University of the Witwatersrand

School of Animal, Plant and Environmental Sciences

Electric fence induced mortality in South Africa

Submitted in fulfilment of the academic requirements for the degree of Masters in Environment, Ecology and Conservation, School of Animal Plant and Environmental Sciences, University of the Witwatersrand.

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Abstract

Recent advances in electronic technology have ensured that electric fences offer a viable means of reducing the chances of wildlife escaping from conservation areas and private game ranches. Electric fencing is even gaining popularity amongst domestic stock farmers in controlling the movement of problem animals into private land. However, there is a growing concern over the number of electric fence induced mortalities in South Africa.

This research project sampled mortality rates in a number of broadly distributed study areas with the aim of determining (1) which species were prone to being electrocuted, (2) the average number of mortalities km^{-1}, and (3) which aspects of electric fence design contribute to most to the observed number of mortalities. This information would then be used in proposing a variety of means of amelioration.

Individuals from 33 species were documented as being killed as a direct result of electric fencing infrastructure. Leopard Tortoises (*Stigmochelys pardalis*), Rock Monitors (*Varanus albigularis*), Southern African Python (*Python natalensis*), Pangolin (*Manis temminckii*), Lobatse Hinged Tortoise (*Kinexys lobatsiana*) and Porcupine (*Hystrix africaeaustralis*) emerged to be the species killed most frequently by electric fences.

Annual mortality rates for reptiles ranged between 0 and 2.15 individuals.$km^{-1}.yr^{-1}$ ($\bar{x}$ = 0.475 individuals.$km^{-1}.yr^{-1}$) with the highest mortality rates occurring areas using low-level tripwires erected below 200 mm. The influence of strand height on mortality rate per km^{-1} was confirmed by the fact that average mortality rates showed a marked decrease in areas where the lowest electrified strand was erected at a height of 200 mm and greater.

Possible means of amelioration include raising the height of the bottom electrified strand to a height of no less than 200 mm, increasing the distance that this lowest electrified strand is offset from the main fence, erecting some form of barrier wall, using rock packed aprons instead of low-level tripwires, and, where feasible, using duty cycle switches to switch the fences on at dusk and off at dawn.

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Declaration

This thesis was supervised by Professor Graham Alexander and conducted in conjunction with the Endangered Wildlife Trust of South Africa.

I hereby declare that this thesis, submitted in the fulfillment of the requirements of the degree of Master of Science at the University of the Witwatersrand, is the product of my own independent research, unless otherwise acknowledged in the text.

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Chapter 1

Introduction and Literature Review

Overarching Introduction

Traditionally, fences have been used in combination with geographical features such as rivers, impassable rocky outcrops and other prominent landmarks to demarcate the usage and ownership of land. This applies to land used for conservation purposes, as well as land used for commercial stock farming. In 1992, South Africa had approximately 3500 privately owned game reserves in addition to state owned conservation areas (Grossman *et al.*, 1992). By 2005, this number had grown to more than 9000 (Macdonald, 2005) and the area covered by private reserves and game ranches in South Africa grew from less than 810 000 hectares in 1979 to approximately 6.5 million hectares in 1996 (Chadwick, 1996). Currently, private reserves cover approximately 13% of the country's total land area (Berger, 2006) compared with the five percent for all national parks combined (Falkena & Van Hoven, 2000).

Until recently, the majority of fences used to demarcate these areas were constructed from barbed wire, supported by iron standards and droppers interspersed between more substantive straining posts. Recent advances in electronic technology have ensured that electric fences now offer a viable alternative to barbed wire fences in most situations, provide the landowner with the added advantages of adaptability and significantly improved cost effectiveness (Van Rooyen *et al.,* 1989).

In South Africa, concern over fence-related mortalities has been reported for a variety of tortoise species (Heard & Stephenson, 1987; Burger & Branch, 1994), Pangolins (*Manis temminckii*) (Jacobsen, 1991; J. Swart, pers. comm.), Southern African Python (*Python natalensis*) (G. Alexander pers. comm. 2006), Flap-necked Chameleon (*Chamaeleo dilepis*) (Cunningham & Cunningham, 2007) and Giant Bullfrogs (*Pyxicephalus adspersus*) (C.A. Yetman, pers. comm. 2006). However, there is very little literature addressing the impact of electric fence-related mortalities of wildlife in South Africa despite the high number of known incidents in conservation and landowner circles.

This study attempts to fill the gaps in current knowledge by investigating incidents of electric fence induced mortality and providing answers to a number of key questions. The results of this study will be used in the developments of experimental fencing designs which will reduce the number of mortalities in the future.

