AARDVARK AND PEOPLE: CAN A SHY SPECIES BE WIDELY KNOWN IN A LOCALISED AREA?

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STUDENT DECLARATION

I **Nolutho Makwati**, student number: **220103061** declare that:

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DECLARATION BY SUPERVISORS

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THESIS ABSTRACT

The increase in human populations has led to humans sharing space with wild animals even in the natural habitats of the animals. Conflicts may arise when people and wildlife attempt to fulfill their needs which can be detrimental to one or both parties, and this type of conflict is called human-wildlife conflict (HWC). The human needs include people hunting wild animals for consumption of the animal and trading in animal body parts. Hunting is one of the factors that decreases populations of numerous animal species, and it occurs in many parts of the world e.g. in Africa, Asia and South America, where it contributes to extinction of species. The conservation and management of burrowing animals is a major challenge due to their elusive and nocturnal behaviour. The aardvark is an African medium-sized, burrowing mammal whose conservation status has not been updated recently due to the difficulties associated with studying nocturnal animals. Aardvarks may play a significant ecological role in the ecosystems in which they occur, such as by changing the landscape through their digging activities, or through affecting the dispersal of seeds. Therefore, the aim of this study was to explore the influence of humans on population trends and activity patterns of aardvarks outside protected areas, and to determine people's perceptions about the animal.

The study was conducted in Ncunjane village in Msinga Local Municipality, KwaZulu-Natal Province of South Africa. To understand people's perceptions about aardvark in their community, I used a semi-structured questionnaire survey. I asked personal information of the participants (sex, level of education and age), and questions related to people's perceptions about the aardvark, such as people's knowledge, myths, and their uses of the animal or its body parts.

To determine activity patterns of the animal, I focused on aardvark foraging activities in a semi- arid savanna ecosystem that is also used as a communal rangeland over eight months between 2020 and 2021. I measured and quantified aardvark foraging holes using 53 50 m × 10 m transects where there was evidence of aardvark activity. In addition, I quantified aardvark burrowing of dens in the dry, wet and early dry seasons using walking transects guided by a research assistant who knows the area.

I found that people have different perspectives about aardvark with the majority (78%) of respondents having strongly positive perceptions. The positive perceptions arise from aardvark not causing physical harm to people, and fleeing away upon sighting people. I found that aardvarks were mainly hunted for meat while some animal body parts were sold to traditional healers for traditional medicine.

All seasons consisted of a greater number (> 51%) of old than new and very old foraging holes.The surface area of new, old, very old holes differed significantly with season ($P < 0.0001$) and the depth of new, old and very old holes also varied with season ($P < 0.0001$). In addition, the contents of foraging holes varied with age of the hole and season in that new holes lacked evidence of plant life across seasons. Aardvark dens were used by other animals such as spiders, wild cats, Cape porcupines and snakes. Hence, an increase in aardvark holes can be associated with significant landscape heterogeneity for vegetation and animal life.

Aardvarks in Ncunjane fed close to their dens presumablyto mitigate against human predation through hunting threats, which may directly affect the extent of aardvark digging activities. These results show that aardvarks may be categorised as ecosystem engineers as the burrows provide shelter for other animals, also, their effects on other animals are disproportionate to their abundance. These results highlight that aardvarks are threatened by human uses and may decline in abundance in the area. Finally, aardvarks remain poorly studied in landscapes shared with humans. Further studies to assess aardvark numbers in human-dominated landscapes are required which can raise awareness and play a significant role in conservation of aardvarks.

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Table of Contents

STUDENT DECLARATION .... **ii**

DECLARATION BY SUPERVISORS .... **iii**

THESIS ABSTRACT .... **iv**

ACKNOWLEDGEMENTS .... **vi**

LIST OF FIGURES .... **ix**

LIST OF TABLES .... **xi**

Chapter 1 .... **1**

Introduction and Literature Review 1

1.0 Background 1

1.1 Description and ecology of the aardvark 3

1.2 Aardvark feeding behaviour 3

1.3 Distribution of aardvarks in Africa 4

1.4 Threats faced by aardvarks in Africa 4

1.5 Population status 5

1.6 Aardvark conservation status 5

1.7 Significance of the study 5

1.8 Overall aims and objectives 5

1.9 Thesis structure 6

References 7

Chapter 2 .... **14**

Perceptions of a local community about the aardvark (*Orycteropus afer*), a shy nocturnal mammal

Abstract 14

2.1 Introduction 14

2.2. Materials and Methods 17

2.3 Results 18

2.4 Discussion 27

2.5 Conclusion 30

References 30

Chapter 3 .... **36**

Seasonal variation of aardvark burrowing activities in a savanna ecosystem **36**

Abstract 36

3.1 Introduction 36

3.2 Materials and Methods 39

3.3 Results 43
3.4 Discussion 48
3.5 Conclusion 50
References 50
Chapter 4 54
General discussion, recommendations and conclusion 54
4.1 Background 54
4.1 Research findings 54
4.2 Limitations 55
4.3 Recommendations for future research 55
4.4 Conclusion 55
References 56
Appendix 57

LIST OF FIGURES

Figure 1 People's knowledge about the season of increased sightings of aardvarks in Ncunjane. Answers 20

Figure 2 People's perceptions about the numbers of aardvarks in the last 10 years (2011-2021). Perceived........ 21

Figure 3 The local people's last record of aardvark sightings in Ncunjane, KwaZulu-Natal, South Africa 21

Figure 4 (A) Aardvark activity when it was encountered by local people and (B) time of day of aardvark 22

Figure 5 Type of encounter of aardvark by male and female respondents at Ncunjane in Msinga area of South Africa........ 23

Figure 6 Known myths about aardvarks in Ncunjane of Msinga area of KwaZulu-Natal, South Africa. 23

Figure 7 (A) The age of individuals who participate in hunting of aardvarks and (B) The frequency of 26

Figure 8 Strategies used to hunt aardvarks in Ncunjane, Msinga, South Africa........ 27

Figure 9 Location of Msinga Local Municipality within the KwaZulu-Natal Province of South Africa. 39

Figure 10 Three different ages of foraging holes of aardvark: (A) new hole with evidence of recent soil 41

Figure 11 (A) Aardvark active den with evidence of aardvark large claw marks and fresh soil excavated 42

Figure 12 Number (%) of different-aged foraging holes across different seasons of the year 2020...... 43

Figure 13 Mean (± SE) area (cm^2) of different-aged foraging holes by season in Ncunjane, Msinga,.. 44

Figure 14 The mean (± SE) depth (cm) of foraging holes across three seasons in Ncunjane, KwaZulu-Natal,.. 45

LIST OF TABLES

Table 1 Outline of the thesis.. 7

Table 2 The gender, level of education and age of respondents (N = 181 individuals) 19

Table 3 People's perceptions about aardvark at Ncunjane village in Msinga area of KwaZulu-Natal, South Africa 24

Table 4 The use of aardvark body parts by local people 25

Table 5 The sale value (ZAR) of body parts of aardvarks used in traditional medicine at Ncunjane in Msinga area of KwaZulu-Natal, South Africa. At time of writing, the exchange rate was R15.46 ≈ US$. 26

Table 6 Materials found inside aardvark foraging holes in the dry, wet and early dry seasons in 2020 and 2021 at Ncunjane, KwaZulu-Natal, South Africa 46

Table 7 Utilisation of active (N = 16) and abandoned (N = 7) entrances of aardvark dens over eight months in Ncunjane, KwaZulu-Natal, South Africa 47

Chapter 1

Introduction and Literature Review

1.0 Background

Large mammals may have considerable influences on the structure and functioning of the ecosystems in which they occur (Ripple et al., 2014; Lacher et al., 2019). There are animals that disturb the soil by creating burrows, digging soil pits, or constructing dams (Jones et al., 1994). The ecological effects of these animals on the landscape are considerable and may be irreplaceable. Thus, the species may be referred to as keystone species (Jones et al., 1994; Bengtsson, 1998). Jones et al. (1994) described organisms that provide resources to other species by changing the physical state of the biotic or abiotic materials as ecosystem engineers. Ecosystem engineers vary in size and adaptation. For example, aardvark (*Orycteropus afer*) (40-80 kg) and pangolins (*Manis* spp.) (12-18 kg) are semi-fossorial, facultative burrowing animals that forage at the soil surface and use burrows as retreats and nesting sites (Seymour and Ackerman, 1980). This distinguishes them from fossorial animals that forage and live underground, such as mole rats (family Bathyergidae), and porcupines except for the crested porcupine (*Hystrix cristata*) which is semi-fossorial (Heffner and Heffner, 1990; Bennett and Faulkes, 2000). In addition, elephants (e.g. *Loxodonta africana*) are also keystone species due to their major role in the ecosystem since they dig when searching for minerals and water thus altering landscapes (Kerley et al.,2008; Haynes, 2012).

For a digging animal to meet the criteria to be classified as a keystone species, the effectiveness of the diggings, mounds created and dams must be evident across the landscape (Jones et al., 1994; Power et al., 1996). Hence, it may be relevant to understand the ecological role of animal burrows in landscapes to understand how significant they are to the ecosystem. The burrowing activities of ecosystem engineers provide refuge to other animals enabling them to escape harsh weather conditions and predators (Wright and Jones, 2004; Whittington-Jones, 2015). In addition, these animals play a significant role in improving soil structure by mixing soil through their digging, which also improves soil aeration while also enhancing nutrient cycling (Garkaklis et al., 2000; Bragg et al., 2005). Ecosystem engineers can be categorised into allogenic and autogenic engineers (Jones et al., 1994; Whitting-Jones, 2006). Allogenic engineers use their physical structure to modify non-living matter. Forexample, aardvark uses forelimbs to dig through soil thus changing the ecosystem (Jones et al., 1994; Whittington-Jones, 2006). In contrast, autogenic engineers change the ecosystem through decomposing their physical structure (Jones et al., 1994). For example, corals and trees add nutrients to soil when their living or dead tissues decompose (Jones et al., 1994).

Aardvarks are African allogenic ecosystem engineers and keystone species (Cilliers, 2002; Whittington-Jones et al., 2011). Aardvarks dig burrows that are used by at least other 30 animals when the burrows are abandoned such as leopards (*Panthera pardus*) and warthogs (*Phacochoerus africanus*) (White and Cameron, 2009; Whittington-Jones et al., 2011), and the vulnerable blue swallow (*Hirundoatro atrocaerulea*) (Skinner and Chimimba, 2005; Evans and Bouwman, 2010; Haynes, 2012). Also, aardvark burrows in semi-arid conditions provide a microclimate that is cooler than the external environment during the day and in times of extreme heat (Louw et al., 2021). In addition, aardvark burrows promote plant germination (Dean and Milton, 1991). For example, aardvark burrows allow the growth of distinct plants such as silky bushman grass (*Stipagrotis uniplumis)*, hard fern (*Pellaea calomelanos)*, and green cliffbrake (*Cheilanthes viridis)* (Haussmann et al., 2018), which are important for grazing in arid areas and traditional medicine. Aardvark burrows also trap seeds thus serving as germination sites, they also trap plant litter which later decomposes thereby enhancing nutrient cycling and positively influencing soil fertility (Whitting-Jones,2006). Aardvarks also assist in seed dispersal of the aardvark cucumber (*Cucumis humifructus*) which aardvarks feed on to obtain water, as a result aardvark cucumber seeds are often found at the entrances of aardvark burrows (Meeuse, 1958; Kingdon et al., 2013). Aardvark burrows also provide breeding sites for many dryland insects, reptiles, birds, and mammals (Whitting-Jones et al., 2011).

Despite the important roles of ecosystem engineers in different landscapes, the animals continue to be threatened mainly by humans. Aardvarks are threatened by humans, who hunt them for bushmeat, recreation, traditional medicine and curiosity (Kingdom, 1971; Melton, 1976; Whiting et al., 2011; Lindsey et al., 2013). Aardvark claws, teeth and hard skin are used to produce traditional medicine in South Africa (Whiting et al., 2011; Lindsey et al., 2013). Similarly, pangolin scales are in demand in China to produce traditional medicine, which has resulted in an increase in hunting of the animal in Africa (Mambeya et al., 2018; Wang et al., 2020; Malimbo et al., 2020). For example, the giant ground pangolin (*Smutsia gigantea*) is at high risk of extinction from hunting due to the big scales which attract illegal hunters (Ingram et al., 2018; Malimbo et al., 2020). Porcupines are also hunted for meat in Africa, and their quills are used to make ornaments (Power, 2014; Gomez, 2021). Hunting is one of the most serious threats to wildlife around the world, and it is a leading cause of extinction of wild animals (Aiyadurai, 2011; Ripple et al., 2019; Gomez et al., 2020). Bushmeat hunting is notable in parts of Africa, Asia and South America (Darimont et al., 2015). Although hunting was likely sustainable in the early 19^{th} century, it became less so once settlers began interest in commercial hunting (Lee and Hitchcock, 2001; Borrini-Feyerabend et al., 2004). Thus, the amount of hunting has increased, and the number of animals in the wild has decreased (Lee and Hitchcock, 2001; Borrini-Feyerabend et al., 2004).

Even though animals are hunted by local people, some are also a threat to humans leading to the inability to coexist. The inability to coexist is defined as when humans and wild animals encounter to fulfil their needs leading to conflict between the two parties which is called human-wildlife conflict (HWC) (Nyhus, 2016). Aardvark and Cape porcupine (*Hystrix africaeaustralis*) are a threat to humans through their digging of holes and damaging fences and other infrastructure (Weise et al., 2014; Rust etal., 2015). The crested porcupine, warthogs, olive baboons (*Papio anubis*) and other animals reportedly destroy crops in the early hours of the morning before farmers awake (Mekonen, 2020). In this way, wildlife can become a pest to humans. As such, as more crops are cultivated across areas shared by humans and wildlife, crop damage is anticipated to rise and cause conflict between farmers and wildlife (Okello, 2005). Additionally, HWC leads to the transfer of zoonic diseases from wildlife to humans, which may cause humans to exterminate wildlife (Mlilo et al., 2015). For example, the Black death disease caused by plague (*Yersinia pestis)* bacterium was transferred from animals to humans and killed about 17% of people in Africa, 33% in Europe and 50% in China (Munyenyiwa et al., 2019). Also, the changes in land use by humans affect the distribution of wildlife and their prey, and it contributes significantly to the decline of biodiversity globally (Ripple et al., 2014; Tilman et al., 2017). Certain animals adapt by exploiting human landscapes by changing their natural behaviours such as dietary and breeding ecology (Ngcobo et al., 2019a, 2019b). For example, in Amboseli, Kenya, people changed land use through an agricultural expansion which was seen to be more profitable than pastoralism or conservation of biodiversity, and the result was a movement of wildlife into communal lands where they destroyed crops (Okello, 2005).

The solution to HWC is for wildlife and humans to coexist, which can be achieved through education and outreach programs that assist local people to gain accurate information and skills to minimise HWC (Jacobson et al., 2006). Another potential solution to HWC is guarding livestock in the veld (Hoare, 2012) to minimise encounters with predators. For example, in the Bale Mountains National Park in southeast Ethiopia, people guard their livestock against leopards during the day while their livestock are out grazing (Mekonen, 2020). Another way to control problem animals includes lethal means such as sport hunting, which generates revenue from which the community can benefit (Hoare, 2012; Soulsbury and White, 2015).

