002	0.0009
		Ptychadena anchietae	0	0.000	4	0.002	0.001
		Pyxicephalus edulis	11	0.006	29	0.017	0.011
		Schismaderma carens	24	0.014	33	0.019	0.016
		Sclerophrys garmani	9	0.005	24	0.014	0.009
		Tomopterna natalensis	2	0.001	8	0.005	0.003
		Unknown	1	0.0006	0	0.000	0.0003
		Total	**47**	**0.027**	**102**	**0.058**	**0.043**
2	R523 (43 km)	*Breviceps adspersus*	0	0.000	1	0.0007	0.003
		Ptychadena anchietae	0	0.000	5	0.003	0.002
		Pyxicephalus adspersus	1	0.0007	0	0.000	0.0003
		Pyxicephalus edulis	6	0.004	16	0.011	0.007
		Schismaderma carens	6	0.004	29	0.019	0.012
		Sclerophrys garmani	7	0.005	12	0.008	0.006
		Tomopterna natalensis	0	0.000	5	0.003	0.002
		Total	**20**	**0.013**	**68**	**0.045**	**0.029**
3	R521 (7 km)	*Pyxicephalus edulis*	0	0.000	7	0.029	0.014
		Schismaderma carens	1	0.004	3	0.012	0.009
		Total	**1**	**0.004**	**10**	**0.041**	**0.022**
Average roadkill rate (100 km segment)			**68**	**0.019**	**180**	**0.051**	**0.035**

Whilst more amphibian roadkill rates occurred on the R522 and R523, the R521 had a slightly lower roadkill incidence and roadkill rates (Figure 11), with few species (*Pyxicephalus edulis* and *Schismaderma carens* only).

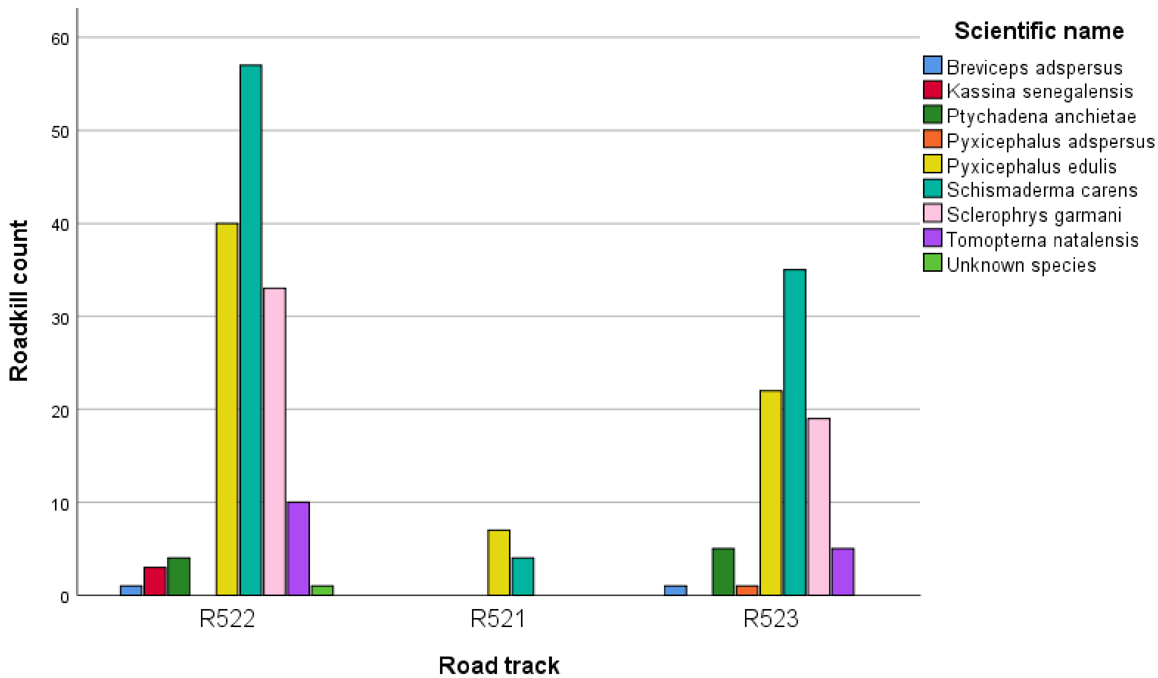

Figure 11: Representation of amphibian roadkill along the three monitored road segments in the western Soutpansberg

4.1.3. Heat map of amphibian roadkill in the western Soutpansberg

The spatial distribution of roadkill incidences along the surveyed regional roads indicated a clustering distribution of roadkill incidents as opposed to a random pattern. Certain road sections had higher roadkill incidents (hotspots), whilst other sections of the road had lower or no roadkill occurrence (Figure 12). The R522 had the most hotspots for amphibian roadkill, whilst the R521 had the least. Moreover, hotspots for amphibian roadkill varied with different land use and roadside habitat types for all the surveyed road segments (Figure 12).

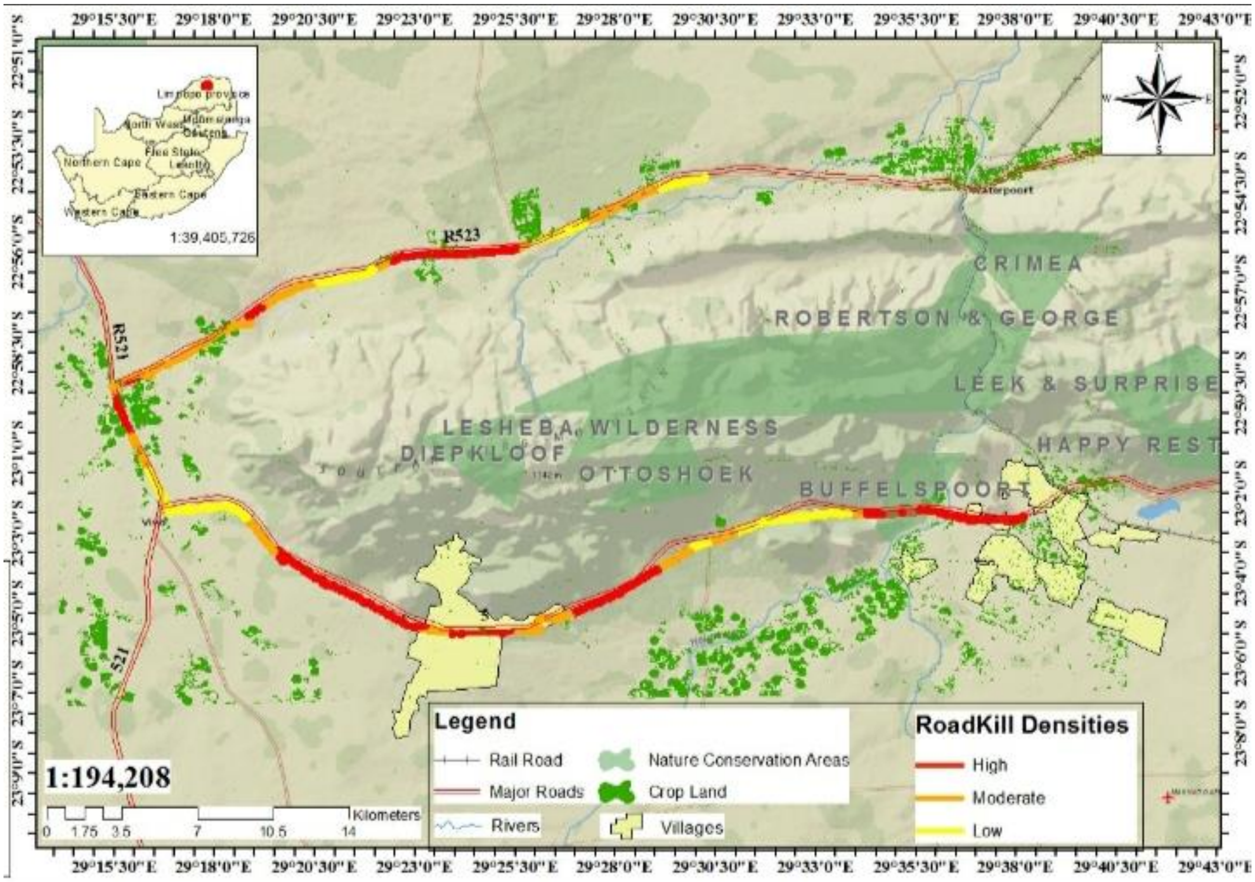

Figure 12: The amphibian roadkill heat map for regional road networks that bisect the western Soutpansberg

4.1.4. Influence of roadside habitat on the occurrence of amphibian roadkill

The results showed that amphibian roadkill occurrence was predominantly influenced by roadside habitat types for both seasons (hot/dry and hot/wet) (χ^2 = 17.091; df = 5; N = 248; $p <$ 0.05).

Based on Jacobs' Index (Figure 13), roadside habitat with open savanna bushland accounted for most amphibian roadkill (all species, Jacobs' Index: 0.17), whilst areas adjacent to a waterbody were associated with moderate roadkill incidences (five species, Jacobs' Index: 0.08). The frequency of roadkill around habitat types that had closed vegetation canopies (dense forest) was close to proportional (five species, Jacobs' Index 0.02) (Figure 13). Roadkill frequency was low in areas that comprised livestock grazing meadow, crop cultivation area and residential area roadside habitat types (Jacobs' Indices of – 0.05, – 0.07 and – 0.18) (Figure 13).