Linear Barriers and Linear Filters

For the purposes of this study, it is important to understand the differences between the terms 'barrier' and 'filter'. Hess & Fischer (2001) addressed the semantics behind the use of the term 'corridor' in biological conservation. As part of their review the authors address the functions of corridors and clearly define the term 'filter' as implying some level of permeability to, allowing individuals of certain species to pass through a feature in the landscape. On the other hand, the term barrier implies a nearly complete blockage or negation of movement where organisms or material cannot cross a corridor or landscape feature (Hess & Fischer, 2001). Filters and barriers thus restrict movement individuals to different degrees.

A single landscape feature may act as a barrier for one species but as a filter for another. An example could be made of fences that completely negate the movement of elephants into an area but allow for smaller wildlife species to move freely through this boundary. Such fences are used around many lodges in South Africa and also in scientific studies aimed at quantifying the impacts of elephant herbivory in specific vegetation types (Young *et al.,* 1998).

Types of linear barriers and filters

The functions of barriers and filters are clearly associated with artificial linear landscape features such as roads, railway lines, power lines, fences and canals. It is this type of artificial infrastructure that imposes movement barriers to many animals, barriers that can isolate populations and lead to long-term population declines (Becker & Iuell, 2003).

A number of studies have addressed the roles of roads as linear barriers or filters to horizontal processes such as animal movement (Barnett *et al*., 1978; Lovallo & Anderson, 1996; Philcox *et al.*, 1999). The results of such studies suggest that roads are fast becoming the leading cause of animal mortality (Maehr *et al.,* 1991; Clarke *et al.*, 1998) and are effectively fragmenting otherwise connected habitats (Trombulak & Frissell, 2000).

In some cases, infrastructure may function more as an ecological trap than a barrier. Electrical transmission lines have been recognized as being a type of ecological trap for a number of species. More than 300 Cape Vultures (*Gyps copotheres*) were electrocuted due to 88 KV suspension powerline towers in South Africa (Ledger & Annegarn, 1981). Both Blue Cranes (*Anthropoides paradiseus*) and Wattled Cranes (*Bugeranus carunculatus*) have suffered a similar plight (Allan, 1994). Johnsingh *et al.* (1990; 1991) attributed the obstruction of elephant movements between Shencottah pass and Idukki-Periyar hills in south India to the presence of railway lines. Features in the landscape can thus function as barriers, selectively permeable filters and ecological traps.

The ecological impacts of linear barriers

Many features in an animal's landscape, both natural and unnatural, act as potential barriers or filters with regards to movement. The ecological impacts that such features have may be presented at both population and community levels.

Landscape Fragmentation and Isolation

Habitat loss and fragmentation have been widely cited as posing major threats to biological diversity as landscapes are transformed in a myriad of ways in order to accommodate people's needs (Pickett *et al.,* 1997; Fielder & Kareiva, 1998; Hess & Fischer, 2001). Traditional definitions of landscape fragmentation describe a series of remnant vegetation patches surrounded by a different vegetation and/or land use (Saunders *et al.* 1991). Such fragmentation has many important consequences for both the flora and fauna of any given area. Fences, roads and railway lines fragment natural habitat into remnants that are isolated to varying degrees (Lovejoy *et al.,* 1984), with the distance between adjacent remnants and the degree to which they are connected to one another being important determinants of the biotic responses to fragmentation (Saunders *et al.,* 1991).

Animals may possess the physical abilities to disperse long distances so that they are able to reach neighbouring patches, but the matrix of features surrounding isolated fragments (e.g., different habitat types, physical barriers such as rivers or fences) may form an effective barrier or filter to such movements (Saunders *et al.,* 1991).

The isolation of animal populations as a result of habitat fragmentation has gained increasing attention amongst conservation biologists over the last decade. Rodriguez *et al.* (1996) stress the importance of identifying and, where possible, ameliorating the effects of potential barriers to animal movement. Populations living in habitat patches surrounded by roads are less likely to receive immigrants from neighbouring habitats, and thus may suffer from a lack of genetic input, potentially resulting in inbreeding (Remmert, 1994). This may lower the probability of population persistence. Concern has been expressed over the potential for inbreeding in fenced conservation areas in the past (Ricciuti, 1993), but the difficulty in maintaining truly impermeable fences and the small number of immigrating animals needed to prevent inbreeding in most species suggests this may not be a pressing problem (Van Rooyen *et al.*, 1989).