1.1 Description and ecology of the aardvark

Aardvarks are the only species in the Afrotherian order Tubulidentata (Springer et al., 1997; Yang et al., 2003), and they have an adult body weight of 40-80 kg (Kingdon, 1971; Taylor et al., 2002). Aardvark is an Afrikaans name, which translates to "earth or ground pig" (Kingdon, 1971) because its anatomy resembles that of pigs in terms of a long, rounded, pig like-snout, and elongated worm-like tongue (Melton, 1976) for eating ants and termites (Skinner and Smithers, 1990; Kingdon et al., 2013). Aardvarks have strong longer hind limbs than forelimbs, which is also found in other species, such as spotted hyaena (e.g. *Crocuta crocuta*). Aardvark forelimbs have sharp claws, which they use to dig holes and break termite mounds (van Aarde et al., 1992; Taylor et al., 2002). Aardvarks have poor eyesight and rely on the sense of smell to locate their prey (Weyer et al., 2016). Aardvarks are generally solitary (Springer et al., 1997; Yang et al., 2003). Male offspring separate from their mothers after six months, whereas females excavate burrows next to their mothers (Melton, 1976).

1.2 Aardvark feeding behaviour

Aardvark diet comprises primarily of termites in the wet seasons and ants in dry seasons when termites become scarce (Melton, 1976; Taylor et al., 2002). The ability of aardvarks to search for food underground is advantageous to them as there is less competition because few other species utilise the same food (Taylor and Skinner, 2004). In addition, aardvarks likely increase their moisture intake by feeding on aardvark cucumber (Melton, 1976; Kingdon et al., 2013). Aardvarks rarely drink water (Taylor and Skinner, 2004; Kerley and Tompkins, 2017), and probably obtain most of their water from the termites and ants they feed on (Taylor and Skinner, 2004; Kingdon et al., 2013). Aardvarks are nocturnal and can travel a distance of 2 to 30 km in one night when foraging (Melton, 1975; Taylor et al., 2013), as a result, they can dig up to 200 foraging holes per night (Taylor et al., 2002). For example, in the False Karoo, aardvarks were found to forage after sunset in summer and in winter they were foraging in the afternoon, which suggests that aardvarks are sensitive to the cold (Taylor and Skinner, 2003). However, little research has been done on how aardvarks respond to seasonal changes (Weyer, 2018).

1.3 Distribution of aardvarks in Africa

Aardvarks occur in sub-Saharan Africa, however, local and regional assessments of their distribution remain poorly known (Lehmann, 2009; Lindsey et al., 2013). In addition, aardvarks have been reported to occur in Madagascar and Eurasia (Lehmann, 2009). Aardvarks inhabit various ecosystems including savanna, woodland, grassland, shrubland and rainforests in central Africa (Taylor and Skinner, 2004; Whitting-Jones, 2006; Lehmann, 2009). The distribution of aardvarks is associated with the availability of their prey (Cilliers, 2002; Taylor, 2013), consequently, aardvarks are absent in rocky areas where digging is a challenge for them (Whitting-Jones, 2006; Taylor, 2013). In addition, aardvarks are completely absent in arid desert habitats (Taylor, 2013).

1.4 Threats faced by aardvarks in Africa

Aardvarks, among other wildlife species, are facing negative threats such as hunting for traditional medicine and bushmeat in Africa (Lindsey et al., 2013). Aardvark body parts are sold in traditional medicine markets, particularly in the Eastern Cape and Gauteng Provinces of South Africa (Whiting etal., 2011). The claws, skins and teeth of aardvarks are used to produce traditional medicine, and this is still growing in South Africa (Lindsey et al., 2013). Furthermore, aardvarks are hunted for bushmeat and their tail is regarded as delicious by people who consume it in Eswatini (Child et al., 2017). Trading aardvark body parts is profitable for hunters, which would result in the hunters' perception of aardvarks being positive because of the financial gain. Aardvarks are disadvantaged during a hunt because they cannot fight back, as hunters use different methods such as dogs, clubs and spears to hunt them (Liebenberg, 2006). As a consequence of human encroachment into wildlife areas, aardvarks may extend their home range into human landscapes when digging. Aardvarks lose their habitats due to agricultural expansion (Power and Verburgt, 2014; Rust et al., 2015). Consequently, aardvarks use farmed areas and create holes that injure livestock (Power and Verburgt, 2014). Through their digging, aardvarks damage crops and fences which results in the animals being considered pests that need to be eradicated by crop farmers (Rust et al., 2015). On account of aardvarks occurring around humans, different perceptions and myths are raised. Myths are traditional stories that a group of people share, and every culture has its own myths (Losada, 2019). Together with perceptions, and myths in a certain culture are often passed through generations and rarely questioned. Generally, many ethnic groups in sub-Saharan Africa such as Lele, Nyanja, and Tshokwe, perceived aardvark as a symbolic animal, often associated with the night, the underworld and the dead (te Velde, 1967). Records of aardvarks in the iron age indicate that they were seen as of ritual importance (te Velde, 1967). Various communities may therefore have different opinions and myths associated with aardvarks.

1.5 Population status

Aardvarks occur in low density, this may be associated with their elusive behaviour, which makes them hard to be investigated (Taylor, 2013). They are considered of "Least Concern" in the IUCN Red List of Threatened Species (Lindsey et al., 2008). Despite this classification, aardvarks are declining in landscapes shared with humans due to being hunted for bushmeat, and body parts sold to make medicine mainly in central and West Africa (Kingdon et al., 2013). Also, climate change is predicted to have a negative impact on aardvark's prey availability and aardvark physiology (Weyer et al., 2016). As a result, several (five of 11 tagged) aardvarks died due to starvation induced by an extended drought period in the Kalahari, South Africa (Rey et al., 2017). The populaton of aardvarks may be declining faster than may be anticipated due to overhunting and climate related factors.

1.6 Aardvark conservation status

There have not been extensive conservation measurements taken to protect aardvarks, particularly in spaces shared with humans. To reduce persecution rates faced by aardvarks due to farmers and landowners, the installation of swing gates and car tyres was seen as a solution (Schumann et al., 2006;Weise et al., 2014; Rust et al., 2015). In Namibia, an experiment showed that the use of swing gates reduced aardvark diggings instead aardvarks used swing gates to pass when extending their geographic distribution outside the game-fenced areas (Schumann et al., 2006; Rust et al., 2015). Also, aardvarks were using tyres to pass through the fence rather than to create holes for passage (Weise et al., 2014). Child et al. (2017) suggested that awareness and teaching people about the importance of aardvarks to the ecosystem such as their role as keystone species would be a solution to their conservation.

1.7 Significance of the study

The area of Ncunjane in Msinga presents aardvarks with a space of no competition for food with other animals because no other insectivore occurs in the area. Aardvark occurring in Ncunjane may face the same threats as other non-burrowing mammals due to the human-wildlife interface. The human-wildlife interface predominantly addresses issues that are related to large animals such as elephants, buffalo (*Syncerus caffer*) including carnivores such as the tiger (*Panthera tigris*), leopard, lion (*Panthera leo*), and their impacts on humans (Ahmed et al., 2012; Hoare, 2012; Ocholla et al., 2013). As a result, animals tend to escape from the boundaries set by protected areas, which then lead them into human spaces resulting in conflict. The escape of animals from protected areas may be driven by limited food availability (Danquah et al., 2006). For example, elephants are a threat to people and their crops in many parts of Africa (Ocholla et al., 2013; Megaze et al., 2017). Local people resort to destroying the animals when a human fatality or injury occurs or when crops are persistently raided (Ocholla et al., 2013). Yet, the aardvark is hunted although it is not a threat to human life.

1.8 Overall aims and objectives

Aims

The aim of this study is to explore the burrowing activity of aardvarks outside protected areas and the influence humans might have on their activity patterns and population sizes at local scales.

Objectives

(1) To determine the relationship between aardvark and humans in a communal area (chapter 2).

(2) To determine the behaviour of aardvark in Ncunjane village (chapter 3).

Specific objectives

(1) To determine a local community's knowledge about aardvarks.

(2) To determine the perceptions of local people about aardvarks.

(3) To determine uses of aardvarks by people in their local area.

(4) To determine aardvark behaviour in a human-dominated landscape.

(5) To determine the size (surface area and depth) and density of foraging holes in different seasons.

(6) To determine the vegetation or animal life that occupies aardvark foraging holes in different seasons.

(7) To determine the distance between active entrances within a den.

(8) To determine the number of active and abandoned entrances at dens.

1.9 Thesis structure

The thesis consists of four chapters (Table 1), two of which are data chapters (chapter 2 and 3). Some repetition is unavoidable in the data chapters, particularly with respect to the description of the study site. The thesis uses the format of the South African Journal of Botany. Chapter 1 and 4 are the introductory and the concluding chapters of the thesis, respectively.

Table 1 Outline of the thesis

Chapter	Title	Summary
1	Introduction and Literature Review	An introduction and literature review of burrowers in Africa is unpacked here, including the threats faced by these animals in Africa. Further, the description and behaviour of aardvark is covered.
2	Perceptions of a local community about the aardvark (*Orycteropus afer*), a shy nocturnal mammal	Investigates the perceptions of local people about aardvarks and their influence on the numbers of aardvarks. This chapter addresses specific objectives 1, 2, 3 and 4.
3	Seasonal variation of aardvark burrowing activities in a savanna ecosystem	Investigates the influence of season on aardvark burrowing activities. This chapter addresses specific objectives 5, 6, 7 and 8.
4	Concluding chapter	Summarises major findings and presents general conclusions of the study and recommendations.

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Chapter 2

Formatted for Nature Conservation

Perceptions of a local community about the aardvark (*Orycteropus afer*), a shy nocturnal mammal

Abstract

Little is known about the perception of local communities about the aardvark. In this regard, I assessed people's perceptions about the aardvark, a shy, nocturnal, medium-sized mammal in a communal area in Msinga, KwaZulu-Natal, South Africa. The influence of humans on the activity patterns, trends in the numbers, and use of aardvarks were also determined. Semi-structured questionnaires were used to conduct interviews with households and persons (N = 181) of different ages (11 to > 70 years) from each randomly selected household were interviewed because of potentially different experiences or perceptions of aardvarks. Respondents' perceptions of the aardvarkwere strongly positive (78%), because the animal does not cause physical harm to people, and flees upon sighting (47%). Aardvarks were predominantly hunted for meat (35%) and to obtain body parts for sale (14%, N = 7) to traditional healers, which may contribute to its decline. I highlight the threats faced by this species due to its occurrence in close proximity to humans. Therefore, the indicated anthropogenic threats on aardvark put at risk the conservation status of the animal.

Keywords: Ecosystem engineers, human-wildlife conflict, hunting, myths, traditional medicine

2.1 Introduction

The global increase in the human population limits the space to coexist with wildlife (Nyhus, 2016). As such, in places shared by humans with wildlife usually experience conflict called human-wildlife conflict (HWC) (Waters et al., 2016; Mukeka et al., 2019). The HWC may arise due to one of the parties encroaching into spaces of the other. For example, humans may encroach into wildlife habitats through livestock and crop farming or move to live where wildlife occurs (Distefano, 2005; Bajracharya et al., 2008). Alternatively, wild animals with a wide geographicrange may escape from the confinement of a protected area into human settlements (Dunham et al., 2009). Wild animals may then destroy crops, attack livestock or people, which results in a conflict when humans try to protect themselves or their property (Dunham et al., 2009; Mekonen, 2020). For example,the blue buck (*Hippotragus leucophaeus*) and the plains zebra (*Equus quagga*) were both extinct in the Cape Colony of South Africa by 1800 and 1883, respectively (Stuart and Stuart, 2015), due to competition with livestock and overhunting (Stuart and Stuart, 2015; Soulsbury and White, 2015; Mwangi et al., 2018). In other situations, livestock invade protected areas for food, which may result in their attack by wildlife. HWC is thus expected to increase with expansion of human settlements due to increased human populations. Furthermore, HWC is driven by humans hunting animals in wildlife areas for consumption (e.g., to feed their families) and trade (Seoraj-Pillai and Pillay, 2016). Wild animals may then respond by attacking the hunters which is likely to result into a conflict between the two parties. Successful hunts are facilitated by planning, trapping and access to and use of weaponry like guns, spears and axes used by hunters (Yasuoka, 2006; Fernandes-Ferreira et al., 2012). Animals living above-ground are prone to attack by humans through hunting because most of them are large in size and thus conspicuous (Rippleet al., 2016; Dobson et al., 2019). As a result, these animals can be shot, chased with spears or snared (Fernandes-Ferreira et al., 2012), which is less feasible for burrowing animals (Duda et al., 2017). Thus, my study determined hunting methods of a large-sized (40-80 kg) burrowing mammal, the aardvark, *Orycteropus afer*.

Hunting is driven by different factors related to economic reasons. Traditionally, persecutions of wildlife are justified as retaliation for injury, damage or loss of human life and human investment (Fischer and Lamey, 2018). For example, Hoffmeier-Karimi and Schulte (2015) found that farmers lost 40% of all crops due to elephant (*Loxodonta africana*) damage in southern Tanzania. Lions (*Panthera leo*) in Tanzania injure and kill people by invading farms and villages seeking human prey (Baldus, 2004; Frank et al., 2006). Thus, wildlife may be killed to reduce future damage and losses (Fischer andLamey, 2018). Wild animals are also hunted for economic reasons so that hunters are able to support their families through a protein supply/supplement (subsistence) or sell the wild meat for financial gain. As a result, the economic or employment status of hunters has an impact on the motivation to hunt (Manqele et al., 2018). Therefore, people without an income may have a greater inclination to hunt than others with a source of income. Moreover, the frequency of travel to town and the ability to afford meat has an impact on the frequency of hunting (Brashares et al., 2011). Frequent hunters may be located far from town, and may not afford the costs of travelling to town and the price of meat. One would thus expect hunting to be prevalent in rural areas. Hunting is primarily a recreational activity for others driven by "the excitement of the chase" (di Minin et al., 2016; Ripple et al., 2016). This may often be linked to illegal hunting, which tends to be unsustainable (di Minin et al., 2016; Gomez, 2021). Poverty is often said to be a driver of illegal wildlife hunting since poor people hunt to meet their fundamental needs (Duffy et al., 2015). Others hunt to procure wildlife body parts that are used in traditional medicine or witchcraft (Lee and Hitchcock, 2001; Lindsey et al., 2015). This is common for primate, ungulate, insectivorous and carnivorous species (Wilkie et al., 2011; Malimbo et al., 2020). Animals are also hunted for the production of ornaments with ungulates making up most of the ornamental trade (ivory, horns, antlers and skins), which too is driven by monetary incentives that serve as a source of occasional income (van der Merwe et al., 2014; Duda et al., 2017). Therefore, the increase in demand for bushmeat and body parts of wildlife has increased the motive for hunting (Ripple, 2016; Malimbo et al., 2020). The various reasons for hunting all place wildlife at risk of extinction, particularly in localised areas.