Table 6: The influence of roadside habitat characteristics on the occurrence of amphibian roadkill in the present study

#	Roadside habitat	Hot / dry season (S1)	Hot / wet season (S2)	Total	Pearson Chi-square	df	*P*-value
1	Open savanna bushland	24	98	122	17.091	5	0.004
2	Area of waterbody	20	29	49			
3	Area of dense forest	14	14	28			
4	Livestock grazing meadow	4	17	21			
5	Crop cultivation area	3	15	18			
6	Residential area	3	7	10			
a. 2 cells (16.7%) have expected count less than 5. The minimum expected count is 2.74							

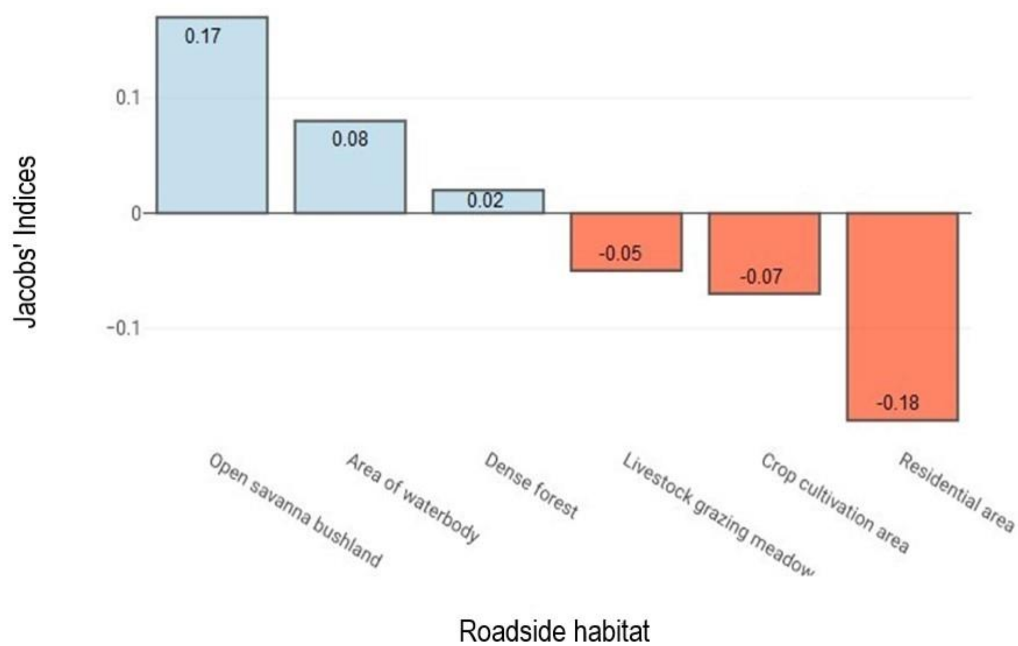

Figure 13: Jacobs' index scores for amphibian roadkill detected along the six habitat types in the SPA

4.1.5. Wildlife roadkill for the other observed vertebrate species in the western Soutpansberg

This study has recorded 356 roadkill of other vertebrate taxa. The carcasses comprised 61 species from 16 orders and 39 families of reptiles, mammals and birds (Appendix E). The data also included three roadkill of domestic animals from the *Bovidae* family (*Bos taurus* and *Capra aegagrus hircus*). When amphibians were included, the overall roadkill magnitude for this study resulted in a total of 604 comprising 69 species from 22 orders and 45 families. The results indicate that amphibians had the highest roadkill magnitude with 41% (n=248), followed by reptiles at 24% (n=142) and birds at 23% (n=136), whilst mammals have a lower roadkill magnitude with 13% (n= 78).

4.2. THE WILLINGNESS OF LOCAL PEOPLE IN HA-KUTAMA VILLAGE TO PARTICIPATE IN AMPHIBIAN ROADKILL CITIZEN SCIENCE PROJECTS

4.2.1. Socio-demography

A total of 246 respondents belonging to 246 households were surveyed using questionnaire-photographic surveys in Ha-Kutama village. Respondents represented three age groups with 44% (n=109) males and 56% (n=137) females, and all were black South Africans. The demography was biased in age with a representation of 71% youth (18 to 35 years), 13% adults (36 to 59 years) and 16% elderly (≥60 years). The educational status of respondents consisted of 10% (n=25) who did not attend school, 7% (n=16) with primary education, 35% (n=86) with secondary education, 24% (n=60) with some tertiary education and 24% (n=59) who have graduated. The results indicated that liking of amphibians, knowledge, cultural beliefs and the likelihood of respondents to participate in amphibian roadkill initiatives varied significantly amongst socio-demographic groups with gender, age and educational status.

4.2.2. Cronbach’s alpha results

The scores showed a higher mean for liking of amphibians (mean = 5.01 and SD = 3.14) compared with knowledge, cultural beliefs and likelihood of volunteering in amphibian roadkill projects (mean = 3.37, 3.87, 2.33 and SD = 1.67, 1.15, 2.67, respectively (Table 7). The findings revealed a reliability coefficient (Cronbach’s Alpha) of 68% or more for all the items measured, with alpha value ranging between 0.682 and 0.835 (Table 7).

Table 7: Univariate statistics and reliability (Cronbach's alpha) of scales used: 'Liking', 'Knowledge', 'Cultural beliefs', and 'Roadkill survey'. For all the scores, the scales used showed a reliable variance, with alpha ≥ 68% (*survey procedure from Ceriaco (2011 and 2012); and Tarrant et al. (2016))*

Scale	Mean	SD	Min.	Max.	Alpha
Liking	**5.01**	**3.14**	**1**	**10**	**0.682**
I like frogs	2.61	1.31	1	10	
I am scared of frogs	2.47	1.28	1	10	
I do not mind having frogs in my yard (property)	2.40	1.14	1	10	
Knowledge	**3.87**	**1.67**	**1**	**10**	**0.704**
Roadkill of frogs reduce their populations in SA	2.57	1.41	1	10	
Frogs eat insects	2.31	1.24	1	10	
Frogs are the most threatened group of animals	2.35	1.36	1	10	
Frogs are sensitive to pollution	2.74	1.37	1	10	
It is important to share the environment with frogs	2.56	1.25	1	10	
Cultural beliefs	**3.87**	**1.15**	**1**	**10**	**0.698**
Frogs call rainfall	2.98	3.14	1	10	
Frogs symbolise evil spirits	4.81	3.79	1	10	
Frogs are used for witchcrafts	4.80	3.22	1	10	
Touching frogs will give you warts	2.64	3.57	1	10	
Amphibian roadkill survey	**2.33**	**2.67**	**1**	**10**	**0.835**
I feel sad when I see frogs smashed on the road	1.93	1.09	1	10	
I can help frogs cross the road safely	2.10	1.10	1	10	
I can report frog roadkill using roadkill reporting App	2.60	1.11	1	10	
I can volunteer in a community frog roadkill project	2.48	1.24	1	10	

4.3. The generalised linear model results

4.3.1. Influence of attitudes to amphibians in Ha-Kutama village

The influence of attitude to amphibians in Ha-Kutama village showed significant variation amongst all the socio demographic variables (Table 8). Liking of amphibians in the study area varied significantly between gender statuses of respondents. Females indicated significantly greater liking for amphibians (mean=2.72, df=1, F–value 7.938, $p < 0.05$) than males (mean= 1.90, df=1, F–value=7.938, $p < 0.05$). In terms of age group, the youth (18 to 35 years) showed a higher mean for liking of amphibians (mean=2.78, df=2, F–value=4.082, $p < 0.005$) than adults (36 to 59 years) and the elderly (≥60 years) (Table 8). Respondents with some secondary education had the most liking of amphibians (mean=3.00, df=4, F–value=4.494, $p < 0.05$), followed by those with tertiary education and graduates (tertiary: mean=2.94 and graduates: mean=2.45; df=4, F–value=4.494, $p < 0.005$, respectively) (Table 8). The results revealed that respondents with some educational background indicated a greater liking of amphibians than those who did not go to school and those with less education (primary education) (Table 8).

The influence of phobia towards amphibians by people of Ha-Kutama village varied amongst the socio-demographic variables, with male respondents showing significantly greater fears (mean=2.87, df=1, F–value=4.739, p <0.05) than females (mean=2.24, df=1, F–value=4.739, p < 0.05). The influence of phobia towards amphibians in terms of age and educational level of respondents did not indicate a significant difference (Table 8). In terms of gender status, male respondents had a higher mean for not having a problem with amphibians being present in their yard (property) than females, however, this difference was not statistically significant. The youth (18 to 35 years) of Ha-Kutama village had the highest mean for not having a problem with amphibians being in their yard (mean=2.60, df=2, F–value=3.032, p < 0.001) than respondents who are adults and elders (>35 years). Respondents who had some educational background indicated that they do not mind having amphibians in their yard (graduated: mean=2.60, secondary: mean=2.32, tertiary: mean=2.05; df=4, F–value=3.032, p < 0.05).