Small populations are known to be particularly vulnerable to environmental stochasticity (Wissel & Stocker, 1991; Boyce, 1992; Remmert, 1994). Confining a population to a reserve or fragment may disrupt metapopulation dynamics, increasing the risk of local extirpation due to increased effects of random demographic, genetic, and environmental events, and decreasing the chances of re-colonization through dispersal events (Levins, 1969; Margules & Pressey, 2000). Even if the survival of relatively few species is directly jeopardized by fragmentation, the loss of those species may precipitate a cascade of community-level effects, making the potential effects of habitat fragmentation on extinction important (Terborgh, 1976).

Migratory Movements and Dispersal Patterns

Fencing may prevent wildlife or livestock from accessing key resources, thus influencing associated migratory movements. This may have subtle effects such as animals finding alternative routes, or profound effects causing thousands of deaths as animals congregate along the break in a migration corridor (Hoare, 1992; Boone & Thompson Hobbs, 2004).

In Botswana, the impacts of veterinary fencing, which was originally installed in the 1950s, introduced an entirely artificial constraint upon wildlife movements (Mbaiwa & Darkoh, 2005). The extent of the negative impact was not revealed until the severe droughts experienced during the 1980s (Keene-Young, 1999). In dry years, wildebeest moved to the northeast to Lake Ngami and the Okavango Delta in search of water, a migration corridor that was severed in 1954 by the Central Ngwato fence (Owen & Owen, 1980; Spinage, 1992). The fence forced animals to continue to the east, toward Lake Xau, where they accumulated and consumed all available forage. In that year alone, Williamson & Mbano (1988) estimated that 52000 wildebeest died in the Lake Xau area, although this number may actually have been as high as 80 000 (Parry, 1987). Migratory wildlife species depend on seasonal migration between rangelands and water sources for their survival. Fences may serve to completely block these migratory routes (Albertson, 1998; Scott Wilson Resource Consultancy, 2000; Grag Gibson/Environmental Investigation Agency, 2004). Thus, even when animals are not completely excluded from habitats, fences act as buffers and may severely restrict their movements.

Habitat Quantity and Quality

Herbivores confined by fencing may overpopulate a fenced area, leading to vegetation degradation and starvation (Mbaiwa & Darkoh, 2005). Ricciuti (1993) described the contrasting condition of vegetation across a boundary fence in Amboseli National Park where the resultant effects of excluding elephants were strikingly obvious. The fenced forest where no elephants were present was dense and green, whereas the acacias outside the fence were broken and stripped bare of leaves (Ricciuti, 1993).

Increased Mortality

Most fences pose some degree of risk of increased mortality and certain fences have become infamous due to the damage they have caused (Boone & Thompson Hobbs, 2004). Wildlife and livestock occasionally attempt to move through fences, with varying degrees of success depending upon the design of the fence and species in question. Individuals may be attracted to forage or crops on the other side of a fence, be drawn by their young that have moved under the fence, or be attempting to escape harassment from dogs, poachers or other predators (Hoare, 1992). Wildlife and livestock can thus become entangled and die in fences, or may be electrocuted (Denney, 1964; Hoare, 1992). Fences with smooth wire can even provide poachers with material for snares.

Other types of man-made linear barriers such as road and highway networks can elevate mortality rates for a variety of species (Case, 1978; Andrews, 1990; Trombulak and Frissell, 2000; Gibbs & Shriver, 2002; Forman *et al.*, 2003; Smith & Dodd, 2003). Clevenger *et al.* (2003) describe how road-kills in the Central Canadian Rocky Mountains tend to occur close to vegetative cover and far from wildlife passages or culverts. The findings of the study also revealed how variables such as traffic volumes, vehicle speeds, road configurations and adjacent habitat type contribute to both the spatial pattern and frequency of vertebrate mortality. Their results suggest that strategically placed culverts designed specifically to facilitate wildlife movements were effective in reducing the number of road kills.

Road mortality may affect the demography of populations when movements associated with foraging, reproduction, or dispersal cause a greater proportion of one sex or life stage to come into contact with barriers. Aresco (2005) showed how population sex ratios were dramatically biased toward males in the Florida Cooter (*Pseudemys floridana*) (80% males), Yellow-bellied Slider (*Trachemys scripta*) (73% males), and common Musk Turtle (*Sternotherus odoratus*) (65% males) in a lake adjacent to a highway compared to those in ponds not affected by road mortality, where the proportion of males ranged from 39% to 60%. However, no studies have addressed the association of such a phenomenon with fencing infrastructure.

Connectivity

Habitat connectivity is a vital property of landscapes and is especially important for sustaining animal movement across a landscape (Becker & Iuell, 2003). The degree to which different areas are connected, or disparate, can thus play an important role in reducing or aggravating the negative effects associated with fragmentation. Various measures have been used in attempts to increase permeability and mitigate barrier effects of road systems (Opdam *et al.*, 1993; Canters, 1997). These efforts include the use of modified drainage culverts, underpasses and overpasses (Clevenger *et al.*, 2001).