Hunting may also be driven by culture, which entails values, norms and beliefs by a group of people towards an object or animal (Kideghesho and Mtoni, 2008). For example, pelts of leopard (*Panthera pardus*) were presented as prized gifts to the king of the Zulus in South Africa (Klopper, 1996; Raum, 2019), which led to increased hunting efforts in the 19th century. Hunting or lack therefore may be driven by people's perceptions and behaviours towards certain animals. For example, in northeastern Madagascar, some people believe that residents have to kill an aye-aye (*Daubentonia madagascariensis*) found in a human settlement, which should be burned and deserted (Glaw et al., 2008). Such social perceptions, cultural acts and myths are usually passed from one generation to the next and often cannot be questioned (Losada, 2015). It is also possible for humans to coexist with harmless wildlife (Struebig et al., 2018; Hunold and Mazuchowski, 2020; Mekonen, 2020), as influenced by culture. There are sacred wildlife species, which are protected from harvesting, killing and consumption by culture through taboos and beliefs. As such, if killed, a fine is imposed on the hunter by traditional healers or clan leaders (Mgumia and Oba, 2003). For example, the spotted hyaena (*Crocuta crocuta*) and the lion are protected because of their symbolic role in the clan and tribe of Ikoma in western Serengeti (Kideghesho and Mtoni, 2008). Similarly, leopards are protected by the Watundu clan in Kagera, Tanzania (Kideghesho and Mtoni, 2008). Due to cultural beliefs, people may develop a no-fear adaptation towards certain wildlife. Level of education may play a significant role in influencing people to change their economic status, cultural and social perspectives on wildlife through the acquisition of new skills and insight (Treves et al., 2007). As a result, any myths and beliefs associated with wildlife by a community are, therefore, unlikely to end without education and awareness.

Hunting is detrimental to wildlife populations and associated biodiversity. For example, overhunting causes extirpation of many wildlife species (Soulsbury and White, 2015), which in turn affects food chains. For example, aardvarks are associated with a variety of animals due to their digging (Whittington-Jones et al., 2011). Specifically, aardvarks create habitats with suitable conditions for mammals, reptiles and birds (Monadjem et al., 2006). Losing aardvarks will result in loss of habitat and potentially a reduction in the populations of animals depending on aardvark burrows for refuge and reproduction.

Animals that are persecuted by humans may develop precautionary behaviours to stay safe. White-tailed deer (*Odocoileus virginianus*) decreased their movement patterns by limiting their exploratory behaviour and distance travelled during the hunting season in Oklahoma, United States of America (Marantz et al., 2016). Lone et al. (2015) showed males of European red deer, *Cervus elaphus*, to use covered areas to conceal themselves from hunters and decreased foraging time in the hunting season. Other animals develop a nocturnal lifestyle (Gaynor et al., 2018). Wildlife may thus respond to hunting and increased human presence by altering their use of space, movement and foraging time.

Information on perceptions of people to wildlife in rural areas has not been extensively conducted in southern Africa (e.g. Mutanga et al., 2015; Thorn et al., 2015; Mogomotsi et al., 2020). Studies have focused on above-ground dwelling diurnal animals. Therefore, this study aimed to investigate the perceptions of local people about aardvarks and their influence on the numbers of aardvarks. The objectives were to: (1) determine local people's knowledge (ecology, experience or encounter, etc.) about aardvarks, (2) determine aardvark behaviour (e.g., sighting, time of day, action of the animal) in a human-dominated landscape, (3) determine the perceptions of local people about aardvarks, (4) determine uses of aardvarks by people in their local area, (5) determine the influence of hunting on aardvark population in Ncunjane. I expected human activities to increase the likelihood of encounter, and the potential for kills. I also expected that killing the animal would require digging it out first.

2.2. Materials and Methods

Study site

The study was conducted in Ncunjane (28º44′S, 30º27′E), a village in Msinga Local Municipality in uMzinyathi District of KwaZulu-Natal Province of South Africa. The study area is situated in a Sub-Escarpment Savanna at an altitude of 350-1000 m (Mucina and Rutherford, 2006). Msinga is characterised by a sparse grass layer (Fowler, 2011) of red oat grass (*Themeda triandra)*, guinea grass (*Panicum maximum)* and African lovegrass (*Eragrostis curvula),* while the woody vegetation is dominated by deciduous trees such as umbrella thorn (*Vachellia tortilis)* and gum arabic tree (*V. nilotica)* (Mucina and Rutherford, 2006). The area receives summer rainfall (600-700 mm)(Cousins et al., 2009) and dry winters with a mean monthly minimum and maximum temperature of 0.2˚C and 38.1˚C in summer, and -4.4˚C and 36.7˚C in winter, respectively. Msinga is characterised by shallow, reddish-brown gritty soil rich in calcium carbonate (van der Eyk et al., 1969). The soil also has limited clay and organic matter content and is therefore unproductive for crop farming (Fowler, 2011). The land is covered with rocky surfaces with high hills, and gravel roads used to travel to homesteads (Fowler, 2011). Msinga has a high unemployment rate (62%), and local people rely on livestock (mainly cattle, sheep (*Ovis aries*), goats (*Capra hircus*) and chickens (*Gallus gallus domesticus*) and social grants for their economic income (Bayer et al., 2004; Msinga Municipality, 2012). The majority of young adults (< 40 years old) have completed secondary education, but persons with tertiary education are few while the proportion of older adults (> 50 years old) with no schooling is considerable (Msinga Municipality, 2012).

Data collection

I obtained human ethical clearance with the ethics committee at the University of KwaZulu-Natal (HSSREC/00002877/2021). I sought and obtained consent from all the interviewees prior to the interview, and I emphasised that participation was voluntary. The interviews were conducted between September and October 2021. The research commenced once in-person research was permissible due to the Covid-19 pandemic. All the Covid-19 rules, i.e. wearing masks, social distancing, sanitising and avoiding handshakes, etc., were followed.

I used a semi-structured questionnaire to conduct the interviews. Questionnaire surveys have been deployed in several studies to research about animals, humans and the environment, uses of plants, medical research and marketing studies (e.g. Inman et al., 2020; Mashele et al., 2021). I interviewed 181 respondents in Ncunjane. The interviewed households were selected randomly, and I interviewed 1-3 persons from the age of 11 to more than 70 years old from each household because different age groups within a household might have different experiences with the study animal. For example, young (> 11 years old) and older (25-49) women collect firewood up to 5 km away from the village and may come across aardvark activity (foraging holes, dens, damaged termite mounds) or the animal. Similarly, boys start to herd or mind cattle when they are about 11 years old. This activity may also be done several kilometres away from the village, which may increase the chance of boys coming across aardvark activities. Men may be involved in hunting and may have more information about the animal they hunt. I defined early morning and afternoon as daytime. All the questions were asked in isiZulu, the main language of the area. I used an isiZulu-speaking research assistant to communicate with the respondents because I speak a different Nguni language to that of the area. It was not uncommon for female respondents to confuse the aardvark with the Cape porcupine (*Hystrix africaeaustralis*), so I used a picture of the aardvark to assist the respondents in identifying the animal. Questions on the questionnaire consisted of personal information of the respondents and their perceptions of aardvarks in their area. Personal information consisted of the age group, sex and level of education of each respondent. To determine people's perceptions about aardvarks, I asked the following questions: (1) people's knowledge about aardvarks i.e. do you know what aardvark is? (2) people's perceptions about aardvark i.e. do you know of any myths about aardvark? and (3) how do people use aardvarks in the area i.e. what are the body parts of aardvarks used for?

Data analysis

The data were prepared and coded using Microsoft Excel. All the respondents were coded to keep them anonymous. Demographic information about respondents was analysed using Pearson's Chi-square test with gender as the independent variable to determine if there was a difference in the level of education by gender and age group. I compared the grouped themes of questions to determine people's perceptions about aardvark and known myths. The use of aardvarks by people was analysed using descriptive statistics to give trends and answers to the research questions pertaining to people's influence on aardvark abundance. All statistical analyses were performed in IBM SPSS statistics for windows version27 (IBM Corp, 2020).

2.3 Results

Demographics of respondents

A total of 181 respondents were interviewed and were made up of more females (57%) than males. Most of the respondents had completed secondary education, with slightly more females than males having attended secondary education. The overall level of education was similar between genders (χ^2 =2.14, df = 2, P = 0.344). I interviewed six different age groups, the least number (9%) of respondents were > 70 years old and the majority (28%) were in the 15-24 age group (Table 1). Most (71%) respondents were between 15-49 years of age. The age of respondents by gender was similar (χ^2 = 8.81,df = 10, P = 0.551) (Table 1).

Table 2 The gender, level of education and age of respondents (N = 181 individuals).

		Gender		
Level of education		Female (N)	Male (N)	Total (%)
	None	13	13	14
	Primary	43	27	39
	Secondary	47	38	47
Age groups				
	11-14	10	5	9
	15-24	27	23	28
	25-34	23	17	23
	35-49	20	17	20
	50-70	13	7	11
	> 70	11	5	9

Knowledge about aardvark

Most of the respondents (92%, N = 167) indicated that they knew aardvark and had previously encountered it in the area. Most respondents (98%, N = 177) were also aware of aardvark foraging holes located not far from homesteads in the village but were uncertain (78%, N = 142) about the season in which most aardvarks were seen, while a few indicated that it was during the rainy season (18%, N = 33), or the dry season (3%, N = 6) (Fig. 1). Many people (82%, N = 149) were uncertain about whether aardvark numbers had changed in the last 10 years, while few thought aardvark numbers are decreasing(6%, N = 10) or increasing (20%, N = 36) or stagnant (3%, N = 5) (Fig. 2). When asked when they had last seen aardvark in their immediate area, the majority last saw it > 2 years ago (51%, N = 92), and the least were people who last saw aardvark in the past 2 years (8%, N = 15) (Fig. 3).

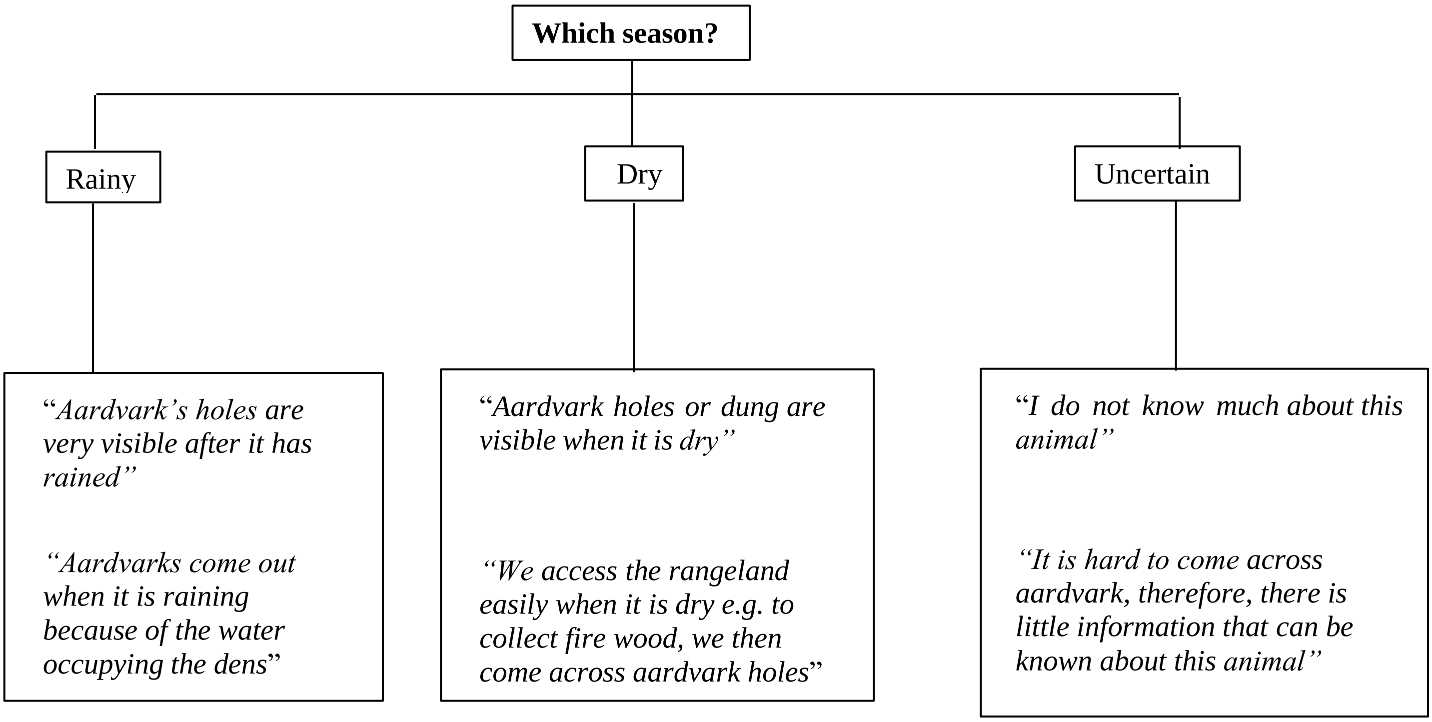

Figure 1 People's knowledge about the season of increased sightings of aardvarks in Ncunjane. Answers from respondents from Msinga Local Municipality, KwaZulu-Natal Province, South Africa, to the open question, "Which season do you see aardvark activities the most in your area?"

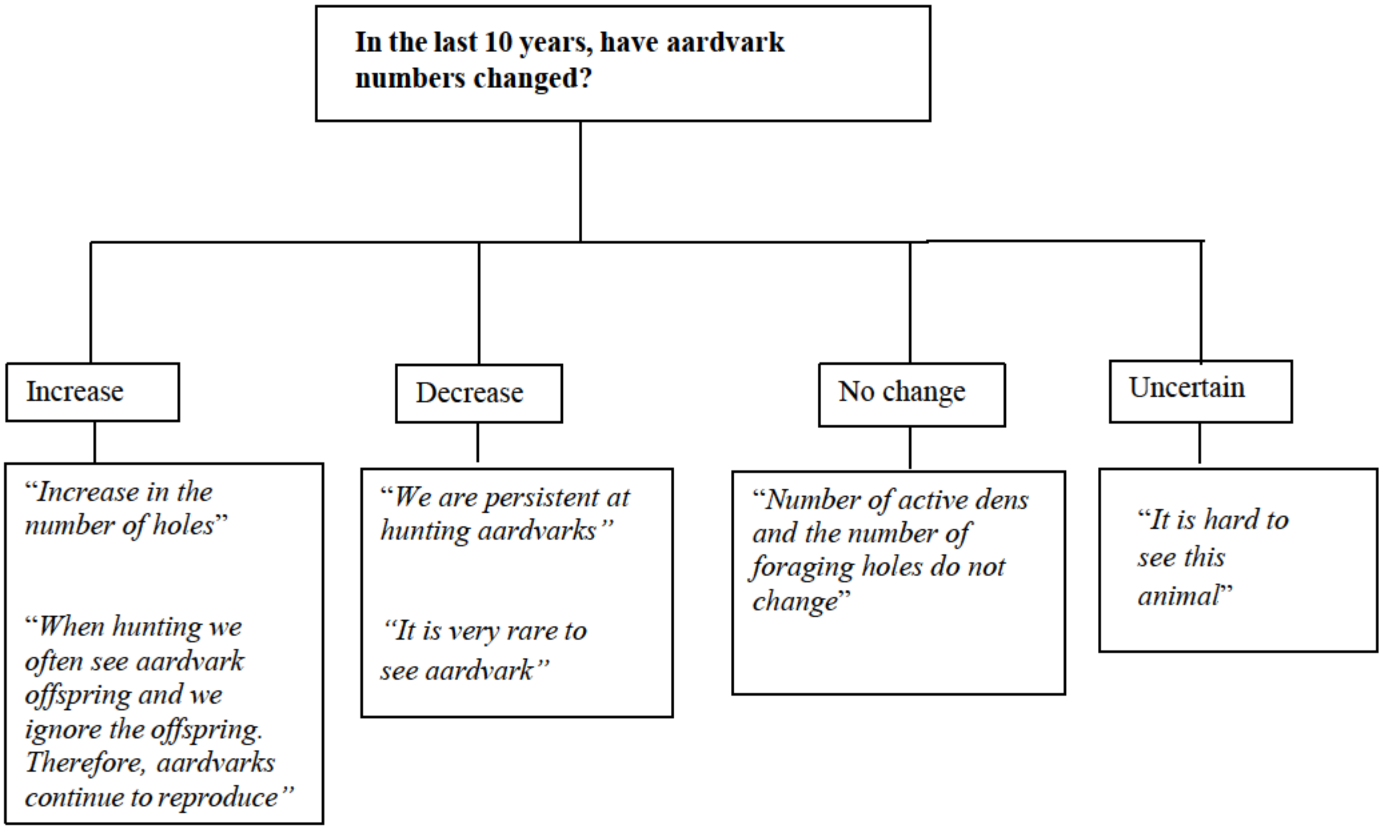

Figure 2 People's perceptions about the numbers of aardvarks in the last 10 years (2011-2021). Perceived knowledge from respondents of Ncunjane village, KwaZulu-Natal Province, South Africa, to the open question,"In the last 10 years, have aardvark numbers changed?"