Table 8: The influence of liking (attitudes) of amphibians according to socio-demography

Demographics	Sample		Mean	df	F-value	*p*-value
	No.	%				
Dependent variable: I like frogs						
Gender: Male	109	44	1.90	1	7.938	0.005
Female	137	56	2.72			
Age (years): 18 to 35	175	71	2.78	2	4.082	0.018
36 to 59	33	13	2.27			
≥60	38	16	1.94			
Educational status: Did not attend school	25	10	1.55	4	4.494	0.002
Primary	16	7	2.15			
Secondary	86	35	3.00			
Tertiary	60	24	2.94			
Graduated	59	24	2.45			
Dependent variable: I am scared of frogs						
Gender: Male	109	44	2.87	1	4.739	0.031
Female	137	56	2.24			
Age (years): 18 to 35	175	71	2.42	2	0.203	0.081
36 to 59	33	13	2.63			
≥60	38	16	2.42			
Educational status: Did not attend school	25	10	2.58	4	0.500	0.736
Primary	16	7	2.10			
Secondary	86	35	2.55			
Tertiary	60	24	2.85			
Graduated	59	24	2.42			
Dependent variable: I do not mind having a frog in my yard (property)						
Gender: Male	109	44	2.10	1	3.854	0.034
Female	137	56	2.05			
Age (years): 18 to 35	175	71	2.60	2	7.997	0.000
36 to 59	33	13	1.80			
≥60	38	16	1.61			
Educational status: Did not attend school	25	10	1.78	4	3.032	0.018
Primary	16	7	1.53			
Secondary	86	35	2.32			
Tertiary	60	24	2.05			
Graduated	59	24	2.60			

4.3.2. Influence of knowledge regarding amphibians in Ha-Kutama village

The influence of knowledge regarding amphibians in the study area varied among all the socio demographic variables (Table 9). The dependent variable "Roadkill of frogs reduce their population in South Africa" showed a significant variation amongst all the demographic variables. Gender showed a statistically significant difference, with females more knowledgeable about roadkill as a threat to amphibians (mean=2.72, df=1, F–value=7.938, p < 0.05) than males (mean=1.90, df=1. F–value=7.938, p < 0.05) (Table 9). According to age group, the youth (18 to 35 years) is more knowledgeable about roadkill as a threat to amphibians than the other two categories (mean=2.78, df=2, F–value=4.082, $p < 0.05$). Educational level of respondents showed a statistically significant variance, with people that had some educational background more knowledgeable (tertiary: mean=3.00, graduates: mean=2.95, and secondary: mean=2.45, df=4: F–value=4.494, $p < 0.01$) than those with primary and no education (mean=1.44 and mean=1.15, df=2; F–value=4.494, $p < 0.01$, respectively) (Table 9).

The dependent variable "frogs eat insects" varied amongst all the socio-demographic variables, and the difference was not statistically significant. The dependent variable "frogs are the most threatened group of animals worldwide" varied amongst all the socio-demographic variables, the difference was not statistically significant. According to gender, females were more knowledgeable about the item statement that frogs are sensitive to pollution (mean=2.56, df=2, F–value=3.047, $p < 0.05$) than males (mean=2.51, df=2, F–value= 3.047, $p < 0.05$). The youth (18 to 35 years) indicated significant greater knowledge about the item statement that frogs are sensitive to pollution than the other two age categories (youth: mean=3.00, pensioner: mean=2.39 and elderly: mean=2.11, df=2, F–value=4.675, $p < 0.05$) The demographic variable gender and educational status of respondents did not show a statistically significant difference on the item statement that it is important to share the environment with frogs. Age categories of respondents showed a significant difference and the youth was more aware that it is important to share the environment with frogs than the other two age categories (youth: mean=2.72, elderly: mean=1.96 and pensioners: mea1.63, df=2, F–value=8.171, $p < 0.001$)

Table 9: The influence of knowledge regarding amphibians according to socio-demography

Demographics	Sample No.	Sample %	Mean	df	F-value	*p*-value
Dependent variable: Roadkill of frogs reduce their populations in SA						
Gender: Male	109	44	1.90	1	7.938	0.005
Female	137	56	2.72			
Age (years): 18 to 35	175	71	2.78	2	4.082	0.018
36 to 59	33	13	2.27			
≥60	38	16	1.94			
Educational status: Did not attend school	25	10	1.15	4	4.494	0.002
Primary	16	7	1.55.			
Secondary	86	35	2.45			
Tertiary	60	24	3.00			
Graduated	59	24	2.95			
Dependent variable: Frogs eat insects						
Gender: Male	109	44	1.92	1	1.499	0.222
Female	137	56	2.21			
Age (years): 18 to 35	175	71	2.10	2	1.721	0.181
36 to 59	33	13	2.31			
≥60	38	16	1.78			
Educational status: Did not attend school	25	10	1.61	4	1.812	0.127
Primary	16	7	2.30			
Secondary	86	35	2.18			
Tertiary	60	24	2.52			
Graduated	59	24	1.92			
Dependent variable: Frogs are the most threatened group of animals						
Gender: Male	109	44	2.89	1	0.451	0.502
Female	137	56	2.72			
Age (years): 18 to 35	175	71	2.99	2	1.888	0.154
36 to 59	33	13	2.78			
≥60	38	16	2.48			
Educational status: Did not attend school	25	10	2.03	4	1.662	0160
Primary	16	7	2.08			
Secondary	86	35	2.88			
Tertiary	60	24	3.18			
Graduated	59	24	3.03			
Dependent variable: Frogs are sensitive to pollution						
Gender: Male	109	44	2.51	2	3.047	0.028
Female	137	56	2.56			
Age (years): 18 to 35	175	71	3.00	2	4.675	0.010
36 to 59	33	13	2.11			
≥60	38	16	2.39			
Educational status: Did not attend school	25	10	2.53	4	1.899	0.111
Primary	16	7	2.77			
Secondary	86	35	2.94			
Tertiary	60	24	2.77			
Graduated	59	24	2.39			
Dependent variable: It is important to share the environment with frogs						
Gender: Male	109	44	2.07	1	0.497	0.482
Female	137	56	2.26			
Age (years): 18 to 35	175	71	2.72	2	8.171	0.000
36 to 59	33	13	1.96			
≥60	38	16	1.63			

Educational status: Did not attend school	25	10	2.33	4	1.184	0.319
Primary	16	7	2.31			
Secondary	86	35	2.46			
Tertiary	60	24	1.94			
Graduated	59	24	1.99			

4.3.3. Influence of cultural beliefs regarding amphibians in Ha-Kutama village

The socio-demographic variables gender, age and educational levels of respondents were significantly related to the cultural belief that frogs call rainfall. According to gender, female respondents showed prominent belief than male respondents (females: mean= 2.72, males: mean=1.90, df=1, F–value=7.938, $p < 0.01$; Table 10). In terms of age, the youth (18-35 years) showed significant greater belief on that frogs call rainfall than respondents from the other two age categories (youth; mean=2.78, elderly: mean=2.27, pensioner; mean=1.94, df=2, F–value=4.082, $p < 0.05$; Table 10). The educational status of respondents varied significantly, respondents with some secondary education showed significant greater belief on the belief that frogs call rainfall than those with primary or no educational background as indicated in table 10 (Secondary: mean=3.00, tertiary: mean=2.94, primary: mean=2.13, did not attend school: mean=1.15, df=4, F–value=4.494, $p < 0.01$).

Gender and age reflected a statistically significant difference in relation to the cultural belief that frogs symbolise evil spirits, with gender (df= 1, F–value = 3.242, $p < 0.05$) and age (df= 2, F–value =3.764, $p < 0.05$; Table 10). Respondents who were adults (35 to 59 years) and elders (≥60 years) had higher means for believing that frogs symbolise evil spirits, whilst the youth had the lowest mean (adults: mean=3.06, elderly: mean=2.43 and youth: mean= 1.97). There was no significant difference between educational statuses of respondents with the cultural belief that frogs symbolise evil spirits (df=4, F–value=0.646, $p > 0.05$).

The cultural belief that frogs are used for witchcrafts indicated a significant variance between gender and age of respondents, with gender (df=1, F–value=9.291, $p < 0.001$) and age (df=2, F–value=3.314. $p < 0.05$) as illustrated in table 10. Male respondents showed prominent belief on the cultural belief that frogs are used for witchcrafts than females (males: mean=2.97 and females: mean=2.13). Respondents from the elderly and adults age categories had higher means for believing that frogs are used for witchcrafts than youth respondents (elderly: mean=3.52, adults: mean=2.83 and youth: mean=1.50). There was no significant difference between gender, age and the educational statuses of respondents with the cultural belief that touching a frog will give you warts (gender: df=1, F–value=0.169, $p > 0.05$, age: df=2, F–value=2.031, $p > 0.05$ and education: df=4, F–value= 1.130, p > 0.05).