Barrier walls and culverts have been used successfully to reduce wildlife mortality and facilitate movement associated with highway systems (Dodd *et al.*, 2004) whilst designs based on similar principles have been used to a lesser extent with medium sized mammals and fencing infrastructure (Van Rooyen, *et al.*, 1989). In the Paynes Praire basin, Florida, USA, mortality rates on a highway system were reduced by as much as 93.5% by the implementation of a barrier wall-culvert system (Dodd *et al.*, 2004).

The Importance of Edge Effect and Perimeter: Core Ratio

Larger parcels of land have proportionately larger core areas that are not exposed to the environmental hazards and biotic changes associated with edges and associated barriers/filters. The shape and size of an area is thus important as it determines the perimeter:core (or edge: interior) ratio. Long, narrow areas have proportionally much more edge than square or round remnants (Diamond, 1975; Wilson & Willis, 1975). Thus, smaller parcels of land enclosed by electric fencing may experience greater mortality rates than larger parcels with a smaller perimeter:core ratio.

With land becoming an increasingly limiting resource, developers and conservation-based conservancies are beginning to utilise and fence smaller and smaller areas of land. In addition to this, game ranchers focusing on the breeding of rare and valuable wildlife species such as Roan (*Hippotragus equinus*), Sable (*Hippotragus niger*), Buffalo (*Cyncerus caffer*) and Lion (*Panthera leo*) often subdivide land into secure camps using electric fences in order to control the spread of disease and eliminate predation (Pers. obs). The impacts of fencing infrastructure, both electrified and non-electrified, associated with the demarcation of these land parcels is of great concern due to the large perimeter:core ratio associated with these small areas.

Electric fencing

Design and function

The core component of an electric fence is the energiser. Most modern energisers generate approximately 5000 volts. The ability of the fence to sustain this charge depends on the capacity (measured in joules) of the energiser. Small energisers (1.0 joule) are adequate for powering small networks (15 km) of fencing whereas larger energisers (20 joules) will power networks of up to 175 km under normal conditions (Macdonald, 2005). Energisers have two terminals, demarcated live and earth (or ground). A thin, insulated strand is charged with electric energy from the fence terminal. A second strand is connected to an earth and runs parallel to this first live strand. When the circuit between the two terminals is closed, an individual receives a substantial, safe (low amperage/high voltage) electric shock.

In an increased effort to limit the movement of animals between two parcels of land, some landowners supplement the traditional electric fence configuration (Fig. 1) with a low-level live strand set between 50 mm and 100 mm above the ground. This live strand is known as a tripwire.

The design of an electric fence will vary according to the species of animals that are to be confined. Species of wildlife in South Africa are broadly categorised as being either jumpers (e.g., Impala (*Aepyceros melampus*), Eland (*Taurotragus oryx*)), crawlers (e.g., Gemsbok (*Oryx gazella*), Tssessbe (*Damaliscus lunatus*)), those that break fences (e.g., African Elephants (*Loxodonta africana*), Giraffe (*Giraffa camelopardalis*)), animals that do not jump (Springbok (*Antidorcas marsupialis*), Blesbok (*Damaliscus dorcus*)), or those that are difficult to fence (e.g., Warthog (*Phacochoerus aethiopicus*), Bushbuck (*Tragelaphus scriptus*), and carnivores) (Van Rooyen *et al.*, 1989).