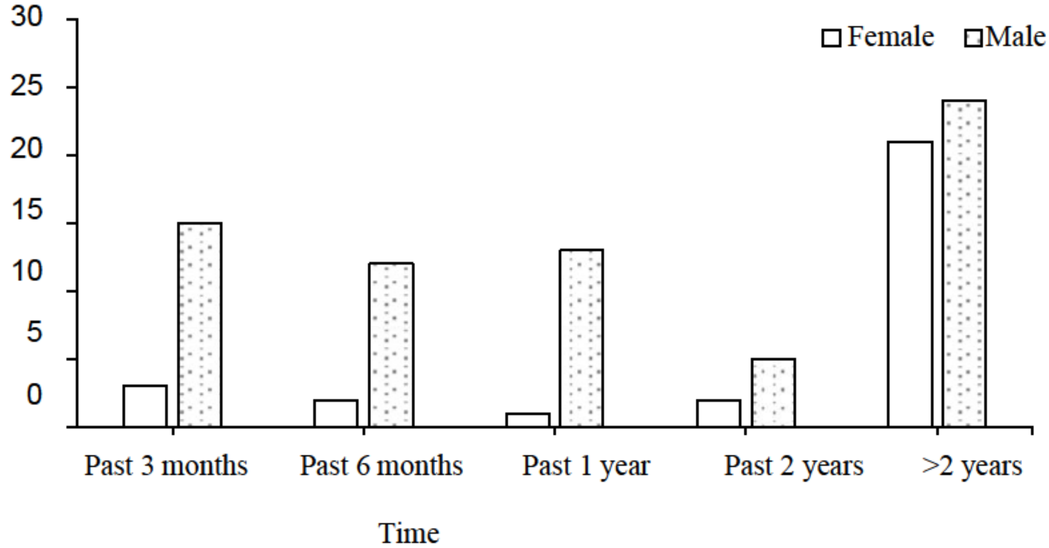

Figure 3 The local people's last record of aardvark sightings in Ncunjane, KwaZulu-Natal, South Africa.

The last time of aardvark encounter differed between genders. The majority of respondents last saw aardvark > 2 year ago, and many of these were males compared to females. In addition, 40% of the respondents reported sightings of aardvark within the last year (2020) and for some, it was as recent as three months prior to the interview.

Aardvark behaviour in a human-dominated landscape

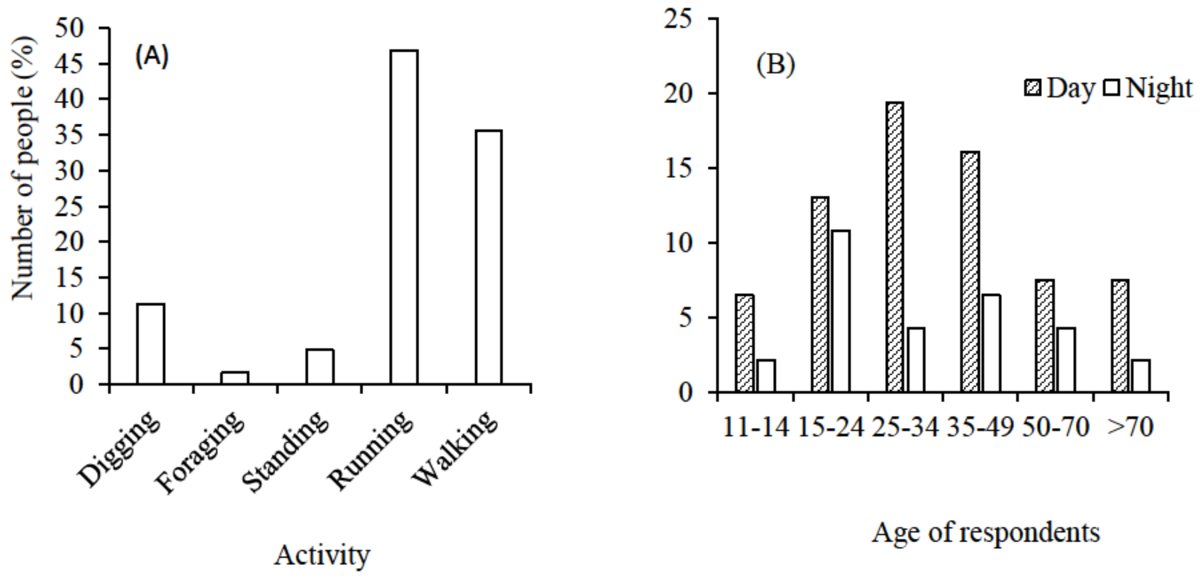

Figure 4 (A) Aardvark activity when it was encountered by local people and (B) time of day of aardvark encounter at Ncunjane in Msinga, South Africa.

Many people (49%, N = 88) of both genders (61 males and 27 females) saw aardvarks in the local area (Fig. 4A). The sightings by local people were associated with night travel (2%, N = 4), day activities (18%, N = 33) and hunting (25% = 46) (Fig. 4B, Fig. 5). Nine animals were killed in 46 hunting attempts reported in the study area. Most people saw aardvark running away from them, others saw it walking, while a few people saw aardvark foraging (Fig. 4A). Additionally, few people saw aardvark standing, probably the animal was not aware of their presence. The highest aardvark encounters occurred during the day, as reported by 25 to 34-year olds, while those between 15-24 years encountered the animal the most at night. Overall, respondents had the most encounters with aardvarks during the day (Fig. 4B).

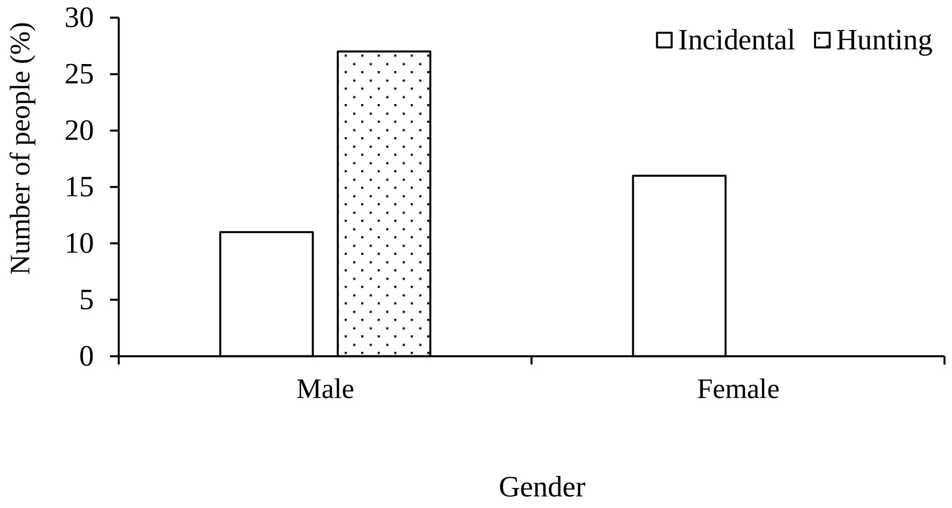

Figure 5 Type of encounter of aardvark by male and female respondents at Ncunjane in Msinga area of South Africa.

The type of aardvark encounter differed between men and women. Females only had an incidental encounter with aardvarks, while a small number of males encountered the animal incidentally and more males encountered the animal while hunting (Fig. 5).

People's perceptions about aardvarks

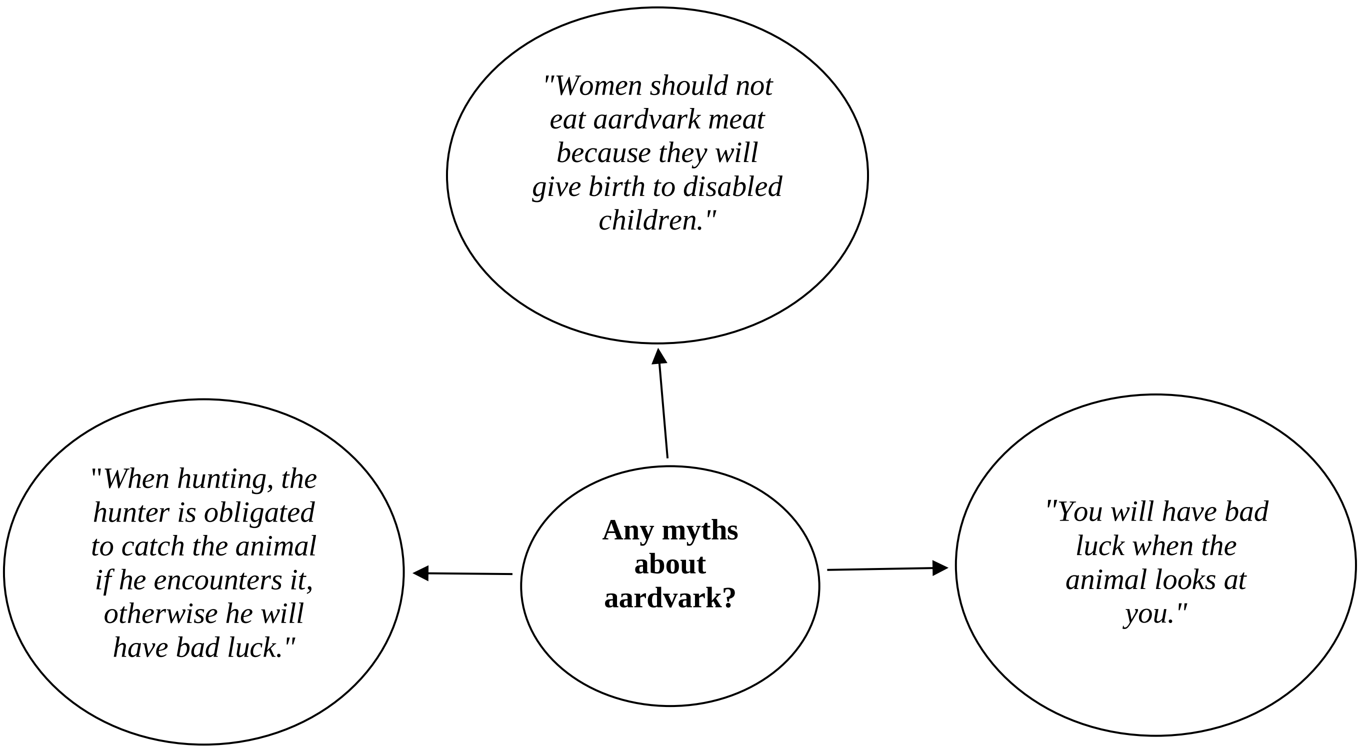

Figure 6 Known myths about aardvarks in Ncunjane of Msinga area of KwaZulu-Natal, South Africa.

The most known myth (96%, N = 165) associated with aardvarks was that bad luck follows people who have had the animal look at them (Fig. 6). Other myths were associated with giving birth to disabled children for women who would have eaten aardvark meat (1%, N = 1) and that hunters are obligated to catch aardvark after encountering it (1%, N = 1) (Fig. 6).

Table 3 People's perceptions about aardvark at Ncunjane village in Msinga area of KwaZulu-Natal, South Africa.

Positive	*"Since it runs away when it sees people"*
	"Aardvarks do not cause physical harm to people"
	"It is a wise animal, and it provides shelter for other animals such as porcupines"
Negative	*"Aardvarks can dig out human remains in graves when burrowing"*
	"Aardvarks destroy our walking paths"
	"It is a scary animal because of its physical appearance"
	"It is a scary animal since it burrows"
	"I view aardvark as a negative animal because you will have bad luck when the animal looks at you"
	"It destroys our gardens and crop fields located away from homesteads by feeding on our maize and watermelon plants"
Neutral	*"It does not bother people, however, it is scary"*
	"I have never seen the animal before, and it never destroyed anything of mine"
Uncertain	*"I do not know the animal; therefore, I am not certain about it"*

People's perceptions of aardvarks were strongly positive (78%, N = 141) because of the animal's shy behaviour, whilst a minority (8%, N = 15) perceived the aardvarks negatively (Table 3). Aardvark elusive behaviour significantly contributed to the neutral (13%, N = 24) and uncertain (1%, N = 1) perceptions people have about it (Table 3).

Use of aardvark

Aardvarks are mainly hunted for subsistence use where the meat serves as a food and protein source forthe hunters (82%, N = 40), while 4% (N = 2) hunt out of enjoyment, as they indicated that they do not like its meat. Finally, among the subsistence hunters, some indicated that they sell aardvark body partsto traditional healers (14%, N = 7, based on responses from N = 49 persons who are hunters).

Table 4 The use of aardvark body parts by local people.