Table 10: The influence of cultural beliefs according to socio-demography

Demographics	Sample No.	Sample %	Mean	df	F-value	*p*-value
Dependent variable: Frogs call rainfall						
Gender: Male	109	44	1.90	1	7.938	0.005
Female	137	56	2.72			
Age (years): 18 to 35	175	71	2.78	2	4.082	0.018
36 to 59	33	13	2.27			
≥60	38	16	1.94			
Educational status: Did not attend school	25	10	1.15	4	4.494	0.002
Primary	16	7	2.13			
Secondary	86	35	3.00			
Tertiary	60	24	2.94			
Graduated	59	24	2.55			
Dependent variable: Frogs symbolise evil spirits						
Gender: Male	109	44	3.22	1	3.242	0.022
Female	137	56	3.18			
Age (years): 18 to 35	175	71	1.97	2	3.764	0.034
36 to 59	33	13	3.06			
≥60	38	16	2.43			
Educational status: Did not attend school	25	10	3.19	4	0.646	0.630
Primary	16	7	3.50			
Secondary	86	35	3.31			
Tertiary	60	24	2.96			
Graduated	59	24	3.03			
Dependent variable: Frogs are used for witchcrafts						
Gender: Male	109	44	2.97	1	9.291	0.000
Female	137	56	2.13			
Age (years): 18 to 35	175	71	1.50	2	3.314	0.024
36 to 59	33	13	2.83			
≥60	38	16	3.52			
Educational status: Did not attend school	25	10	2.83	2	0.773	0.083
Primary	16	7	2.80			
Secondary	86	35	2.76			
Tertiary	60	24	2.77			
Graduated	59	24	2.56			
Dependent variable: Touching frogs will give you warts						
Gender: Male	109	44	2.35	1	0.169	0.068
Female	137	56	2.61			
Age (years): 18 to 35	175	71	2.07	2	2.031	0.133
36 to 59	33	13	2.37			
≥60	38	16	2.70			
Educational status: Did not attend school	25	10	2.49	4	1.130	0.0743
Primary	16	7	2.09			
Secondary	86	35	2.50			
Tertiary	60	24	2.59			
Graduated	59	24	2.23			

4.3.4. Likelihood to volunteer in amphibian roadkill projects

The likelihood of respondents to participate in amphibian roadkill citizen science projects showed a significant variance amongst all the socio-demographic variables for all the measured item statements, except for educational status under the item statement “I can report frog roadkill using a cell phone reporting App” (df=2, F–value=2.962, $p > 0.05$; Table 11). Gender, age and educational status of respondents varied significantly in relation to the item statement “I feel sad when I see frogs smashed on the road”, with gender (df=1, F–value=7.938, $p < 0.01$), age (df=2, F–value=4.082, $p < 0.05$) and educational status (df=4, F–value= 4.494, $p < 0.01$).

The socio-demographic variable gender, age and educational status of respondents varied significantly for the item statement “I can help frogs cross the road safely” in the study area (gender: df=1, F–value=5.721, $p < 0.05$, age: df=2, F–value=9,291, $p < 0.001$ and educational status: df=4, F–value=3.241, $p < 0.05$. Female respondents showed a significantly greater interest of reporting amphibian roadkill using a cell phone reporting App than males (females; mean=2.76 and males: mean=2.50, df1, F–value=3.638, $p < 0.05$; Table 11). Respondents who were at tertiary and graduates showed prominent likelihood of reporting amphibian roadkill using a cell phone reporting App than respondents with poor educational background (tertiary: mean=3.04, graduates: mean=2.76, secondary: mean=2.54, Primary: mean=2.14, df=4, F–value=3.319, $p < 0.05$; Table 11).

Female respondents were more willing to volunteer in amphibian community projects than males (females: mean=2.50 and males: mean=2.05, df=1, F–value=3.638, $p < 0.005$; Table 11). A significant difference was observed for age group, with the youth (18 to 35 years) of Ha-Kutama village showing a significantly greater desire to participate in amphibian roadkill citizen science projects (mean=2.70) than adult (mean=2.17 and elderly (mean=2.00) respondents, this difference was statistically significant (df=2, F–value=3.233, $p <0.05$; Table 11). Respondents with tertiary education had prominent willingness to participate followed by graduates and those with secondary education (tertiary: mean=2.60, graduates: mean=2.40, secondary; mean=2.39, df=4, F–value=2.656, $p < 0.005$) as illustrated in table 11.

Table 11: The likeliness of respondents to participate on amphibian roadkill citizen science initiatives according to socio-demography

Demographics	Sample No.	Sample %	Mean	df	F-value	*p*-value
Dependent variable: I feel sad when I see frogs smashed on the road						
Gender: Male	109	44	1.90	1	7.938	0.005
Female	137	56	2.72			
Age (years): 18 to 35	175	71	2.78	2	4.082	0.018
36 to 59	33	13	2.27			
≥60	38	16	1.94			
Educational status: Did not attend school	25	10	1.55	4	4.494	0.002
Primary	16	7	2.15			
Secondary	86	35	2.94			
Tertiary	60	24	3.00			
Graduated	59	24	2.45			
Dependent variable: I can help frogs cross the road safely						
Gender: Male	109	44	1.62	1	5.721	0.018
Female	137	56	1.84			
Age (years): 18 to 35	175	71	2.44	2	9.291	0.000
36 to 59	33	13	2.37			
≥60	38	16	1.64			
Educational status: Did not attend school	25	10	2.31	4	3.241	0.013
Primary	16	7	1.75			
Secondary	86	35	2.51			
Tertiary	60	24	2.74			
Graduated	59	24	3.01			
Dependent variable: I can report frog roadkill using roadkill reporting App						
Gender: Male	109	44	2.50	1	3.638	0.038
Female	137	56	2.76			
Age (years): 18 to 35	175	71	2.82	2	2.962	0.057
36 to 59	33	13	2.79			
≥60	38	16	2.29			
Educational status: Did not attend school	25	10	2.40	4	3.319	0.025
Primary	16	7	2.14			
Secondary	86	35	2.54			
Tertiary	60	24	3.04			
Graduated	59	24	2.76			
Dependent variable: I can volunteer in a community frog roadkill project						
Gender: Male	109	44	2.05	1	8.370	0.004
Female	137	56	2.50			
Age (years): 18 to 35	175	71	2.70	2	3.233	0.041
36 to 59	33	13	2.17			
≥60	38	16	2.00			
Educational status: Did not attend school	25	10	2.06	4	2.656	0.034
Primary	16	7	1.96			
Secondary	86	35	2.39			
Tertiary	60	24	2.60			
Graduated	59	24	2.40			

CHAPTER 5: DISCUSSION

5.1. AMPHIBIAN ROADKILL IN THE WESTERN SOUTPANSBERG

Roadkill inventory

This study investigated the impacts of roads and road users on amphibians during the hot / dry and hot / wet ecological seasons between December 2018 to February 2019 and November 2019 to January 2020 in the western Soutpansberg following amphibian activity each year. The occurrence of amphibian roadkill varied significantly between the two ecological seasons, demonstrating the importance of seasonality on animal activity, which appear significant for road ecology studies (Main and Allen, 2002; Carvalho *et al.,* 2017). Even though there was an overlap between the two seasons, the hot / wet ecological season (November 2019 and January 2020) accounted for 73% (n=180) of amphibian roadkill, with the remaining 27% (n=68) occurring in the hot / dry ecological season (December 2018 to February 2019). This demonstrated that the difference in roadkill between the two seasons was more likely an effect of differing weather conditions between the two monitoring periods. This further signified the importance of sampling year-round to observe and capture the activity patterns of the species under investigation under different weather conditions.

The study showed that three species of amphibians were more vulnerable to roadkill in the study area (*Schismaderma carens*, *Pyxicephalus edulis* and *Sclerophrys garmani*). However, this was likely a reflection of their abundance throughout the region (van Huyssteen, 2018). This emphasises the link between species abundance and the occurrence of wildlife roadkill (Gonçalves *et al.,* 2018). Furthermore, the life history and ecology of each species may be critical in defining its resource use and movement (Zhang *et al.,* 2018). For example, *Breviceps adspersus* inhabits bushland, dry savanna and agricultural land; and its breeding phenology does not associate with a waterbody as eggs are laid in a subterranean chamber after rainfall (Du Preez & Carruthers, 2009) and it moves slowly (IUCN, 2020). Therefore, despite this species being common in the SPA (van Huyssteen, 2018), it accounted for less than 1% of roadkill. We suggest this may be because of its ecology and habitat-use-pattern.

Roadkill rate comparison

A survey of global amphibian roadkill studies indicated that roadkill rates differed significantly. For example, amphibian roadkill rates for this study (0.035 roadkill·km^{-1}·day^{-1}) were lower than those of Garrah *et al.* (2015) in Ontario, Canada (3.32 roadkill·km^{-1}·day^{-1}) and Zhang *et al.* (2018) in

Wanglang National Nature Reserve, China (0.38 roadkill·km^{-1}·day^{-1}). Although there are no published amphibian roadkill studies in Africa, local comparison relied on the existing vertebrate roadkill studies that incorporated amphibians in their general wildlife roadkill inventories. A comparison of the current study findings with other African vertebrate roadkill studies showed that amphibian roadkill rates for this study (0.035 roadkill·km^{-1}·day^{-1}) were higher than the rates reported by Kioko *et al.* (2015) (0.004 roadkill·km^{-1}·day^{-1}).