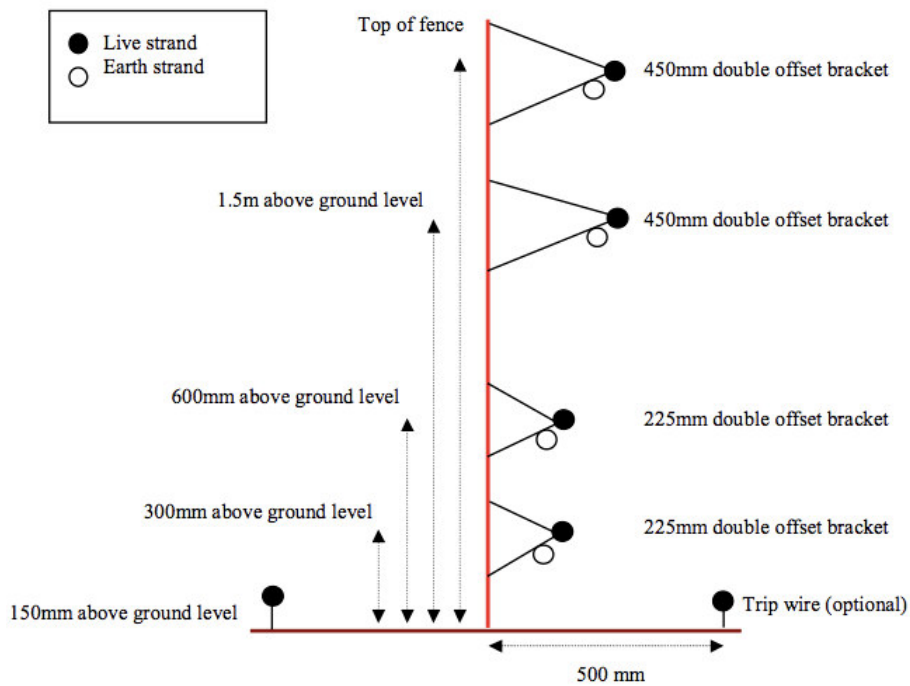


Figure 1. A typical electric fence (Macdonald, 2005) showing the positioning of paired earth and live wires as well as the spacing and positioning of additional tripwires.

Provincial Legislation

There is currently no formal national guideline pertaining to the design of electrified game fences in South Africa. There are however, a number of documents, which outline proposed minimum requirements for the efficient containment of game species. Such documents are often compiled by privately-owned electric fencing companies.

According to Mr D. Von Wielligh (pers. comm.), it is these documents that are used by provincial conservation officials in the assessment of new electric fences. A review of some of these documents reveals that the design specifications outlined vary greatly between the nine provinces of South Africa.

The Wild Dog Action Group of South Africa (WAG-SA) (2004) state that although the use of a tripwire is optional, the fitment of such a tripwire and the associated expense, is worth the effort in the long term in order to prevent predators from escaping through the bottom section of the perimeter fence. A number of conservation areas have opted to use a bonnox or diamond mesh apron in order to prevent Warthogs from digging beneath the fence and opening up holes that could then be used by Lion (*Panthera leo*) and Spotted Hyaena (*Crocuta crocuta*). Such aprons consist of bonnox or diamond mesh buried below ground (approximately 0.4 m) and extending 1 m up the fence. Rock packing along the base of the fence further reinforces such aprons.

The Benefits Associated with Electric Fencing

The most obvious benefit associated with fencing is the ability to control access, so that livestock or wildlife may be confined, or given exclusive access to landscape patches (Hoare, 1992). Fenced paddocks allow managers to move livestock between these patches, optimising grazing and allowing for the recovery of unused patches, which can increase productivity (Hoare, 1992). There is a large body of literature describing the economic and ecological benefits of such grazing systems made possible by the use of fencing to control the timing and duration of landscape utilisation by large herbivores (e.g., Werner & Urness, 1998; Williams & Hammond, 1999; Kie & Lehmkuhl, 2001; Halstead *et al.,* 2002).

Fences have not only been used to confine and facilitate the exploitation of wildlife, but also to reduce animal conflicts with humans. A good example of this is the use of fencing to reduce crop-raiding by African Elephant (*Loxodonta africana)* in the Laikipia district of Kenya (Thouless & Sakwa, 1994). Fencing barriers are an important tool in reducing vehicle accidents associated with livestock and wildlife wandering onto road and highway networks (Clevenger *et al.*, 2001; Boone & Hobbs, 2004). Furthermore, fencing may act as a barrier to limit or eliminate the mixing of wildlife and livestock, thus decreasing predation and the risk of the spread of disease. Fencing may also be used to exclude herbivores entirely to control erosion, prevent trampling and protect streams or water supplies (Maschinski *et al.,* 1996). Fencing clearly has many benefits for both the conservation and preservation of fauna and flora, but also in limiting potential conflict between humans and wildlife.

The Negative Consequences of Electric Fencing

Most electric fences pose some degree of risk to both wildlife and livestock. Many of the negative effects associated with electric fencing can be directly linked to the impacts reviewed in detail under the section "The Ecological Impacts of Linear Barriers" (see above). These potential negative impacts, as well as those cited by Boone & Thompson Hobbs (2004), are summarized as follows:

- Landscape fragmentation and isolation
- Disruption of migratory movements and dispersal patterns
- Reduced habitat quantity and quality
- Overgrazing by confined livestock and wildlife
- Increased mortality rates
- Reduced connectivity of areas
- The potential for inbreeding within fenced land parcels
- Prevention of access to key resources
- Provision of smooth wire for the construction of snares by poachers
- The potential to modify behaviour as seen in hunting behaviour of Wild Dogs

Target Species

The objectives and designs of electric fences vary between wildlife conservation, game ranching and livestock farming circles (Table 1). The most obvious difference regarding the objectives of fences between these land use types is that in livestock farming and game ranching, fences are used to keep predators out rather than in.