Use	Body part
Sold for traditional medicine	*"Teeth, skin, claws, head, bones, left and right forelimbs, bile and tail"*
Traditional medicine	Medicine for animals - inflammation *"We boil the aardvark bones and throw them away when done boiling the water, the boiled water is then used to rub or wash the cow udderto heal inflammation"* Medicine for people - pelvic bone ache *"We normally boil the bones, then take the water to massage or washthe pelvic bone region"*
End products	Whip *"Aardvark skin is very strong. After slaughtering and cooking the meat, we dry the skin. Out of the skin, we then make whips used in driving domestic animals"* Necklace *"We make necklaces using the teeth and claws of aardvarks"* Bracelet *"The skin covering the tail is used to make bracelets"*
Unused body parts	*"We don't use claws, teeth, and the skin of aardvark, we throw them away"*
Edible body parts	*"We shave the aardvark skin, then boil it till it is soft to be eaten as normal meat. Due to its toughness, it takes time to cook it"*
Protection	*"Because of the toughness of aardvark skin and tail, we use them to make bracelets or ornaments worn on the waist for protection against evil spirits"*
Love magic/spell	*"The head is burnt to make love portion; it is also burnt to make a spell to win court cases"*

Many of the local people were unaware about the uses of aardvark body parts (71%, N = 128), due to limited interaction with the animal. Those who were aware indicated that the animal's body parts are used for various purposes including physical healing of livestock and people (8%, N = 4) (Table 4). While aardvark body parts are known (25%, N = 45) to be mostly sold to traditional healers, ordinary people also use them for medicines, other end products as well as for producing love magic/spells (Table 4). When the animal is hunted for meat the claws, teeth and bile are often discarded (3%, N = 5) while the tough skin may also be utilised as meat (Table 4).

Table 5 The sale value (ZAR) of body parts of aardvarks used in traditional medicine at Ncunjane in Msinga area of KwaZulu-Natal, South Africa. At time of writing, the exchange rate was R15.46 ≈ US$.

Age group of respondents	Body parts	Price (Rand)
11-14	Teeth, skin and claws	500-1000
11-14	Claws and head	400
15-24	Bones, teeth, skin and claws	500
25-34	Teeth, skin and forelimbs	50-100
25-34	Head	3000
25-34	Teeth, skin and claws	2000
35-49	Teeth, skin, claws head and bones	800
50-70	Teeth, skin, claws and head	800

Aardvark body parts were only sold by 14% (N = 7) of the hunters, and the value of each body part differed per hunter and by age group (Table 5). Most adult (25-34) hunters sold aardvark body parts ata higher price than younger hunters.

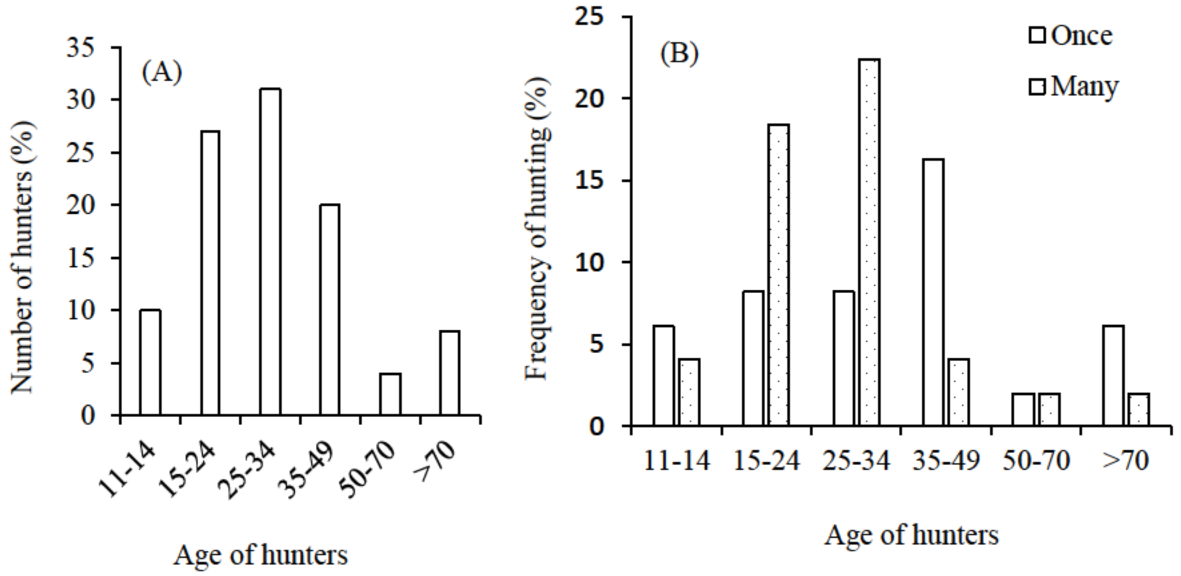

Figure 7 (A) The age of individuals who participate in hunting of aardvarks and (B) The frequency of hunting per year (N = 49 individuals) in Ncunjane, Msinga, KwaZulu-Natal.

Hunters tended to be young (15-34 years old), while there were only a few in the 50-70-year age group (Fig. 7A). Most hunters of 15 to 34 years of age hunt aardvarks regularly, while only a few persons from the other age groups hunt the animal regularly (Fig. 7B).

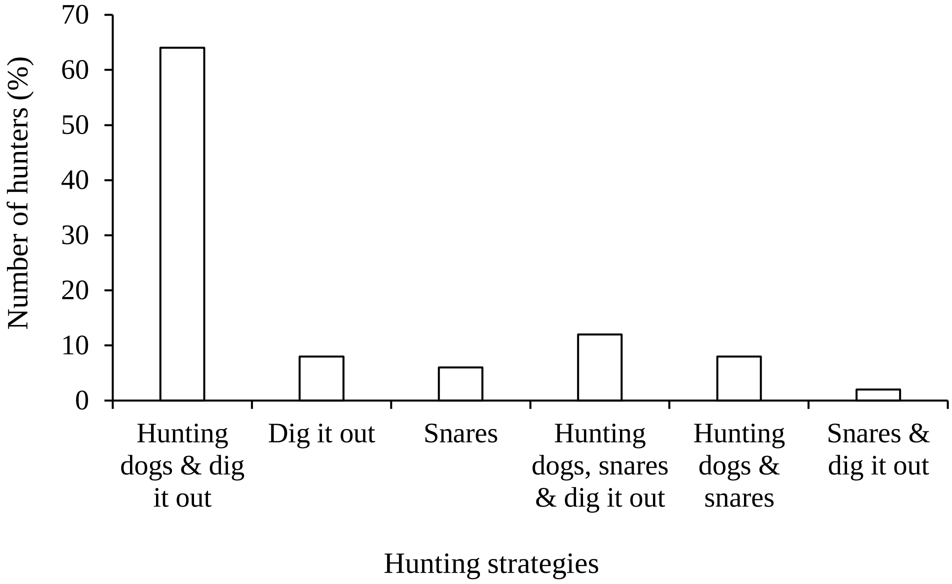

Figure 8 Strategies used to hunt aardvarks in Ncunjane, Msinga, South Africa.

Hunting strategies mainly consisted of hunting dogs used to identify occupied dens before digging out the aardvarks. Other strategies, such as snares and smoking out the animal or digging the aardvark out were least utilised (Fig. 8). The hunters usually hunted in groups using trained hunting dogs. Hunters noted the areas where aardvarks occurred when minding cattle, and they could easily identify the aardvark dens due to their large size compared to foraging holes. The presence of flies at the entrance of the den was used as an indicator of the presence of aardvark in a specific den. Also, when hunters saw a fresh mound at a den, they knew that there were high chances that an aardvark was still inside or close. The hunters indicated that dogs could validate if there was an aardvark in the den by continuous barking. When the dogs were barking, the aardvark inside would dig a new burrow inside the den to escape or block the entrance to prevent the dog from advancing towards it.

Snares were set at the entrance of the den. One of the hunters indicated that they would set fire at the entrances of the den and dug the animal from one or two entrances. The smoke could drive the aardvark to one of the entrances or exit holes. When the aardvark tried to get out through the entrance, it would be caught in the snare and the hunters would kill it using digging tools (shovels and hoes).

2.4 Discussion

Understanding people's perceptions about non-carnivorous animals like aardvark in human-dominated landscapes has not been extensively studied. As expected, I found that the majority of people were aware of aardvarks in their local area although it was common for some people to confuse aardvarks with Cape porcupines, as both these animals are burrowers. Taylor et al. (2002) reported that aardvarks about 200 foraging holes a night. This increased the likelihood of awareness of aardvarks by respondents who had never seen the animal before. Thus, diggings manifest their activities in the landscape. For some respondents, aardvark diggings were consistent throughout the year, and could therefore not distinguish between seasonal activities of the animal. Some respondents indicated that most diggings of aardvark in the area occurred during the rainy season. This could likely be explained by increased aardvark foraging holes for ant prey, which are abundant in the wet season in semi-arid areas (Lindsey and Skinner, 2003). In addition, aardvark habitat overlapped with the livestock and crop faming activities of some of the local people, which contributed to their familiarity with the animal. However, respondents had little information on multiple response questions about the animal such as the season in which sightings were common. This was not surprising as only 27% (N = 49) of the respondents indicated hunting aardvarks, which increased their chances of interacting with the animal. The deficiency of information on aardvark in the past 10 years and the last time respondents saw aardvark in their area showed that aardvark is not a common animal to come across, only the diggings attest to their presence. Overall, 88 (49%) local people saw aardvarks in the area, this was dominated by older females and younger males. Female sightings occurred more than two years prior to the interview, while males were within a year. This is attributed to the hunting activities males undertook for aardvarks. As a result, five animals were reported to have been successfully hunted within a two- year period. This indicated a heavy investment in hunting, which may likely threaten an animal occurring in low population densities such as the aardvark. As such, Taylor and Skinner (2003) found approximately eight aardvarks per 1000 ha in the Karoo, a semi-arid area in South Africa.

People's positive perceptions of aardvarks, in my study, originate from understanding that aardvarks do not charge at people, which could result in a physical altercation. This is attributed to the shy nature of the animal (Taylor et al., 2002). Therefore, aardvarks were less likely to face persecution in Ncunjane for threatening human lives. The area is homogenous in terms of ethnicity (same ethnic group) and thus scant myths exist about aardvarks. Some people mentioned that the animal quickly looks down when a person approaches it, thereby casting doubt on the myth that a person will experience bad luck if it looks at them. The behaviour also attests to its shy nature, and may also dissuade attacks by the local people. In Ghana, seeing an aardvark is viewed as a sign of rainfall, which is positive for communities in need of rain (Emieaboe et al., 2014). All who were aware of the myths believed in them and complied, even women who were not aware of the myth still attested to not eating its meat. This suggested that hunters did not share aardvark meat with families or it was only eaten by males in the families including young boys. Meat from pangolins was only eaten by males in the family in the Democratic Republic of Congo (DRC) (Malimbo et al., 2020). Women were also discouraged from touching nor coming across the white-bellied pangolin (*Phataginus tricuspis*) when collecting firewood or when it has been hunted in the Lele region, DRC (Walsh, 2020).

The primary reason for aardvark hunts in Ncunjane was subsistence. Malimbo et al. (2020) alsoshowed that several species of pangolins (*Manis tetradactyla, M. tricuspis* and *M. gigantea*) were mainly hunted for consumption in and around the Tayna Nature Reserve in the DRC. Porcupines (*Hystrix sumatrae, H. brachyura,* and *H. javanica*) are also exploited as an alternative protein source in Indonesia (Mustikasari et al., 2019; Nurliani et al., 2020; Gomez, 2021). Hunting aardvarks for commercial purposes is likely significant with increased hunting frequency in my study area. Despite the challenges associated with difficulty in hunting the animal, the financial incentive to be gained from hunts may motivate the hunters. The trade of aardvarks for traditional medicine was the most popular means of commercialisation. Specifically, the hunters sold body parts of aardvarks to traditional healers,which concurs with Whiting et al. (2013)'s report of vertebrate body part sale in Johannesburg, South Africa. Also, Shepherd et al. (2017) showed that pangolins were hunted and sold to make traditional medicine in Zimbabwe. Porcupines are also hunted for traditional medicine in South Africa and Asia (Hayward, 2009; Gomez, 2021).

Aardvark body parts are not only used by traditional healers but also by local people, which is common with uses of the porcupine and pangolin (Mustikasari et al., 2019; Malimbo et al., 2020; Gomez, 2021). Different kinds of medicine, love and magic spells are produced by people using aardvark body parts. The same has been reported for porcupine body parts (Mustikasari et al., 2019; Malimbo et al., 2020). For example, porcupine quills are used as a charm against black magic, and women use them to pin their hair (Mustikasai et al., 2019; Gomez, 2021), and men use them to decorate their hats. Using the body parts of these animals to produce such products may be associated with the belief that bushmeat is medicinal (Namusisi et al., 2021). Aardvarks were significant to the Tabwa people (Congo) during ancient times, while pangolins were of the least concern (de Heusch, 1985). However, this sentiment has changed with time and aardvarks are now commonly used to produce medicine and for rituals (Walsh, 2020). This may be due to the similar traits and adaptations aardvarksshare with pangolins such as burrowing and insectivory (de Heusch, 1985; Walsh, 2020).

To increase hunting success, hunters use a combination of hunting techniques, which may influence the number of animals caught (Conover, 2001; Nasi et al., 2011). Similarly, various techniques were used by hunters in this study to catch aardvarks, the most popular being hunting dogs and digging tools. Malimbo et al. (2020) reported the same strategy of using various techniques for hunting burrowing animals in the DRC. Use of hunting dogs and tools required joint efforts from severalhunters, which results in splitting of the meat or profits after a successful hunt. Alternatively, hunters lure the animal out of the burrow through smoke, which is a similar technique used to hunt various species such as porcupines (Duda et al., 2017; Loke et al., 2020). The use of snares alone as a hunting technique to trap aardvarks was not popular in my study area. This may have been caused by the fact that there was a high investment associated with this technique, which includes regular visits to the trapping site to collect any potential catch or reset the snares, which has also been reported elsewhere in sub- Saharan Africa (e.g. Duda et al., 2017). Regular hunting of aardvark was influenced by age of hunters in the current study, which in turn was likely influenced by financial gain for older hunters. A high frequency of hunting by older men may be influenced by the fact they rely on the animal for financial gain to support themselves and their families (Angelsen et al., 2014). Mature men (20-50 years old) tend to be responsible heads of households in this area, which is consistent with findings from other regions (e.g. Vitekere, 2015; Kyamakya et al., 2018). I found hunting opportunities to be seasonal for the younger hunters, as influenced by the school calendar. Specifically, hunting was only possible during school holidays for young hunters. Staying in school may thus play a role in reducing hunting pressure on aardvark in Ncunjane.

2.5 Conclusion

Despite the aardvark's shy behaviour, its proximity to human settlements increases chances of encounter and that these encounters tend to be deliberate, as facilitated by male hunters. Positive perceptions about aardvarks prevailed because of their inability to cause physical harm to humans. However, like many societies across the world, myths associated with bad omens were prevalent regarding this nocturnal animal in Ncunjane. Despite the aardvark's elusive behaviour around humans in Ncunjane and the labour intensive activity of hunts, their pursuit for meat and traditional medicine may ultimately lead to their demise in the local area, which will negatively impact other fauna dependent on aardvark for survival. The number of hunters is high and exacerbated by the frequency of hunts. This likely puts the aardvark at risk of local extinction. Education programmes and increased conservation efforts may help to decrease the harvesting of aardvarks and other burrowing mammals. This will be feasible since the majority of people perceive aardvark as a positive animal. Therefore, this will improve the conservation status of the aardvark.