The current study reported lower amphibian roadkill rates compared with the vertebrate roadkill inventory of Collinson *et al.* (2015) which reported 0.2 roadkill·km^{-1}·day^{-1} from three species (*Breviceps adspersus*, *Sclerophrys garmani* and *Chiromantis xerampelina*) in the Greater Mapungubwe Transfrontier Conservation Area (GMTCA, Limpopo Province). As these two studies were undertaken in different parts of the VBR, our inventory included more amphibian species than the inventory of Collinson *et al.* (2015) which only had roadkill specimens belonging to three species. The difference in amphibian species composition between the two studies indicated that the Soutpansberg region of the VBR have high diversity of amphibian (with ~38 species) (van Huyssteen, 2018) compared to the GMTFCA which has poor amphibian richness (with ~12 species) (Braack, 2009; Carruthers & du Preez, 2011).

The findings for both studies indicate that *Sclerophrys garmani* is widespread within the VBR and roadkill of this species was more predominant in both the western Soutpansberg and GMTFCA. The difference in amphibian species composition between the study area (western Soutpansberg) and the GMTFCA, may be the result of variation in rainfall, as the southern region of the VBR receives more rainfall than the north where the GMTFCA is located (Hahn, 2010). As a result, this caused variation in habitat type and species composition between these two areas in the VBR (Hahn, 2010). This further demonstrated that surveys quantifying road impacts on wildlife could provide information regarding the distribution of species, new and rare species, as well as the ecology of species (Schwartz *et al.,* 2020).

Habitat and rainfall influence

Roadside habitat and land-use characteristics along the monitored road stretches significantly influenced the distribution of amphibian roadkill, and was critical in forming spatial clustering of roadkill incidents on specific road locations as illustrated on the amphibian heat map (Appendix B). Furthermore, this supported the findings of Coelho *et al.* (2012) and Girardet *et al.* (2015) who had reported on the clustering pattern of roadkill on certain sections of the road. However, this was in contrast to the findings of Clevenger *et al.* (2002) who stated that roadkill is randomly distributed along the road track monitored. The identification of amphibian roadkill hotspots in relation to roadside landscape may have substantially influenced the habitat use for the available species in the area (Coelho *et al.,* 2012). Most amphibian roadkill incidences were observed on road sections dominated by open savanna bushland compared to areas that were adjacent to a waterbody, whilst roadkill occurrence was low on road stretches adjacent to livestock grazing meadow, crop cultivation and residential areas. This was likely due to land-use change in the area which had degraded the landscape, making certain areas less favourable for amphibians. This resulted in those sections of the area having less roadkill (Kioko *et al.,* 2015).

Rainfall was related to the occurrence of amphibian roadkill in the study site (Appendices C and D), which support previous studies that reported higher amphibian activity when it rains (Carruthers & Du Preez, 2009; Grant, 2012; Grant *et al.,* 2013; Olgun *et al.,* 2020). However, due to insufficient rainfall data for the study site, this study was not able to measure the influence of rainfall on the occurrence of amphibian roadkill even though more roadkill (~64%) were observed during monitoring days that had a rainfall event.

5.2. ATTITUDES OF HA-KUTAMA VILLAGE RESIDENTS TOWARDS FROGS

Amphibians are perceived negatively by many tribes across Africa. Majority of people are still uneasy around amphibians compared to other taxonomic groups (Ceriaco, 2012; Tarrant *et al.,* 2016), which may be influenced by existing cultural beliefs and attitudes towards amphibians. The present study revealed that gender and age of the respondents were related to the item statement that "I am scared of frogs", which indicate that majority of people in the study area have significant fears for amphibians. However, the study still presents prominent liking of amphibians in Ha-Kutama village. The results demonstrated a statistically significant association between the all the sociodemographic variables and the item statement "I like frogs" (gender: df=1, F–value=7.938, $p < 0.05$, age: df=2, F–value=4.082, $p < 0.05$ and education status: df=4, F–value=4.494, $p < 0.05$). To support this, gender, age and educational status of respondents were all related to the item statement "I do not mind having a frog in my yard (property), which is an indication of positive attitude. The majority of respondents who confirmed to do not mind having amphibians in their 'yard' or on their property, mainly believed that frogs are God's creatures. This is an indication of positive attitudes and provides a good starting point for improving awareness and educational campaigns that will improve their knowledge concerning conserving frogs in Ha-Kutama. The current study supports the findings of Tarrant *et al.* (2016) which discovered a good indication of attitudes of people towards amphibians in South Africa. The current study discovered that female respondents had greater liking for amphibians than males, which is contrary to the findings of Tarrant *et al.* (2016) who found a significantly greater liking of frogs from males.

Although all the socio-demographic variables were related to the item statement that "roadkill of amphibians reduce their population is South Africa", which reflects some knowledge about amphibian roadkill being a potential threat, the overall knowledge scale reveals that most local people from the Ha-Kutama have limited knowledge regarding amphibians. Despite amphibian roadkill not scientifically explored in Africa, it still indicate that there should be more knowledge generated about this threat and initiative taken to address it and this supports the recommendations of Glista *et al.* Collinson *et al. (*2015). Gender, age and education status of respondents were not related to the item statement that frogs eat insects. Moreover, the respondents were not aware that amphibians are the most threatened groups of animals, with all the socio-demographic variables indicating a non-statistically significant association. Majority of the respondents were also not knowledgeable about that it is important to share the environment with amphibians, with both gender and educational level status not statistically significant. This indicate that there is no recognition of some of their importance in the environment.

Strong cultural beliefs exist about amphibians among village elders in the study area. With the study findings reflecting a significant relationship between cultural beliefs and socio-demographic variable gender and age. This implies that many people in this village still believe unproven myths about amphibians that could promote their dislike and fear towards them. Despite majority of the youth respondents being less likely to believe negative folklore about amphibians, the study also discovered positive beliefs from some of the elders who never attended school. In relation to cultural perceptions, one of the respondents stated that, "amphibians are clean creatures that love themselves, thus, inhabit and breed in clean streams" which explains their liking for amphibians (Tarrant *et al.,* 2016). This interpretation shows that the local people have some knowledge regarding the ecology of amphibians, as Phaka *et al.* (2017) and du Preez and Carruthers (2009) stated that amphibians can be used as bio-indicators of ecosystem health and tadpoles play a critical role in purifying water through regulating algae in river systems.

Gender was also shown to influence attitudes significantly, with the majority of male respondents having dominant cultural beliefs about amphibians, this may have contributed to the poor liking of amphibians by males in the study site. Women were more prone to liking amphibians and this is a reflection of their prominent likelihood to volunteer in amphibian roadkill citizen science initiative in Ha-Kutama village.This suggests that females in the study area are more environmentally-oriented than males. This appears to be in contrast with other studies that had reported more active participation of males than females in conservation citizen science initiatives in Africa and

Australia (Larson *et al.,* 2016; Brown *et al.,* 2018). Even though the majority of people in the study area strongly believing in cultural beliefs that have the potential to promote anti-conservation attitudes to the conservation of amphibians similar to the findings of Ceriaco (2012), the study still presents a positive indication of the attitudes of the people of Ha-Kutama towards amphibians.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

The aim of this dissertation was to investigate the impacts of road infrastructure and their associated users on amphibians on three regional roads that surround the western Soutpansberg Mountains of the VBR in the Limpopo Province. The findings of the study confirmed that comparison of roadkill amongst vertebrate groups indicated roadkill for amphibians was highest, followed by reptiles. The results of this study provide evidence that wildlife roadkill may be a potential conservation concern in the study area. Moreover, road infrastructure and its traffic may gradually be a potential contributor to population declines of several amphibian species in the Soutpansberg (eg. *Schismaderma carens*, *Pyxicephalus edulis* and *Sclerophrys garmani*). This case study has provided an amphibian roadkill inventory that comprise 248 roadkill specimens from eight known species and one specimen which was not identifiable.

Even though the study did not determine the traffic volumes for the studied road sections, it has discovered significant amphibian roadkill rates on the studied roads. The study findings presented baseline data for amphibian roadkill in one of the important conservation areas of South Africa. This case study has examined the extent of roadside habitat characteristics influencing amphibian roadkill, which is imperative for surveying hotspots for roadkill. The findings of this study also support similar studies showing that amphibians suffer threats from roads in the vicinity of their preferred habitats (Glista *et al.,* 2008; Heigl *et al.,* 2016; Zhang *et al.,* 2018), as is the case with other animal taxa.

Through questionnaire-photo surveys, this study shows that people's perceptions about amphibians have the potential to make them less interested in volunteering in amphibian community initiatives (e.g. roadkill reporting and mitigation projects). This highlights the need for investment in modifying people's attitudes and perceptions towards wildlife (Ceriaco, 2012; Tarrant *et al.,* 2016; Brom *et al.,* 2020). The current research study, although limited in scope, still presents an opportunity for researchers in conservation ecology to collaborate in creating more robust survey techniques for wildlife roadkill around South Africa, particularly for threatened taxonomic groups. This will improve national and regional inventories for wildlife roadkill for local species, which is important for expanding the checklist of species at risk from roads. Furthermore, this study has also emphasised collaborative approaches towards combating wildlife roadkill, through involving local communities, and stakeholders, on South African roads.

6.2. RECOMMENDATIONS

This dissertation provides baseline data and it is recommended that additional research is needed about the population dynamics of amphibians in the Soutpansberg i.e. to provide a comparison of amphibian populations that are at a greater or lesser threat from roadkill. This will build robust data sets to guide recommendations for future mitigation measures that will ensure safe crossing places for amphibians and other wildlife during their seasonal breeding migrations.