Predation on small livestock in South Africa is widespread. Many farmers lose up to 30 % of their lamb crop from birth to adulthood, to predation by wild animals (Rowe-Rowe, 1986). Over 90 % of this predation is attributed to Caracal (*Felis caracal*) and Black-backed Jackal (*Canis mesomelas*).

Traditional control measures have almost exclusively concentrated on the elimination of these predators from an area. Methods used include hunting by means of dog packs, rifles, leg-hold traps, poison baits, baited cages, poison collars placed on lambs' necks and even poisonous explosive baits (Rowe-Rowe, 1986). An ever-increasing number of farmers are combining such measures with the use of electrified fencing in an attempt to completely exclude predators.

Table 1. Primary objectives of fencing infrastructure in varying land use types in South Africa.

Land Use Type	**Primary Objectives of Electric fencing**
Livestock Farming	*Single electrified strand at base used to keep predators* ***out*** *of the property.*
Wildlife Conservation	*Multiple electrified strands placed at varying heights* ***used to contain*** *a variety of wildlife* ***species within a protected area.***
Game Ranching	*Multiple electrified strands placed at varying heights used to* ***contain a variety of species*** *within a camp whilst simultaneously* ***limiting the spread of disease*** *and* ***eliminating predation*** *from the system.*

Electric Fence Related Mortalities

The reaction of most mammals upon receiving an electric shock is to jump away from the stimulus. However, animals can become entangled in an electric fence, or their behavioural response to the electric shock may make them prone to being electrocuted to death.

Snakes often curl around an electric wire after receiving a shock, remaining in contact with the electrified strand and ultimately being electrocuted (Lund & De Silva, 1994). Upon receiving an electric shock, tortoises usually withdraw their head and limbs into the shell. The tortoise thus remains in contact with the live wire and is still part of the electrical circuit, receiving regular pulses of electricity as they are conducted along the live wire from the energiser (Burger & Branch, 1994).

The nature and extent of physical injuries incurred during electrocution depend on a number of factors such as the type and amount of current, the path and duration of current flow and the conductivity of the surface exposed to the current (Anderson, 1957). Resultant injuries or mortality may arise from the direct destruction of cells by heat, electrolysis or by the malfunctioning of vital centres and organs (Anderson, 1957). Tortoises that are exposed to direct solar radiation for long periods suffer from environmentally mediated heat stress and dehydration in addition to the direct effects associated with electrocution (Perrin & Campbell, 1981).

Electrocution by electric fences was sighted as one of the major threats to the reintroduction of Babcock's Leopard Tortoises (*Stigmochelys pardalis babcocki*) into the wild areas of KwaZulu-Natal (KZN Wildlife, 2004). Lund & De Silva (1994) note that in some cases, altering the wire spacing slightly may decrease the incidence of electrocution without compromising the effectiveness of the fence as a barrier. Burger & Branch (1994) as well as KZN Wildlife (2004) recommend that the lowest wire of a 'tortoise-friendly electric fence' should be at least 250 mm above the ground surface and that this lowest wire should preferably be neutral. However, the implications of such alterations of strand height on the effective control of movement of target species beneath fences, as well as its effects on tortoise mortality have not been fully investigated.

There is currently no information documenting the susceptibility of native South African wildlife to being killed or injured on electric fences. Long and Robly (2004) performed such a review for Australia during a study aimed at assessing the impacts of feral animal exclusion fencing in areas of high conservation value. The results compiled from surveys provide insight into the types of wildlife that are susceptible to being injured or killed by feral animal exclusion fences (Table 2).

Table 2. Native Australian wildlife killed or injured by feral animal exclusion fences. The frequency column refers to the percentage of survey respondents that indicated that the taxa had been affected by their exclusion fence (n=20) (Adapted from Long & Robly, 2004).

Fauna	**Cause of injury/death**	**Frequency**
Snakes	*Electrocution and entanglement in wire netting*	*35%*
Tortoises	*Electrocution and dehydration*	*15%*
Echidnas	*Electrocution*	*15%*
Spiders	*Electrocution*	*5%*
Geckoes	*Electrocution*	*5%*
Frogs	*Electrocution*	*5%*
Platypus	*Electrocution*	*5%*
Pygmy possums	*Electrocution*	*5%*
Koalas	*Electrocution*	*5%*
Flying foxes	*Electrocution, collision and entanglement in wire*	*5%*

The potential negative impacts that electric fencing may have on South Africa's native fauna are of great concern, considering the degree to which growth in both the agricultural and wildlife sectors has taken place in the last decade. The associated increase in the length of fencing infrastructure used in the demarcation and subdivision of these land parcels may potentially pose a substantial threat to native fauna which are susceptible to being killed along electrified fence-lines.