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Chapter 3

Seasonal variation of aardvark burrowing activities in a savanna ecosystem

Abstract

Aardvarks change the ecosystem through digging for food and shelter thus providing habitats for various animals in sub-Saharan Africa. However, little research has been conducted on aardvark foraging holes,which, like dens may play a significant role as a sink for plant and animal litter and seeds. The aim of this study was to explore the ecological effects of aardvark foraging activities in a semi-arid savanna ecosystem that is also used as a communal rangeland. I quantified aardvark foraging holes and dens in the dry, wet and early dry seasons of 2020 and 2021 in Ncunjane village of KwaZulu-Natal Province, South Africa. 50 m × 10 m belt transects were used to quantify aardvark foraging holes in each site of aardvark activity. For each aardvark foraging hole in each transect, the maximum depth and two perpendicular lengths on the ground surface were used. Furthermore, I recorded evidence of plant and animal materials (e.g. forbs or grasses, plant and animal litter, seeds, arthropods, spider webs, etc.) were recorded in each foraging hole. Dens were identified using walking transects guided by a research assistant who knows the area. The number of inactive or abandoned entrances and anything (e.g. animal faeces and spider webs) inside the hole were counted and recorded, respectively. The effect of season, age, and their interaction on area and depth of foraging holes was tested using General Linear Models (GLM). All seasons comprised a greater number (> 51%) of old than new and very old foraging holes. The area of different-aged holes differed significantly with season($P < 0.0001$) and the depth of different-aged foraging holes varied with season ($P < 0.0001$). In addition,the contents of foraging holes varied with age of the hole and season, new holes showed no grass or forb plant life across seasons. Dens were constructed close to feeding areas, which may be necessary in a human-dominated environment. In Ncunjane, aardvark den holes provided refuge to other animals such as spiders, wild cat, Cape porcupine and snakes. Therefore, an increase in aardvark holes can be associated with significant landscape heterogeneity for both vegetation and animal life.

Keywords: Ecosystem engineer, foraging holes, dens, semi-arid savanna ecosystem, vegetation.

3.1 Introduction

Soil disturbance by animals contributes to spatial and temporal heterogeneity in various landscapes (Eldridge and Mensinga, 2007; Muvengwi et al., 2018). Soil disturbance in terrestrial ecosystems is of much greater effect when carried out by a group of animals called ecosystem engineers, which create, modify and maintain habitats of other organisms (Whittington-Jones, 2006; Fleming et al., 2014). Ecosystem engineers include many species of mammals such as aardvarks (*Orycteropus afer*), meerkats(*Suricata suricatta*) and Cape porcupines (*Hystrix africaeaustralis*) (Melton, 1976; Bragg et al., 2005). The aardvark is among burrowing mammals whose digging abilities are evident in various landscapes such as savanna, grassland, rainforest and woodland of many parts of sub-Saharan Africa (Taylor and Skinner, 2004; Kingdon et al., 2013). Compared to other burrowing animals, aardvark diggings are abundant and deep (Taylor and Skinner, 2004; Whitting-Jones, 2006

Kingdon et al., 2013), which makes aardvarks among the most effective ecosystem engineers. The extraordinary digging abilities of aardvarks are due to their long claws and muscular limbs (Kingdon, 1971; Haussmann et al., 2018). The large sized-burrows (e.g. den or foraging hole) may be attributed to the large body size of the animal.

Ecosystem engineers dig burrows for habitation and foraging, which can capture water, soil and seeds (Wilby et al., 2003; James and Eldridge, 2007). Aardvarks dig two types of burrows, namely, theforaging hole, which is usually shallow and small for the animal to fit its whole body (Melton, 1976; Taylor and Skinner, 2004). Aardvarks also dig den burrows where the animal lives or rear their offspring. A den is a burrow system that incorporates a network of several to many burrows (Hagenah et al., 2013). The den can comprise up to eight different entrances connected by short lateral tunnels (Kingdon et al., 2013), aardvarks use these multiple entrances to enter and leave for feeding (Melton, 1976; Taylor and Skinner, 2003; Taylor and Skinner, 2004). In addition, aardvarks tend to use the abandoned burrows that are abundant within their home range instead of digging new burrows (Taylor et al., 2002). These burrows allow the mixing of soil from below-ground to the ground's top surface, resulting in land heterogeneity (Whitford and Kay, 1999; Muvengwi et al., 2018). There are several organisms that live below-ground which include earthworms and arthropods (Acari, Collembola, Isopoda, termites and ants) that feed on dead plant materials and microbes. The feeding activities of these organisms permit the recycling of essential nutrients into soil (Curry, 1989; Edwards, 2004; Giribet and Edgecombe, 2012). Termites and ants are potent arthropods that are common in savanna ecosystems wherein they transform litter when feeding thereby making the soil fertile (Dowuona et al., 2012). Additionally, the tunnelling and burrowing activities by arthropods provide air passage and water infiltration which assists in the mixing of organic matter with the upper soil layers (Culliney, 2013). Consequently, the mixing of organic matter with the upper soil layers leaves the environments with fertile soils (Wilby et al., 2003; James and Eldridge, 2007). The burrows dug by ecosystem engineers vary in size and depth because of physical properties of soil (Anderson and Allred, 1964; Reichman andSmith, 1990), soil with fewer rocks is easy to dig (Weiss and Verts, 1984; Shenbrot et al., 1997). Similarly, semi-fossorial animals such as aardvarks can change soil fertility because nutrient concentration increases with depth (Eldridge and Whitford, 2009), the diggings make nutrients stored below-ground level to be available to the topsoil and thus encouraging the establishment of distinct plant species such as *Stipagrotis uniplumis* (Louw et al., 2021). Semi-fossorial animals can be found in semi-arid regions (Kinlaw, 1999; Whittington-Jones et al., 2011). They have degraded due to historical land use by humans, i.e. farming leading to low soil organic carbon (SOC) content and poor environmental structure (FAO, 2016). Therefore, the activity of aardvark in semi-arid regions may increase the fertility of soils and contribute to the rehabilitation of the ecosystem.

Burrowers promote the growth of annual plants, for example, the Indian gerbil (*Tatera brandtii)* in South African dune fields creates bare ground when burrowing thus creating space for annual plants to germinate and grow (Dean and Milton, 1991). Consequently, burrows create distinct and new microhabitats that may favour a range of plant and animal species (Louw et al., 2019). For example, aardvark burrows allow the growth of plants in unfavourable environments such as the hard fern (*Pellaea calomelanos)* and green cliffbrake (*Cheilanthes viridis)*, and other fern plants thus, increasing landscape heterogeneity (Haussmann et al., 2018). However, age of burrows has a significant influence on the level of plant species richness. For example, old and abandoned burrows favour high plant species richness in contrast to fresh burrows and mounds (Whitford and Kay, 1999; Haussman et al., 2018). Burrows also change the patterns of animal community diversity since they provide shelter for other animals (Stachowicz, 2001; Louw et al., 2019). For example, Ceballos et al. (1999) recorded an increase in species richness of small mammals that usecolonies of another ecosystem engineer, prairie dog (*Cynomys ludovicianus*). Burrows provide protection to a variety of species other than the digger by reducing temperature and moisture extremes (Whittington-Jones et al., 2011). For example, southern hairy-nosed wombat (*Lasiorhinus latifrons*) use burrows as shelter to minimise respiratory water loss (Finlayson et al., 2006). Similarly, aardvark burrows provide shelter to animals such as Karoo-toad (*Bufo gariepensis)*, Ground agama (*Agama aculeata)* and Cape crested porcupine (*Hystrix afriaeaustralis)* (Whittington-Jones et al., 2011). In addition, burrowers can transform land by displacing sendiment and changing the hydrology of the burrow. Laundre (1993), using ground squirrels (Townsend's ground squirrel; *Spermophilus townsedii* and Wyoming ground squirrel; *Spermophilus elegans*), showed that winter precipitation entered the soil near burrows allowing vertical penetration of water to deeper portions of the soil profile than in non- burrowed areas. Therefore, burrows generally are cooler and moist, which allows seed germination and seedling establishment even in unfavourable environments (Gutterman, 2003; Haussman et al., 2018). Burrows can trap windblown seeds, thus providing food for granivorous and omnivorous animals such as rodents (Whitford and Kay,1999; Bragg et al., 2005). Also, seed germination may be influenced by organic matter derived from insect debris, and animal dung trapped in burrows (Dean and Milton, 1991). In addition, the mound created by burrowing animals can rise one metre above the surrounding topography (Löffler and Margules, 1980), thus altering the topography of the environment. Therefore, burrowers are of significance in their ecosystems of occurrence.

Aardvark digging activities may be influenced by prey availability and seasonality (Lindsey et al., 2013). Aardvarks feed on termites dominantly in the wet season and on ants during the dry season (Taylor et al., 2002; Kingdon et al., 2013), and the extent of digging foraging holes depends on food availability (van Aarde et al., 1992; Taylor and Skinner, 2003). Considering that ants and termites are very small invertebrates, aardvarks consume them in large quantities when feeding in order to meet their energetic requirements (Kingdon et al., 2013). The feeding requirements of aardvarks result in the abundance of their foraging activities i.e. foraging holes and destruction of termite mounds in the landscape, while den burrows occur at a lesser extent. The size (depth) of the foraging holes is influenced by prey type, aardvarks dig deeper to catch termites compared to ants (Taylor et al., 2002). Aardvarks generally dig into the centre of the colony where most of prey is located (Melton, 1972; Kingdon et al.,2013). Both foraging holes and dens of aardvarks can trap plant litter, water, seeds, and serve as germination sites (Dean and Milton, 1991; Whittington-Jones, 2006). Regardless, research has been focusing on aardvark den burrows, neglecting the ecological importance of aardvark foraging holes. Therefore, the aim of this study was to explore the seasonal burrowing activities of aardvark, the ecological effects (plant and animals occurring therein) and size-characteristics of foraging holes and dens. The objectives were to determine: (1) the size (surface area and depth) and density of foraging holes in different seasons, (2) the vegetation or animal life that occupies aardvark foraging holes in differentseasons, (3) the distance between active entrances within a den, and (4) the number of active and abandoned entrances at dens. I expected foraging holes to be deeper and wider, and to increase in number in the wet season when termites are abundant. Also, I expected old and very old foraging holes to be occupied by increased vegetation and animal life than new. In addition, I expected more active and closely located den entrances ease of escape and for aardvarks to travel shorter distances from their dens to feeding sites in the communal landscape.

3.2 Materials and Methods

Study site

The study was carried out in the Ncunjane communal area (28º44′S, 30º27′E) of Msinga Local Municipality in the KwaZulu-Natal Province of South Africa (Fig. 9). Msinga is located in the upper basin of the Thukela stream, which is approximately 100 kilometres away from Indian Ocean (east) and Drakensberg Mountains (west) (Fowler, 2011).

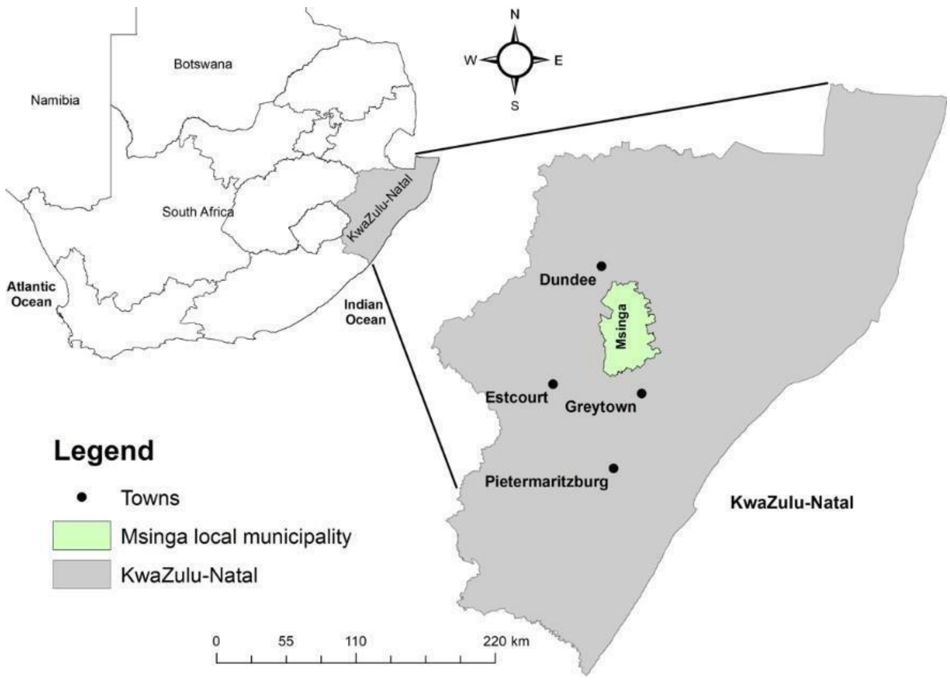

Figure 9 Location of Msinga Local Municipality within the KwaZulu-Natal Province of South Africa.

Soil type and geology

The soil is gravelly with limited amounts of clay and organic matter content, thus the region is relativelynon-arable (van der Eyk et al., 1969), except for the floodplain of the Tugela river where crop farming occurs on some 840 hectares (Cousins, 2013; Maziya et al., 2017). Msinga soil is shallow and reddish –brown (van der-

Eyk et al., 1969). The area is noted for its steep slopes and rocky surfaces. Msinga comprises of broad alluvial plain (400-650 m asl) rising to the highveld north and south of the Thukela River (1200-1600 m asl) (Fowler, 2011).

Vegetation and climate

The area is characterised by vegetation comprising bushveld and thornveld with sparse grass cover on rocky terrain (Fowler, 2011). The grass layer consists of red oat grass (*Themeda triandra),* guinea grass (*Panicum maximum)* and African lovegrass (*Eragrostis curvula),* while the woody vegetation is dominated by deciduous trees such as umbrella thorn (*Vachellia tortilis),* sweet thorn (*V. karroo)* and gum arabic tree *V. nilotica)*, and evergreen trees such as common olive (*Olea europaea),* blue guarri (*Euclea crispa),* and shepherd tree (*Boscia albitrunca)* (Mucina and Rutherford, 2006). Msinga receives a mean annual rainfall of 682 mm (Cousins, 2013), that fluctuates between 400 and 900 mm (Mkhabela, 2005) and the majority of which falls from December to February. Temperature, rainfall and vegetation of Msinga correspond with the altitude of the region (Fowler, 2011).

Sampling

Foraging hole selection and classification

Sampling of aardvark digging activities occurred in the dry season (October 2020), rainy season (November 2020) and early dry season (May 2021). Sampling sites, as defined by aardvark activities, tended to be located away (> 1.2 km) from households in the village. Areas of aardvark activity were identified based on knowledge of the local people, who come across the sites while collecting firewood, poles or traditional medicines, or minding their livestock (cattle, goats and sheep), or hunting. 50 m x 10 m belt transects were used to quantify aardvark foraging holes in each site of aardvark activity. Aardvark foraging holes were distinguished using the characteristic of aardvark foraging hole shape and claw marks, which were often evident on the sides of the hole. Sampling was dictated by areas of foraging activity, thus 7 transects were sampled in the dry season, and 23 in the wet and early dry seasons. For each aardvark foraging hole in each transect, the maximum depth and two perpendicular lengths (cm) on the ground surface were measured. The number of foraging holes that were immeasurable due to trampling by livestock and human movements were also recorded. Furthermore, evidence of plant and animal materials (e.g. forbs or grasses, plant and animal litter, seeds, arthropods, spider webs, etc.) in each foraging hole was recorded. Foraging holes were categorised as new, old, or very old based on evidence of plants, soil disturbance, and mound-size. New holes showed evidence of recent soil disturbance, which resulted in the presence of a fresh mound and no plant growth on the mound. Old foraging holes also had an absent or reduced mound and plant growth on previously disturbed areas. Additionally, very old foraging holes tended to collapse there by losing the characteristic shape structure and comprised of no mound, and mature and considerable vegetation cover in the foraging hole.