In addition, this study further highlights the need for South Africa to invest in training more road ecologists (at the grassroots level (primary, secondary and tertiary)); this will contribute to developing human capital for road ecology and is critical in ensuring sustainable transportation infrastructure development that will promote socio-economic development while safeguarding a viable future for South Africa's wildlife assets. There is also a need for extensive research and effective collaboration (environmental agencies, government and biological scientists), to examine how and to what extent variables such as traffic volumes, season, climatic / weather and habitat contribute to wildlife roadkill, which will generate knowledge to broaden the understanding of road ecology. Moreover, this may also enhance the establishment of policies to be followed during road planning to manage and address the negative impacts of roads on wildlife.

Citizen science has been recognised as a useful tool for promoting environmental sustainability and for amphibian conservation planning in particular (Measey *et al.,* 2019). Although the Toad NUTS team was successful in reducing roadkill of the *Sclerophrys pantherina* in an urban, more affluent, area of the Western Cape Province, South Africa, through citizen science, it remains unknown if the same approach will thrive when applied in a different demography (rural areas). The current study recommends for it to be initiated and supported in the western Soutpansberg and elsewhere in South Africa to save amphibians and other vertebrate taxa from roadkill.

With amphibians being less appreciated and valued by most people, there is a need to provide financial and moral support for citizen science projects around the western Soutpansberg and other areas across South Africa. Volunteering initiatives have the potential to foster fruitful collaboration between NGOs, the state, the private sector and the general public. This will assist in creating awareness about the importance of conserving amphibians and further help modify people's attitudes and behaviour towards this animal class. This is critical in promoting positive conservation attitudes towards amphibians and may motivate members of the public, specifically rural communities, to actively participate in amphibian roadkill projects.

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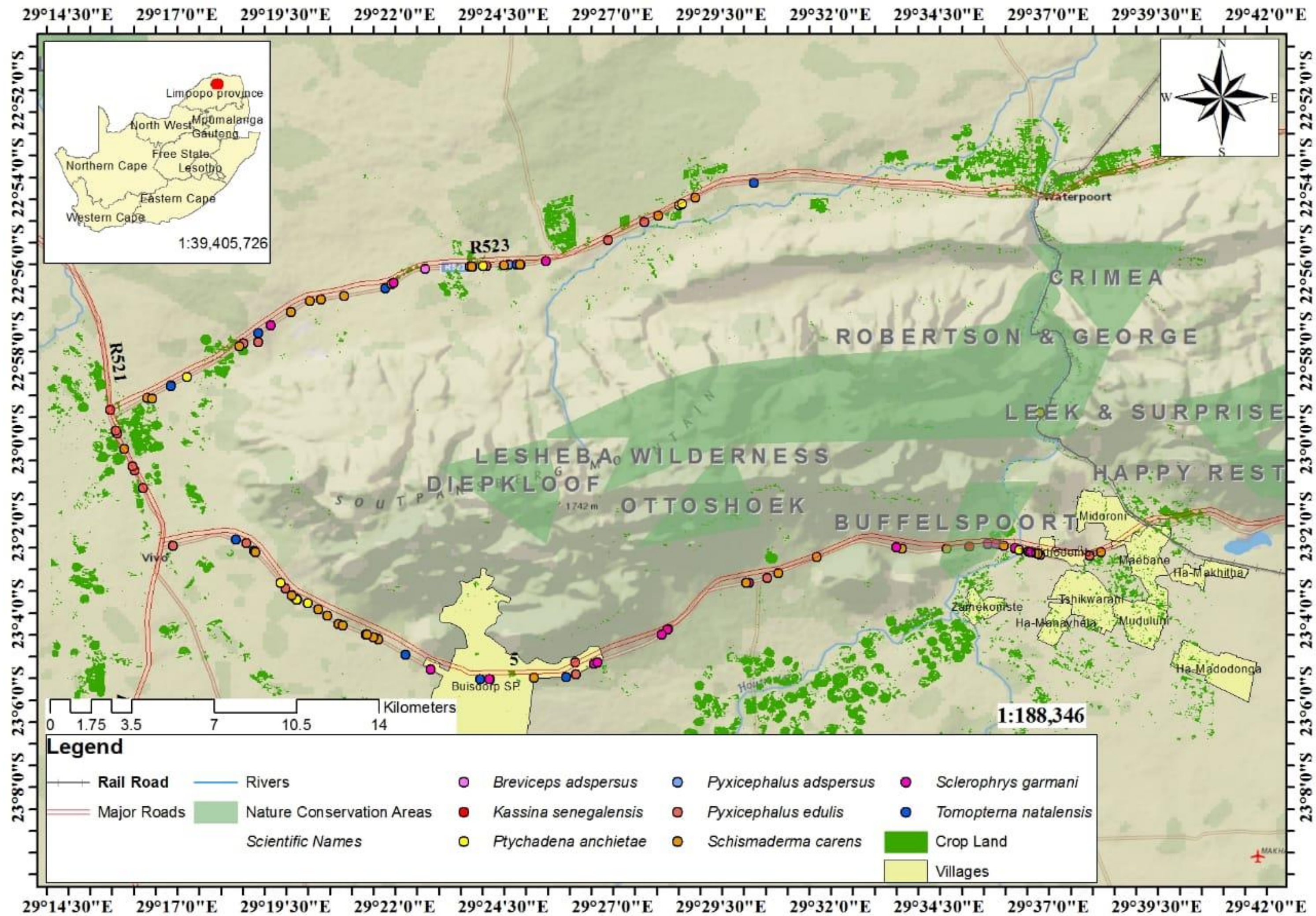
APPENDICES

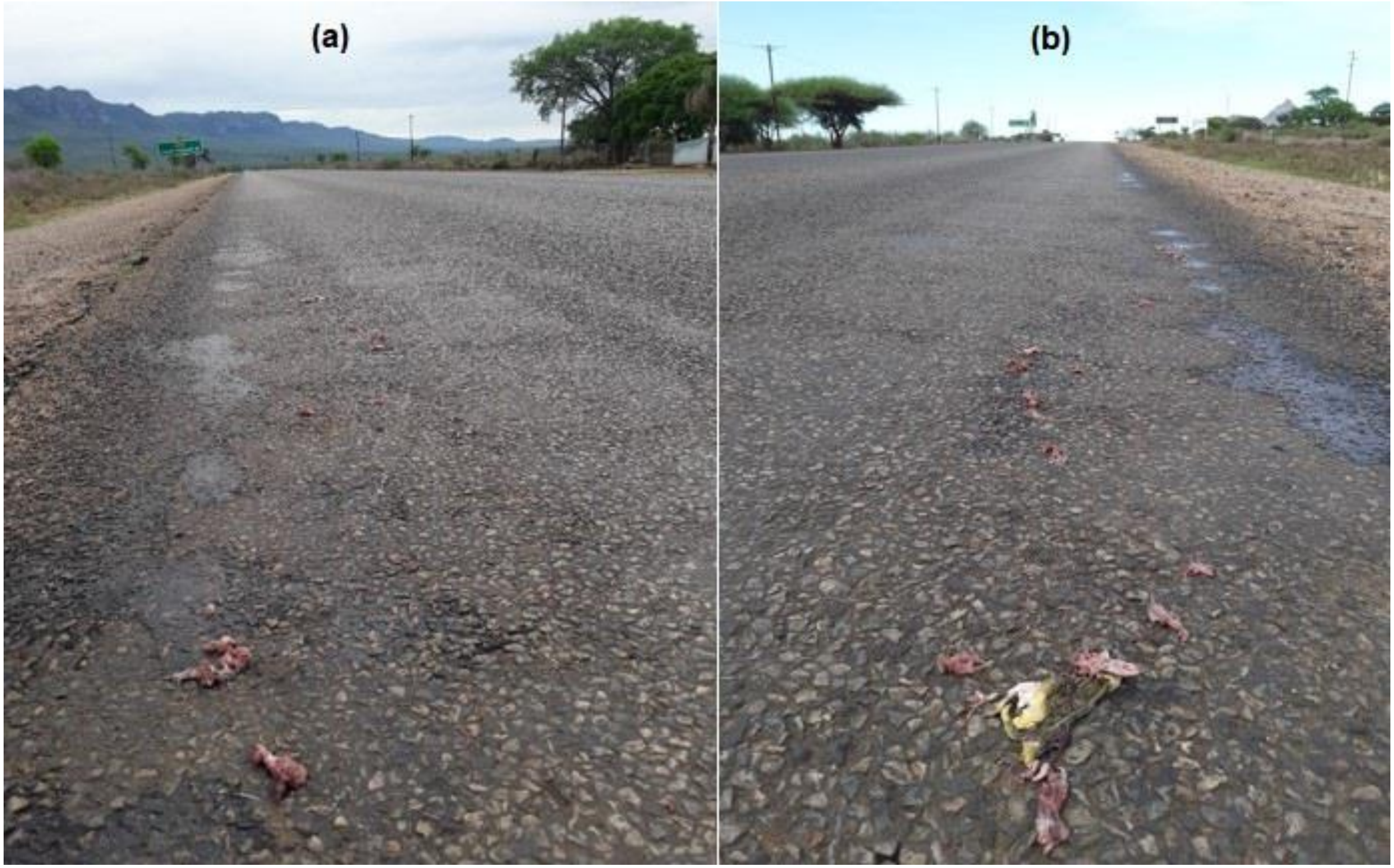
APPENDIX A: List of *Anura* species that were discovered during the herpetological surveys that were undertaken in Medike Nature Reserve and Sand River, SPA, Limpopo Province (Surveys were undertaken by Ryan van Huyssteen and Thabo Hlatshwayo) in November 2019)