Project Significance

An extensive literature review revealed only a single paper that specifically addresses electric fence associated mortality of South African fauna. Burger & Branch (1994) evaluated the extent of mortalities for tortoise species on the 1000 ha Thomas Baines Nature Reserve in the Eastern Cape in 1994. The lack of literature addressing the threats and impacts that electric fencing infrastructure poses to South African fauna since Burger & Branch (1994) is of great concern.

This project is significant in that it aims to:

- Identify species that are susceptible to electrocution in a number of regions within South Africa.
- Quantify mortality rates for these species.
- Address the seasonality of observed mortality rates.
- Identify possible means for reducing the current mortality rates.

Overarching Aim and Key questions:

The study aimed to quantify mortality rates and assess the direct impact of electric fences on small animals in South Africa, as well as to identify possible measures of mitigation.

The following key questions were addressed:

1. Which species are prone to being electrocuted on electric fences?
2. How many individuals are killed along electric fences in South Africa per annum?
3. How do kill rates vary over the country?
4. Do mortality rates exhibit any significant patterns regarding:
    a. selectivity towards certain species?
    b. the size classes of individuals within a site?
    c. the height of the bottom electrified strand between sites?

    d. seasonal differences?

5. What are the conservation implications for species prone to electric fence induced mortality?
6. What mitigation measures can be put in place in order to reduce electric fence induced mortalities in the future?

Study Areas

Geographic Location

A number of conservation areas and domestic livestock farms supported this project by providing data and allowing access to their properties. Participating conservation areas include the Sabi Sand Game Reserve, Jubatus Cheetah Reserve, Pilanesberg National Park, Tswalu Kalahari Reserve, Phinda Private Game Reserve (Munyawara Conservancy), Marakele Pty. Ltd and Venetia Limpopo (Fig. 2). Four domestic livestock farms in the De Aar and Middelburg districts also contributed to this study (Fig. 2).