A B C

Figure 10 Three different ages of foraging holes of aardvark: (A) new hole with evidence of recent soil excavation and no plant growth, (B) old hole with mound of soil, and (C) very old hole with grass growth and no mound present. The 100 cm long metre rule was used for measurements.

Den sampling

Den and foraging hole sampling took place simultaneously during the three seasons of sampling. I distinguished aardvark foraging holes from dens by size. Specifically, foraging holes are shallow with a maximum depth that can be seen, while holes of dens are large and deep and the end of the hole is not visible from outside because it may be too deep (> 2 m depth) (Kingdon, 2013; Kingdon et al., 2013), or the holes are at an inclination from the soil surface, and also change direction. Dens were also characterised by several active and inactive/abandoned entrances. The majority of the active dens were indicated by the presence of flies (reddish in colour) around the entrance which follow the animal, and whose presence indicates a burrow system occupied by at least one aardvark. Abandoned dens were old and further classified as collapsed in instances where the roof of the den broke or was no longer in use. The number of inactive or abandoned entrances distance between active entrances within a den, the number of de entrances used for refuse, and any other material (e.g. animal faecas, spider webs, etc) were recorded. Also, I recorded den entrances covered with rocks that were placed by people to prevent their utilisation by snakes such as the Central African rock python (*Python sebae*). Holes dug by aardvark were distinguished from holes dug by hunters by their shape, angle and characteristics of the walls of each hole. For example, holes made by hunters are vertical, less rounded, with flat walls showing evidence of the tool used in digging, such as a spade or shovel, while holes dug by aardvarks are inclined at about 30-45º from the ground surface, have claw marks on the walls, and may be partially covered by overhanging vegetation (Fig. 11). During the dry and early dry season, I measured the distance (m) from the foraging area to the closest den entrance, which can indicate whether the animal seeks to separate the foraging and refuge (den) areas. Furthermore, I was accompanied by one of the village hunters to give additional information on the trends of aardvarks in the village, and how many aardvarks they managed to catch over the eight months I was conducting my research.

A

B

Figure 11 (A) Aardvark active den with evidence of aardvark large claw marks and fresh soil excavated.The den was old but still in use and (B) hole dug by humans to catch aardvark with footprints of huntingdogs.

Data analysis

The total number of foraging holes, immeasurable foraging holes, and aardvark and human made holes at dens were calculated. Further grouping of immeasurable foraging holes according to factors that affected them and season. All data were analysed using IBM SPSS statistics for windows version 27 (IBM Corp,2020). The depth and area of foraging holes were compared among season (dry, wet and early dry) and age (new, old and very old). The area (cm^2) and depth (cm) were the dependent variables, whilst season and age were the independent variables. The data did not conform to normality after testing using a One-Sample Kolmogorov-Smirnov test, and suitable transformation could not normalise residuals of the data. Generalised Linear Models (GLM) which can be used for non-normally distributed data was used to determine if there was a difference in the area and depth of foraging holes by season, age, and their interaction. Where significant ($P < 0.05$) the season and age treatments were further compared using a Bonferroni post hoc test. The frequency of occurrence was used to present the materials found in aardvark foraging holes, also for the materials and characteristics of active and abandoned dens. I used GPS pointsof active dens to calculate the distance between neighbouring dens and independent active dens. Dens that were > 1 km apart were regarded as independent and thus may have represented different animals. The number of animals is not accounted for in this study because I had no way to quantify it.

3.3 Results

Abundance of foraging holes and den burrow system

Foraging holes (N = 639) were approximately 27 times more abundant than the dens (N = 24) during the three seasons of sampling in year 2020 and 2021 at Ncunjane, Msinga, KwaZulu-Natal. These occurred over an area of approximately 64.7 km^2.

Foraging holes

A total of 88 foraging holes were measured in the dry season, 276 in the wet season and 275 in the early dry season (Fig. 12). A total of 34 very old foraging holes in the dry season were immeasurable because of livestock trampling and human movements. The wet season also consisted of 34 immeasurable very old foraging holes due to trampling by livestock or human movements and activities, or covered by grass or the foraging holes were dug under *Vachellia* trees. The early dry season had 42 immeasurable very oldforaging holes because of livestock trampling and establishing vegetation.

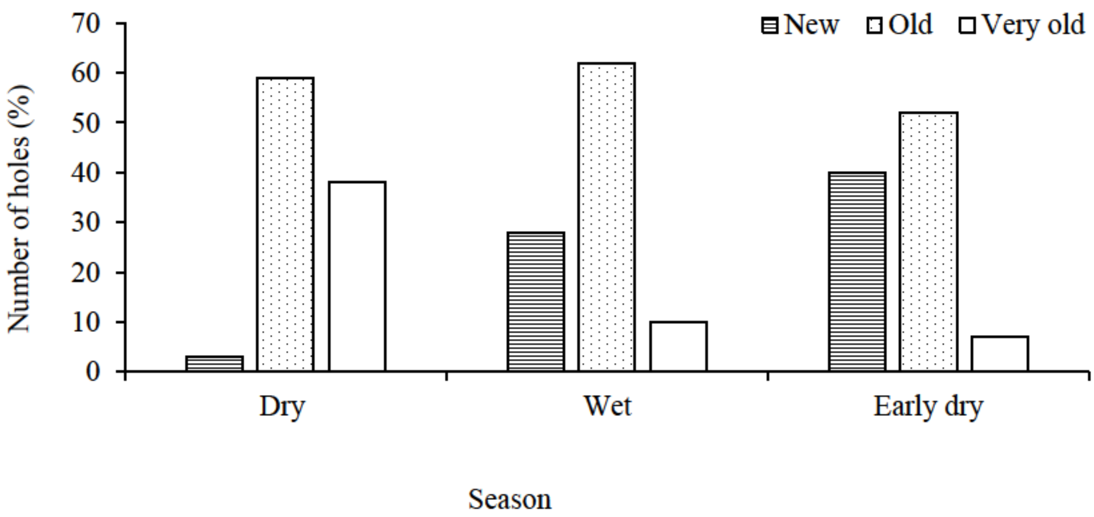

Figure 12 Number (%) of different-aged foraging holes across different seasons of the year 2020 and 2021 in Ncunjane, KwaZulu-Natal, South Africa.

All seasons comprised a greater number (> 51%) of old than new and very old foraging holes (Fig. 12). New holes increased in number in the wet and early dry seasons compared to the dry season. Most of the new (76%) and old (71%) foraging holes had a mound, while 64% of very old holes had no mound.

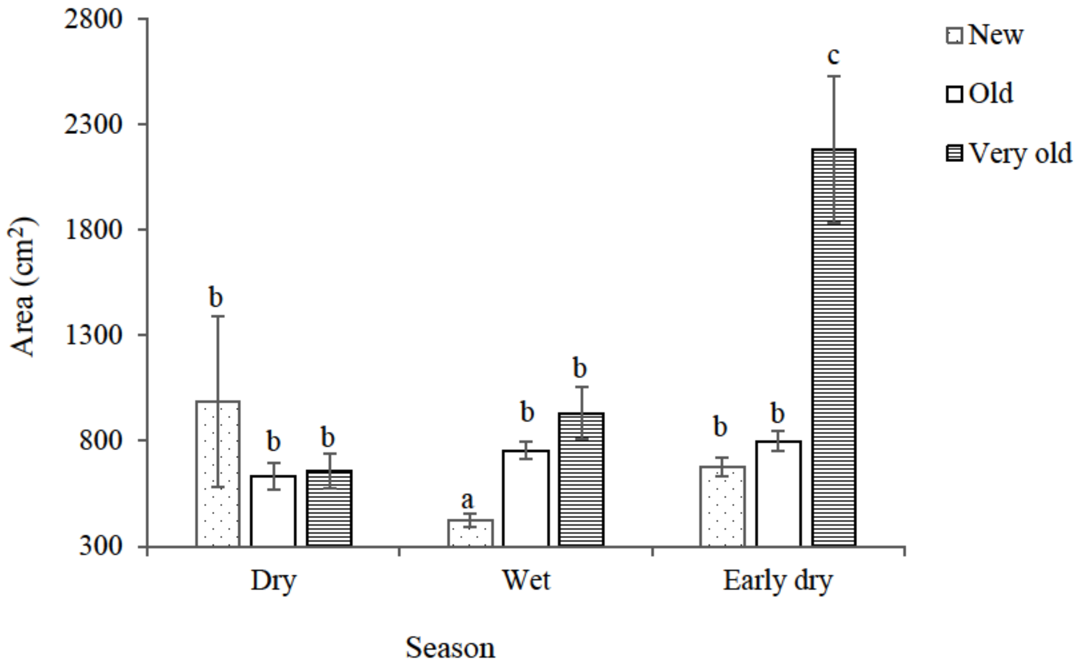

Figure 13 Mean (± SE) area (cm^2) of different-aged foraging holes by season in Ncunjane, Msinga,KwaZulu-Natal, South Africa. Different superscript letters indicate significant differences (P < 0.05) between age within each seson.

The area of different-aged holes differed significantly with season (χ^2 = 30.33; df = 4; P < 0.0001) (Fig.13). The area of very old holes in the early dry season was significantly greater than that of other holes (P < 0.001). New holes in the wet season were smallest in area (P = 0.028) (Fig. 13).

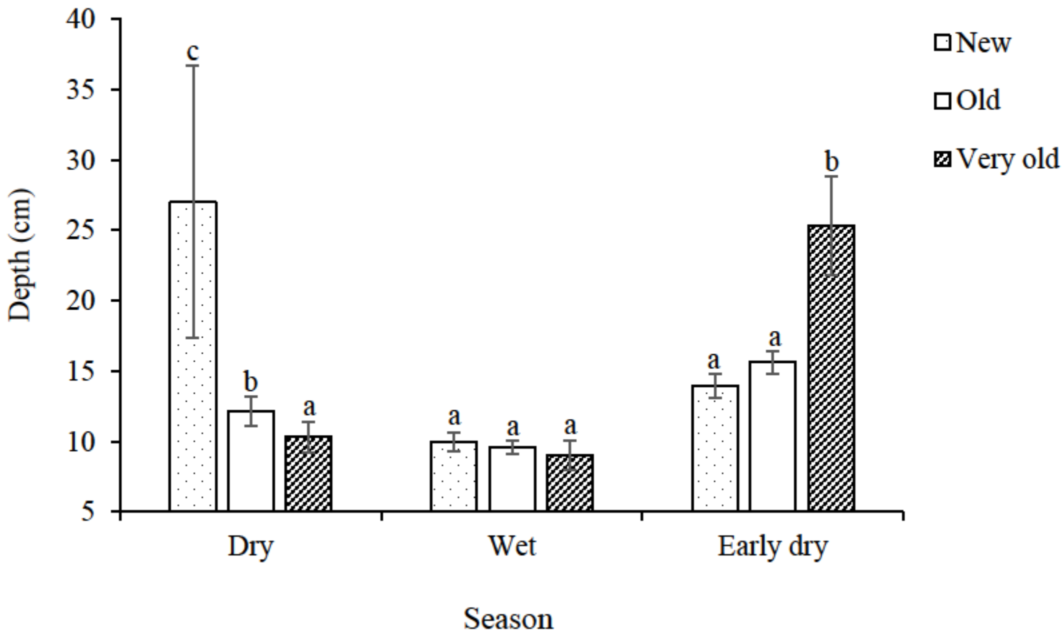

Figure 14 The mean (± SE) depth (cm) of foraging holes across three seasons in Ncunjane, KwaZulu-Natal, South Africa. Different superscript letters show significant differences ($P < 0.05$) between age within each season.

The depth of different-aged foraging holes varied with season ($\chi^2 = 22.01$; df = 4; $P < 0.0001$) (Fig. 14). All the holes were shallow in depth in the wet season while the dry and early dry seasons had deeper, new and very old foraging holes (Fig. 14).

Table 6 Total number of materials found inside aardvark foraging holes in the dry, wet and early dry seasons in 2020 and 2021 at Ncunjane, KwaZulu-Natal, South Africa.

	Dry season			Wet season			Early dry season		
Material	New	Old	Very old	New	Old	Very old	New	Old	Very old
Grasses	-	3	2	-	98	9	-	17	7
Forbs	-	-	-	-	30	4	-	-	-
Spider web	-	1	1	-	16	2	3	16	2
Termites/ants	-	-	1	49	10	4	22	6	-
Litter (plant)	2	50	40	17	49	15	77	100	10
Vachellia pods	1	-	-	-	-	-	-	-	-
Unidentified pods	-	7	4	-	-	-	3	9	-
Goat dung	-	9	9	-	11	8	1	1	-
Cow dung	-	5	7	-	5	3	1	2	-
Unidentified seeds	-	3	-	-	-	-	-	-	-
Unidentified roots	1	-	-	2	3	-	13	5	1
Unidentified insect scale	-	-	1	-	-	2	-	-	-
Unidentified plants	-	-	-	-	23	1	2	16	1
Beetle	-	-	-	2	-	-	-	-	-

The contents of foraging holes varied with age of the hole and season (Table 6). New holes had no grass or forb plant life across seasons. Termites or ants were common in newly dug holes in the wet andearly dry seasons. In contrast, old foraging holes had the most litter, grass and forb plants in the wet season. Similarly, spider webs were prevalent in old holes in the wet and early dry seasons. In addition,all foraging holes had plant litter across the different seasons. Plant life was greater in the wet season than in the dry and early seasons. Goat and cow dung were always present on old and very old but not for new foraging holes across the seasons. Some foraging holes comprised of seeds in the dry season.

Table 7 Utilisation of active (N = 16) and abandoned (N = 7) entrances of aardvark dens over eight months in Ncunjane, KwaZulu-Natal, South Africa.

Content	Number of entrances occupied
[#]Snake	2
Spider web	28
Disposable nappies	1
Plastic - rubbish	4
Grass	12
Cape porcupine	4
Rocks	18
Snare (sticks and wire)	2
Ashes and used charcoal	1
Wildcat faeces (*Felis silvestris/lybica*)	1

[#]An African rock python and a Mozambique spitting cobra were observed entering aardvark dens

There were 91 active den entrances and 66 entrances not in use (abandoned) over the eight months. Whilst, hunters' dug 15 new holes and 39 old holes from dens. There were 18 den entrances closed with rocks by hunters or local people to block entrances of dens. Hunters also indicated that 2 aardvarks were caught over the eight months of the study. In addition, a number of animals used aardvark dens such as wildcats (*Felis silvestris/lybica*) and Cape porcupines (Table 7). These were evidenced by faeces and spines, respectively. Also, humans used the dens to dispose of disposable nappies and plastic waste (Table 7). In addition, grasses occurred inside abandoned den entrances. One of the hunters indicated that an aardvark of a certain den was caught leaving the den unoccupied for a while, and we observed the reoccupation of the den when we passed through the same den with the hunter.