#	Scientific name	Common name	Location
1	*Amietia quecketti*	Common River Frog	Sand River
2	*Amietophrynus garmani*	Eastern Olive Toad	Medike
3	*Amietophrynus maculatus*	Flat-backed Toad	Sand River
4	*Chiromantis xerampelina*	Southern Foam Nest Frog	Sand River
5	*Hemisus marmoratus*	Mottled shovel-nosed frog	Medike
6	*Hyperolius marmoratus*	Painted Reed Frog	Medike
7	*Kassina senegalensis*	Bubbling Kassina	Medike
8	*Phrynomantis bifasciatus*	Banded Rubber Frog	Medike
9	*Ptychadena anchietae*	Plain Grass Frog	Sand River
10	*Pyxicephalus edulis*	African Bullfrog	Sand River
11	*Schismaderma carens*	Red Toad	Sand River
12	*Tomopterna natalensis*	Natal Sand Frog	Sand River
13	*Tomopterna marmorata*	Russet-backed Sand Frog	Sand River
14	*Xenopus laevis*	Common Platanna	Medike

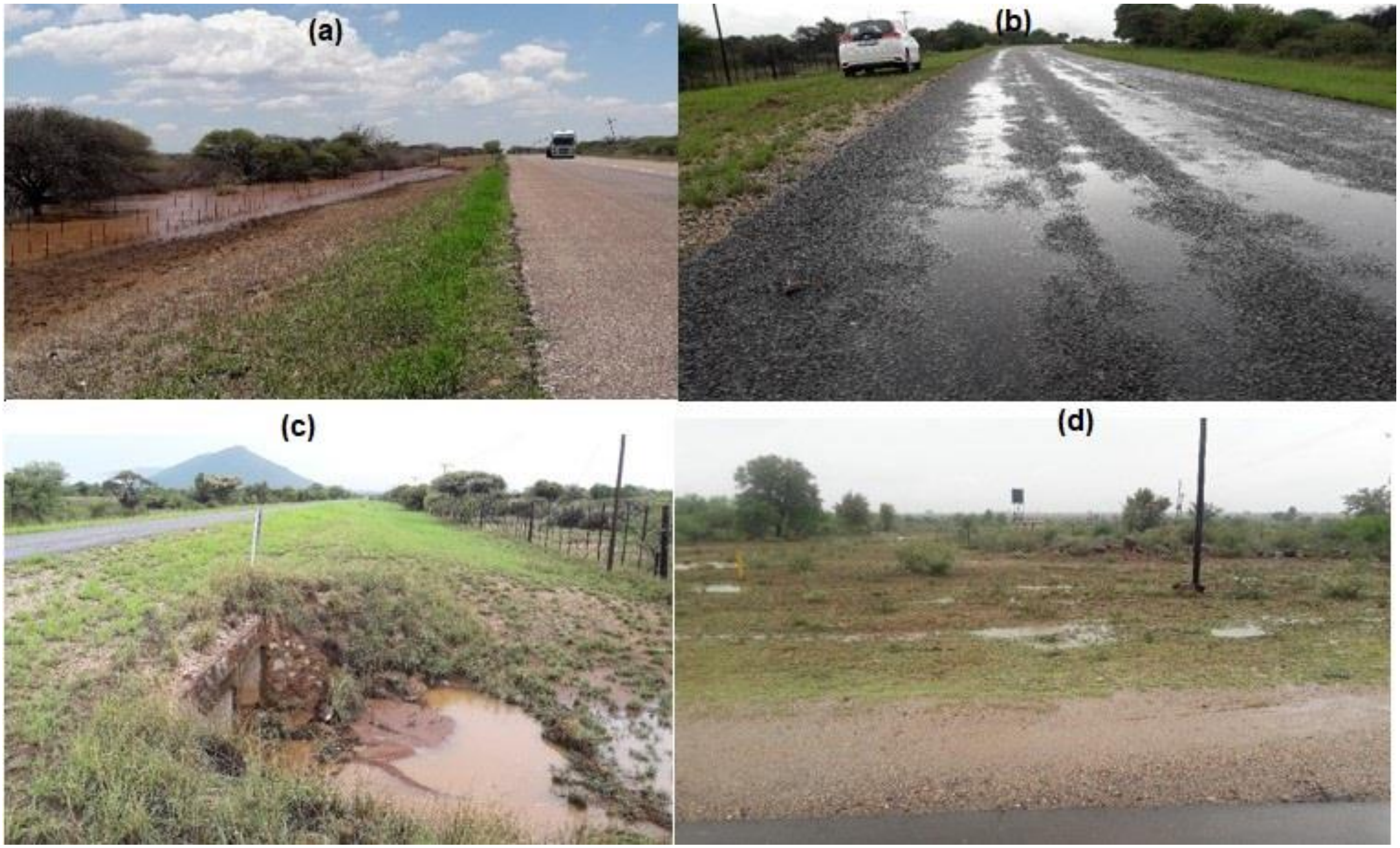
APPENDIX B: Amphibian roadkill distribution map for regional roads that cut through the western Soutpansberg



APPENDIX C: Evidence of amphibian roadkill in the western Soutpansberg



APPENDIX D: Temporary pools created by rainfall (may form potential breeding sites for amphibians on the road verges)



APPENDIX E: The vertebrate roadkill of other species that were observed over the two ecological seasons on the 100 km road stretches of the R522, R521 and R523 monitored in the western Soutpansberg of VBR, South Africa

Class	Order	No.	Family	Scientific name	Common name	Activity	Hot/dry	Hot/wet	Total
Reptilia	**Testudine**	1	Testudinidae	*Geochelone pardalis*	Leopard Tortoise	D	10	6	16
	Squamata	2	Varanidae	*Varanus albigularia albigularis*	Rock monitor	D	7	9	12
		3	Agamidae	*Acanthocercus atricollis*	Southern Tree Agama	D	0	1	1
		4	Scincidae	*Trachylepis capensis*	Cape Skink	D	2	2	4
		5	Gerrhosauridae	*Gerrhosaurus flavigularis*	Yellow-throated Plated Lizard	D	1	2	3
		6	Chamaeleonidae	*Chamaeleo dilepsis*	Flap-necked Chameleon	D	6	4	10
		7	Boidae	*Python natalensis*	South African Rock python	D	1	3	4
		8	Elapidae	*Naja mossambic*	Mozambique spitting cobra	N	6	11	17
		9	Elapidae	*Dendroaspis polyelpis*	Black mamba	D	1	3	4
		10	Elapidae	*Aspidelaps scutatus*	Shield cobra	N	0	2	2
		11	Colubridae	*Lycophidion c. capense*	Cape Wolf Snake	N	1	0	1
		12	Colubridae	*Prosymna s. sundevallii*	Lined Shovel Snout	N	1	0	1
		13	Colubridae	*Lamprophis capensis*	Brown House Snake	N	9	14	23
		14	Colubridae	*Crotaphopeltis hotamboeia*	Herald Snake	N	0	4	4
		15	Colubridae	*Dasypeltis scabra*	Rhombic Egg Eater	N	3	5	8

Reptilia	**Squamata**	16	Colubridae	*Philothamnus semivariegatus*	Spotted Bush Snake	D	0	3	3
		17	Colubridae	*Dispholidus typus*	Boomslang	D	0	2	2
		`18	Atractaspididae	*Atractaspis bibronii*	Bibron's Stilletto Snake	N	2	3	5
		19	Lamprophiidae	*Psammophis mossambicus*	Olive Grass Snake	D	0	3	3
		20	Lamprophiidae	*Psammophis subtaeniatus*	Western yellow-bellied Sand Snake	D	4	8	12
		21	Viperidae	*Bitis arientans arientan*	Puff Adder	C	3	4	7
Mammalia	**Primates**	22	Galagidae	*Otolemur crassicaudatus*	Thick-tailed galago	N	1	3	4
		23	Galagidae	*Galago moholi*	Southern lesser galago	N	1	0	1
		24	Cercopithecidae	*Chlorocebus (Cercopithecus) pygerythrus*	Vervet monkey	D	0	3	3
	Rodentia	25	Sciuridae	*Paraxerus cepapi*	Tree squirrel	C	12	8	30
		26	Muridae	Unknown rodent	Unknown rodent	-	3	2	5
	Eulipotyphla	27	Erinaceidae	*Atelerix frontalis*	Southern African Hedgehog	N	2	0	2
	Carnivora	28	Canidae	*Octocyon megalotis*	Bat-eared fox	B	1	2	3
		29	Canidae	*Canis mesomelas*	Black-backed Jackal	B	6	8	14
		30	Viverridae	*Civettictis civetta*	African civet	N	1	3	4
		31	Viverridae	*Genetta tigrina*	South African Large-spotted genet	N	0	1	1