Aardvark dens

The distance among active neighbouring den entrances was 0. 5 km (N = 14; range: 0.1-1.0 km), 2.2 km (N = 9; range: 1.1-3.4 km) for abandoned dens and 2.9 km (N = 5; 1.7 to 3.9 km) for active independent dens. The average number of active entrance holes (N = 4) in each den was less than that of abandoned holes (N = 6), the distance between entrances within a den ranged between 9.12 ± 1.07 m. Overall, I found 24 dens, 14 of which were active while 10 were abandoned. The length of a den system ranged between 8.7 ± 1.1 and 31.2 ± 26 m. The distance between the foraging area and nearest den during the dry season was 12.7 ± 0.7 m, while in the early dry season it was 45.9 ± 37.2 m. Aardvarks were feeding close to their dens in the dry season compared to the early dry season.

3.4 Discussion

Foraging hole and den burrow system abundance

Aardvarks occurred at the periphery of the village, where their dens and foraging activities were evident. The area outside the human settlement was used as a rangeland for crop and livestock farming by humans. Thus, habitat use by aardvark in Ncunjane overlapped with human activities. Correspondingly,many very old foraging holes were immeasurable (N = 114), and the effects of very old holes on landscape were then suppressed by human activities and livestock. The foraging activities of aardvarks were restricted to the rangeland and did not occur within the village. In addition, I found the foraging areas to be located close to dens, which would limit the distance travelled by aardvarks in the rangeland. Aardvark movements in Ncunjane may thus be limited compared to theircounterparts occurring in protected areas, where they are reported to travel distances of up to 4 km a night (van Aarde et al., 1992).

As predicted, the present study showed that foraging holes were more abundant compared to dens in the wet season. This likely coincided with increase intermite prey availability (Taylor et al., 2002; Kingdon et al., 2013; Kanyi et al., 2021). These results are similar to those reported by Martin (2017), which showed that foraging holes were 15 times more abundant than dens in one season of data collection at Samara Private Game Reserve in the Eastern Cape Province of South Africa. The findings were expected as aardvarks occur at low densities (Kingdon et al., 2013). In addition, one aardvark can have a significant impact on the landscape, as Taylor et al. (2002) indicated that aardvarks dig up to 200 foraging holes per night over a six-month study. One of the consequences associated with aardvarks establishing next to a human settlement is trampling, which influences the lifespan of foraging holes and potentially their role in hosting plants and animals. Jones et al. (1994) reported that the persistence of burrows contributes to determining the effects of burrows in landscapes i.e. burrows with longer lifespan tend to have a significant impact on the vegetation. The most severe impact by humans on aardvarks is hunting, which likely contributed to an increased number of abandoned dens, and therefore, to aardvark numbers. The extent of trampling by humans and animals on foraging holes is less severe than the acts of digging carried out on dens. Assuch, foraging holes play an important ecological role across landscapes compared to dens due to their high abundance.

The variation in number of foraging holes in each season could be attributable to the availability of ant and termite prey. Ants and termites were observed on the soil surface in the wet and early dry seasons, which agreed with the extent of digging foraging holes by aardvarks (van Aarde et al., 1992; Taylor and Skinner, 2003), thus the two seasons recorded a significant number of foraging holes. In contrast to expectation, aardvarks dug new shallow foraging holes in the wet season presumably because their prey was available on the surface because of water. Conversely, I recorded wider foraging holes in the early dry season, which likely presented scarcity in termite prey, as they settle below-ground in the dry season (Braack, 1995). The increase in size of foraging holes might also indicate increased search effort to find food. Ants and termites can be scarce when food is not available for them e.g. plants and insects, and in the early dry season little plant and animal life was recorded. In addition, Taylor et al. (2002) showed that aardvarks dug foraging holes of 5-10 cm for ants and up to 2 m for termites, in contrast, foraging holes in Ncunjane were shallow (≤ 27 cm). The shallow foraging holes may suggestthat aardvarks in my study area fed predominantly on ants or that the termites were available close to the surface. Thus, food availability associated with season influenced the variation in digging effort.

Vegetation occupying aardvark holes

As expected, I found more grasses and forbs in the old and very old foraging holes since abandoned and collapsed burrows favour high plant species richness (Haussmann et al., 2018). Materials captured in aardvark holes may decompose and add nutrients into the soil, therefore promoting soil fertility and landscape heterogeneity. Animal dung, which further supported use of the rangeland by domestic animals, was common to come across in all the different- aged holes, and livestock dung captured can influence seed germination (Dean and Milton, 1991).As a result, seeds captured in the aardvark foraging holes may germinate (Boeken et al., 1995), and allow plant growth if not disturbed. These findings agree with Dean and Milton (1999) and Whittington-Jones (2006) who showed that aardvark foraging holes provide sites for resource capture, shelter for plants and germination sites. The age of foraging holes influences species richness of plants; thus, many plants and grass plants began to be evident in old to very old holes. New foraging holes had no plants because digging may remove old plants and create a bare surface. These findings are consistent with Haussmann et al. (2018) and Louw et al. (2021) who also showed that fresh holes and mounds had lower plant species richness. Similarly, the Indian crested porcupine (*Hystrix indica*) diggings decrease plant species richness in fresh holes and mounds (Gutterman and Herr, 1981). Mounds created by ecosystem engineers encourage the mixing of nutrients from below-ground level with the top soil (Haussmann et al., 2018; Louw et al., 2021). Therefore, burrowers can change soil fertilitywhen digging (Eldridge and Whitford, 2009), promote plant growth and restoration of the ecosystem.

Aardvark diggings provide refuge to other animals

My results showed that abandoned dens are used by other animals other than aardvarks. Also, rocks were placed by local people to close aardvark dens because snakes can utilise them. This assents with the scientific literature that aardvark holes provide shelter to various animals (Whittington-Jones et al., 2011; Pike and Mitchell, 2013). Spider webs used old foraging holes and den entrances probably for refuge, capture and nesting sites. Some spiders build webs that increase their prey capture efficiency (Nyffeler et al., 1994). Populations of spiders may thrive by making use of aardvark holes as nesting and/or trapping sites. Therefore, the results showed that foraging holes also provide refuge and nesting sites to other animals including invertebrates. It is also possible for aardvarks to reuse abandoned den entrances because they may connect to active dens. Conversely, Taylor et al. (2002) showed that aardvarks do not use dens for a long period of time, aardvarks use their dens at an average of 7 days. In accordance with my expectation, the number of active den entrances was greater in the den systems. Contrary, protected areas report different patterns (Taylor et al., 2002). The distance between active den entrances in a den was short presumably aardvarks did not extend their home range due to the landscape shared with local people.

People in my study area used aardvark dens as sites for waste disposal, which likely obligates aardvarks to leave that particular den and dig elsewhere due to possible threats, and invasion. In addition, the evidence (snares, hunter diggings and ashes) shows that aardvarks are persecuted in Ncunjane by people. Therefore, aardvarks in my study area face threats from local people, which is a consequence associated with co-existing with humans, which in turn threatens their future occurrence in the area. The neighbouring dens could be used by the same aardvarks because Van Aarde et al. (1992) indicated that aardvarks have a home range of 180 ha and 350 ha, and aardvarks do not share their dens (Taylor et al., 2002). As such, the dens, which were located over 1 km from each other likely represented different animals. The use of the landscape by aardvarks is influenced by prey availability (Taylor et al., 2002; Taylor and Skinner, 2004), but may also be limited by human activities and hunting.

3.5 Conclusion

The present study has proven that variation by season has an important implication for aardvark conservation; so is the refuse in or closure of foraging holes. The large size of dens allowed many animals to use them such as spiders, which may create a niche for invertebrate function. Also, ageing holes are more important for plants and other animals since they provide habitat for them. The ability of foraging holes to capture seeds, debris and livestock dung likely increases soil fertility and provide germination sites, which maybe activated by rains in the wet season. Also, I showed that old foraging holes captured more resources compared to very old holes due to the increased likelihood of destruction of very old holes. Aardvarks sharing the rangeland with local people likely affected how aardvarks use the landscape and their movement patterns.

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Chapter 4

General discussion, recommendations and conclusion

4.1 Background

Aardvarks (*Orycteropus afer*) are the only extant representatives of the order Tubulidentata, which makethem important study animals (Springer et al., 1997; Yang et al., 2003). Aardvarks live underground and, as a consequence, have profound effects on soil physical and chemical properties. The diet of ants and termites (Skinner and Smithers, 1990; Kingdon et al., 2013), also dictates interaction with soil. Therefore, digging, which is achieved by their strong and clawed forelimbs, facilitates plant and animal life (van Aarde et al., 1992; Taylor et al., 2002). The importance of aardvarks is also strengthened by their ecological engineering role in various landscapes across sub-Saharan Africa (Lehmann, 2009; Lindsey etal., 2013). Like African elephants (*Loxodonta africana*), aardvarks create habitats for other vertebrates, and contribute to their success by providing refuge and conducive conditions for incubating eggs and protecting their young. Local and regional assessments of aardvark populations are inadequate (Lehmann, 2009; Lindsey et al., 2013), which limits revision or updates of their status, currently listed as “Least Concern” by the IUCN (Lindsey et al., 2008). As a result, there have not been extensive conservation measurements taken to protect aardvarks, particularly in spaces shared with humans. The animal is also elusive and thus difficult to study. This, too, limits a better understanding of their behaviour and population sizes. Aardvarks are facing threats from humans through hunting for traditional medicine and bushmeat in Africa (Kingdon et al., 2013; Lindsey et al., 2013). As a consequence of the expansion in the human population and demand for land for settlement and agriculture, wildlife and humans may have overlapping uses of space, which often breeds conflict (Okello, 2005; Nyhus, 2016). Alternatively, wildlife may lose their habitat due to agricultural expansion (Power and Verburgt, 2014; Rust et al., 2015). Another immediate threat to aardvarks is climate change, which is predicted to have a negative impact on prey availability and physiology of aardvarks (Weyer et al., 2016).

4.2 Research findings

The first objective of the study was to understand the relationship between aardvarks and humans in a communal area using data obtained qualitatively (Chapter 2). I found that men were most familiar and knowledgeable about aardvarks through their hunting activities in Ncunjane. Men also came across aardvarks during night travel, which they were most likely to undertake than women. Women also knew about aardvarks through the animal’s digging activities. Overall, aardvarks were not viewed as a threat to humans or their animals. Yet, aardvarks are hunted in Ncunjane mainly for consumption and to generate income by selling aardvark body parts to traditional healers.

The second objective was to determine the behaviour of aardvarks in Ncunjane village using a quantitative approach (Chapter 3). I found that aardvarks changed their natural feeding behaviour in Ncunjane due to hunting threats. In particular, aardvarks were feeding closer to their dens. Also, local people utilise aardvark dens dumping rubbish pits. The dens are also used as a refuge by various animals.The extent of aardvark digging while foraging was driven by food availability. Ultimately, the extent of aardvark digging determined the degree to which aardvarks contribute to landscape heterogeneity in Ncunjane.

4.3 Limitations

Sampling for foraging holes was impossible on rainy days as the age of holes could not be determined when the soil was wet. Also, the number of animals in the area could not be determined. Therefore, the conclusions about aardvark numbers are based on numbers of den systems encountered.

4.4 Recommendations for future research

I recommend that:

- Future research on people's perceptions about aardvark should be carried out in areas of different ethnic groups as different cultures may use or perceive the animal differently, which may influence conservation of the aardvark.
- Advanced equipment should be used to carry out research on burrowing animals to contribute to determining their abundance. For example, camera traps can be placed inside the burrow systems of dens to determine numbers and demographics of the animal.
- Increased numbers of studies in rural areas on aardvarks in Africa, particularly in South Africa,can raise awareness and play a significant role in the conservation of aardvarks. Also, when persons who hunt the animal are part of the research team, perhaps as research assistants, maybe encouraged to stop hunting aardvarks.
- Research on aardvark genetics and health should be conducted to improve understanding of the population changes in response to climate change as it is anticipated to affect aardvark physiology.
- Studies of this nature to use nearby protected area that has aardvarks as a control in order for the increased risk of predation by humans in communal areas can be assessed.

4.5 Conclusion

This thesis elucidates the relationship between aardvark and humans, and the behaviour of aardvark in Ncunjane village of KwaZulu-Natal Province of South Africa. Aardvarks maintain their shy behaviour around people. Aardvarks in Ncunjane are mainly threatened through hunting and some hunters gain financial incentives by selling aardvark body parts. The occurrence of aardvarks in close proximity to humans influenced animal movement patterns and their use of the landscape. Aardvarks may have modified their behaviour by feeding in close proximity to their dens.

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APPENDIX

Questionnaire survey used to conduct the research on people's perceptions and influence on the numbers of aardvark in Ncunjane village of KwaZulu-Natal, South Africa.

CONSENT TO PARTICIPATE IN THE STUDY

I (name) ____________________________ have been informed about the study entitled "Aardvark and people: can a shy species be widely known in localised areas?". I understand the purpose and procedures of the study. I have been given an opportunity to answer questions about the study that have been answered to my satisfaction. I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to. If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at ____________________

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact: Dr Manqhai Kraai of the University of KwaZulu-Natal.

I hereby provide consent to: Manqhai Kraai, Zivanai Tsvuura and Nolutho Makwati utilise the questionnaire entitled "Aardvark and people: can a shy species be widely known in localised areas?" solely for research purposes, to be published in peer reviewed journal articles should they be accepted for publication.

Signature of Participant ______________________________ Date _________

Signature of Witness (Where applicable) ____________________ Date _________

Signature of Translator (Where applicable) ___________________ Date _________

Area ____ Date _________

Aardvark and people: A questionnaire survey in Ncunjane Village, Msinga

Gender?

Male	Female	Prefer not to say

What is your age group (in years)?

6-10	11-14	15-24	25-34	35-49	50-70	70+

What is your highest level of education?

None	Primary	Secondary	Tertiary

Information on Aardvark

Do you know what an aardvark is?

Yes	No	Uncertain

Have you seen an aardvark before in your immediate area?

Yes	No

Do you know of aardvark holes nearby?

Yes	No

When last did you see aardvark in your immediate area?

Past 3 months	Past 6 months	Past 1 year	Past 2 years	> 2 years

What activities did you see aardvark doing?

____

In the last 10 years, do you feel aardvark numbers have changed?

Increase	Decrease	No change	Uncertain

Which season do you see the most aardvark in your area?

Dry season	Rainy season	Uncertain

What is your perception of aardvark?

Positive	Neutral	Negative

Do you know of any myths or folklore about aardvark?

Yes	No	Uncertain

If so, what is the myth or folklore?

____

Do you hunt/eat aardvark?

Yes	No	Uncertain

How do you hunt aardvark?

Hunting dogs	Snares	Dig it out

When last did you eat aardvark meat in your immediate area?

Past 6 months	Past 1 year	Past 2 years	> 2 years	Never

How many times would you want to eat aardvark meat per year?

____

Why?

____

What are other parts of the aardvark (teeth, claws, skin) used for?

____

Other parts (specify)

____

____

____