Mammalia	**Carnivora**	32	Felidae	*Felis silvestris cafra*	African wild cat	N	0	1	1
		33	Felidae	*Felis silvestris catus.*	Domestic cat	D	0	1	1
	Tubulidentata	34	Orycteropodidae	*Orycteropus afer*	Aardvark	N	0	1	1
	Artiodactyla	35	Bovidae	*Bos Taurus*	Domestic cow	D	2	3	5
		36	Bovidae	*Capra aegagrus hircus*	Domestic goat	D	0	1	1
	Perissodactyla	37	Equidae	*Equus asinus*	Domestic donkey	D	1	1	2
Aves	**Bucertiformes**	38	Bucerotidae	*Tockus leucomelas*	Southern Yellow-belled hornbill	D	1	1	2
	Coliiformes	39	Ciliidae	*Colius striatus*	Speckled Mouse Bird	D	1	0	1
	Coraciiformes	40	Dacelonidae	*Halcyon albiventris*	Brown Hooded kingfisher	D	2	5	7
		41	Meropidae	*Merops pusillus*	Little Bee Eater	D	1	0	1
	Columbiformes	42	Columbidae	*Streptopelia senegalensis*	Laughing dove	D	2	4	6
	Passeriformes	43	Alaudidae	*Chondestes grammacus*	Sparrow Lark	D	1	3	4
		44	Alaudidae	Unknown Lark	Unknown Lark	D	1	0	1
		45	Estrildidae	*Amadina fasciata*	Cut Throat Finch	D	1	0	1
		46	Ploceidae	*Ploceus intermedius*	Lesser marked weaver	D	3	2	5
		47	Ploceidae	*Ploceus ocularis*	Spectacled weaver	D	1	0	1
		48	Ploceidae	*Quela quela*	Red billed quela	D	32	10	42
		49	Cisticolidae	*Coaticola chiniana*	Rattling cisticola	D	1	0	1

Aves	**Passeriformes**	50	Cisticolidae	*Unknown cisticola*	Uknown cisticola	D	5	0	5
		51	Hirundinidae	*Hirundo rustica*	Barn Swallows	D	9	4	13
		52	Hirundinidae	*Hirundo atrocaerulae*	Blue Swallows	D	4	2	6
		53	Estrildidae	*Pytilia melba*	Green winged pytilia	D	3	12	15
		54	Emberizidae	*Emberiza tahapisi*	Cinnamon Breasted Bunting	D	1	0	1
		55	Fringillidae	*Crithagra mozambica*	Yellow-fronted Canary	D	1	0	1
		56	Unknown Passerine	Unknown Passerine	Unknown Passerine	D	1	0	1
		57	Corvidae	*Corvus albus*	Pied crown	D	0	2	2
	Strigiformes	58	Strigidae	*Bubo africanus*	Spotted Eagle owl	N	0	2	2
	Unknown	59	Unknown	Unknown bird	Unknown bird	2	0	1	3
	Galliformes	60	Numididae	*Nimida meleagris*	Helmeted Guineafowl	C	5	6	11
		61	Phasianidae	*Dendroperdix sephaena*	Crested Francolin	C	1	3	4

APPENDIX F: The live vertebrate species that were observed during monitoring either on the road verge or crossing the road over the two ecological seasons on the 100 km stretch of the R522, R521 and R523 monitored in the western Soutpansberg of the VBR, South Africa

Class	No	Order	Family	*Scientific name*	Common name	Activity	Hot/dry	Hot/wet	Total
Reptilia	1	**Testudine**	Testudinidae	*Geochelone pardalis*	Leopard tortoise	D	3	2	5
	2	**Turtles**	Testudinidae	*Psammobates tentorius*	Tent tortoise	D	1	0	1
	3	**Squamata**	Varanidae	*Varanus albigularia albigularis*	Rock monitor	D	1	2	3
	4		Epiladae	*Dendroaspis polyelpis*	Black mamba	D	0	1	1
	5		Colubridae	*Lamprophis capensis*	Brown House Snake	N	2	4	6
Mammalia	6	**Ruminantia**	Bovidae	*Aepyceros melampus*	Impala	D	1	2	3
	7		Bovidae	*Hppotragus niger*	Sable Antelope	D	1	1	2
	8	**Artiodactyla**	Bovidae	*Bos taurus*	Cattle (herd)	D	28	35	63
	9		Bovidae	*Capra aegagrus hircus*	Domestic goat	D	6	12	18
	10	**Rodentia**	Sciuridae	*Paraxerus cepapi*	Tree squirrel	D	1	3	4
	11	**Primate**	Cercopithecidae	*Ppio ursinus*	Chacma Baboon (troop)	D	45	57	102
Mammalia	12	**Primate**	Cercopithecidae	*Chlorocebus (Cercopithecus) pygerythrus*	Vervet monkey (troop)	D	36	48	84
Aves	13	**Galliformes**	Numididae	*Nimida meleagris*	Helmeted Guinea fowl	C	20	14	34
	14		Phasianidae	*Dendroperdix sephaena*	Crested Francolin	C	13	9	22
	15	**Struthioniformes**	Struthionidae	*Struthio camelus*	Ostrich	D	2	0	2

APPENDIX G: *Psammobates tentorius* crossing the R523 in the western Soutpansberg (Waterpoort)

APPENDIX H: The roadkill data collection sheet used for recording wildlife roadkill over the two ecological seasons on the 100 km stretch of the R522, R521 and R523 roads monitored in the western Soutpansberg of VBR, South Africa

Sheet 1 - General roadkill inventory (R1)

Date	Time	Specimen ID no.	Species Identification		Co-ordinates of location		Elevation	Activity (N/D/Cr)	Position on road	Order
			Common name	Scientific name	Latitude	Longitude				

Sheet 2 - Landscape, fencing structure characteristics along the road surveyed

Specimen ID	Roadside Habitat Type		Road Verge Vegetation								Type of fencing structure					
			Left				Right				Left			Right		
	Left	Right	Type/class	Grass height	Seed	ΔX from R/V	Type/class	Grass height	Seed	ΔX from R/V	Fence Type	Fence height	ΔX from R/V	Fence Type	Fence height	ΔX from R/V

Sheet 3- Daily morphological weather records

Date	Day of the week	Temperature (12h00)		Humidity (12h00)	Moon Phase	Weather type (1-3)	Rainfall	Wind (Speed/direction)
		Min	Max					

Sheet 4-Reference/Key sheet

Morphological weather type

Type	Description
1	Warm sunny, high cloud level
2	Moderate temperature, with mid-level clouds
3	Low, cool temperature, with low cloud level

Fence classification

Fence Type	Symbol
Cattle	C
Game	G-0
Electric	E
Gate	G-1
Barrier/Bridge	B
Other	O

Carcass Decomposition R...

Condition	Description
A	Flattened
B	Not Flattened
1	Stain Dry/ Remains
2	Cannot Identify (feathers, bones, fur, decay
3	Bone, fur
4	Not fresh but identifiable, bloated
5	Fresh and Identifiable

Position on the

Zone	Position on road	Description	Code
0	Verge Left	Verge Left	VL
1	1m from verge Left	Middle Verge Left	MVL
2	2m from verge Left	Centre Middle Left	CML
3	Centre of road	Centre	C
4	2m from verge Right	Centre Middle Right	CMR
5	1m from verge Right	Middle Verge Right	MVR
6	Verge Right	Verge Right	VR

Roadside Habitat type

Habitat type	Code
Open savanna bushland	OSB
Waterbody	WB
Area of dense forest	AoDF
Crop cultivation area	CCA
Livestock grazing meadow	LGM
Residential area	RA

APPENDIX I: Amphibian roadkill questionnaire survey in Ha-Kutama village in the Soutpansberg Protected Area

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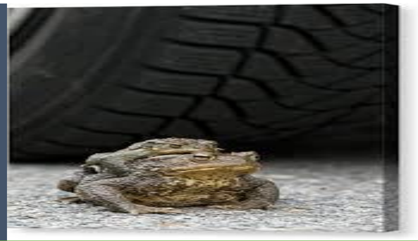

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General

Name									
Address									
Activity in the project									
Age	18- 35		36-59		60+				
Gender	Male		Female						
contact no									
Do you live around Soutpansberg	Yes		No						
do you see frogs around this area	Yes		No						
Level of Education	Primary		Secondary		Tertiary		Graduated		Never

Questions

Liking	Strongly agree	Agree	Unsure	Disagree
I like frogs				
I am scared of frogs				
I do not mind having frogs in my yard (property)				

Knowledge	Strongly agree	Agree	Unsure	Disagree
Roadkill of frogs may reduce the population of other frog species in South Africa				
Frogs eat insects				
Frogs are the most threatened animals in the world				
Frogs are sensitive to pollution				
It is important to share the environment with frogs				

Cultural beliefs	Strongly agree	Agree	Unsure	Disagree
Frogs call rainfall				
Frogs symbolise evil spirits				
Frogs are used for witchcraft				
Touching a frog will give you warts				

Amphibian roadkill citizen science in Ha-Kutama		**Strongly agree**	**Agree**	**Unsure**	**Disagree**
	I feel sad when I see frogs killed on the road				
	I can help this frog cross the road safely				
	I can report frog roadkill sightings through WhatsApp or FB App.				
	I can take part in a community project to solve frogs roadkill in my community				