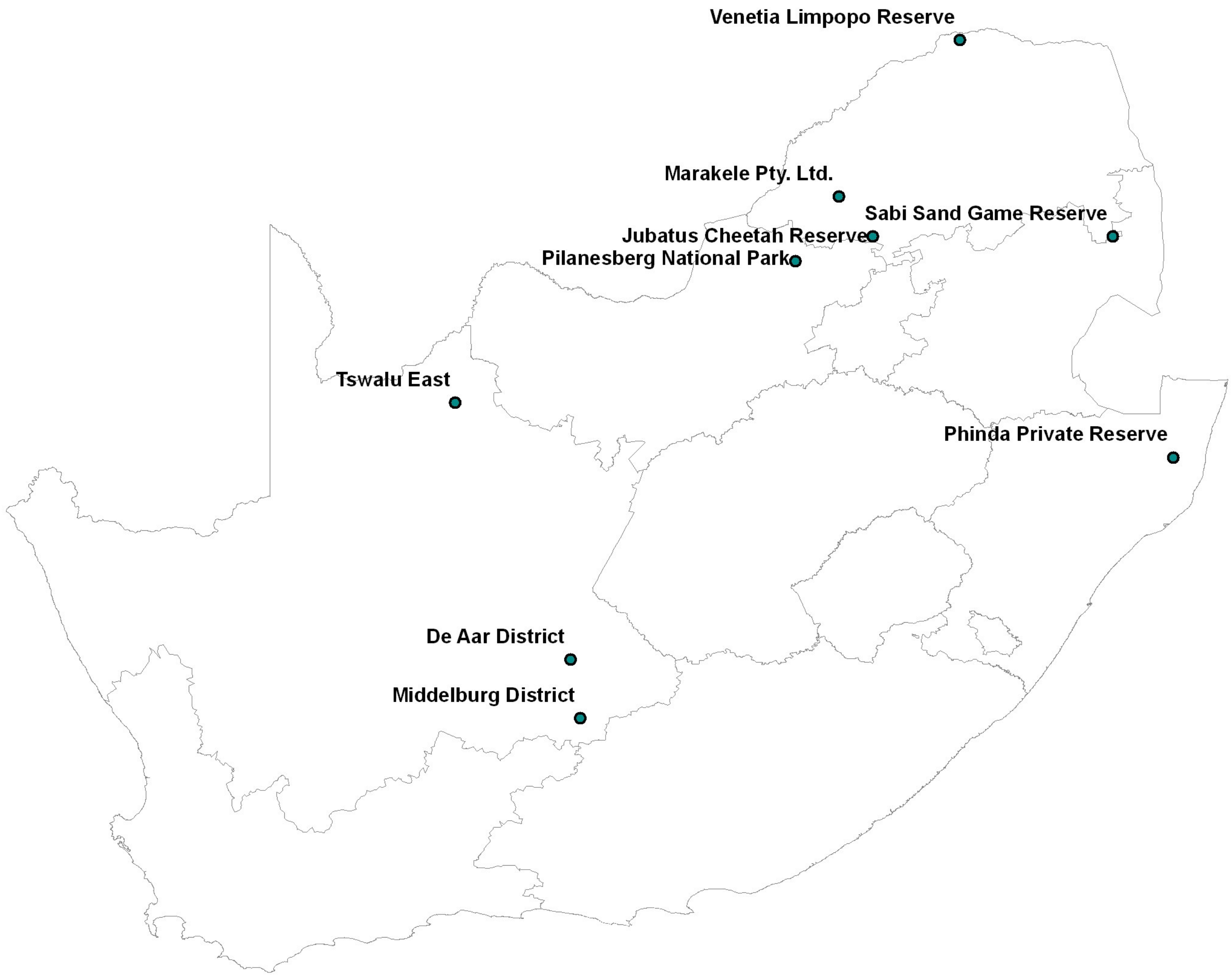


Figure 2. Geograpahic location of the study areas in South Africa.

Climate

There are likely to be general patterns exhibited across the country with regard to mortalities. In order to evaluate these patterns accurately one needs to sample broadly over the range. Hence the broad distribution of study sites within a number of the provinces in South Africa.

South Africa is generally classified as being a semiarid country with highly variable precipitation. More than one-fifth of the country is arid, receiving less than 200 mm of precipitation annually, while almost half is semiarid and receives between 200 and 600 mm annually (Mucina & Rutherford, 2006). Only about 6 % of the country averages more than 1000 mm per year. Mean annual precipitation gradually declines from east to west (Fig 3). The mean annual precipitation figures for each of the study areas are presented below (Table 4).

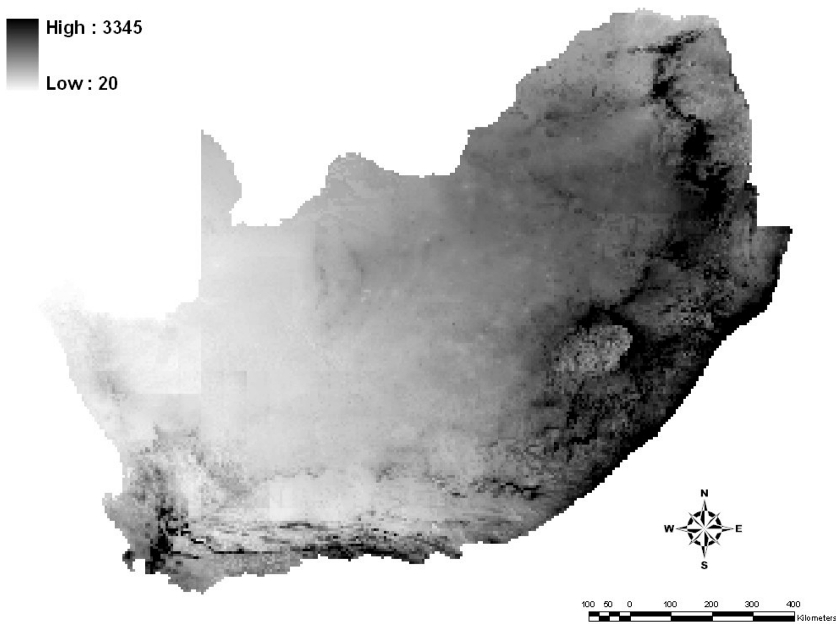


Figure 3. Mean annual precipitation for South Africa (mm) (Mucina & Rutherford, 2006)

Summers are warm to hot, with daytime temperatures generally ranging from 21-32 °C. Higher elevations have lower temperatures, while the far northern and northeastern regions and the western plateau and river valleys in the central and southern regions have higher temperatures. Winters are mostly cool to cold, with many higher areas often having temperatures below freezing at night but readings of 10-21 °C in the daytime. Mean annual temperatures decline from east to west (Fig. 4).

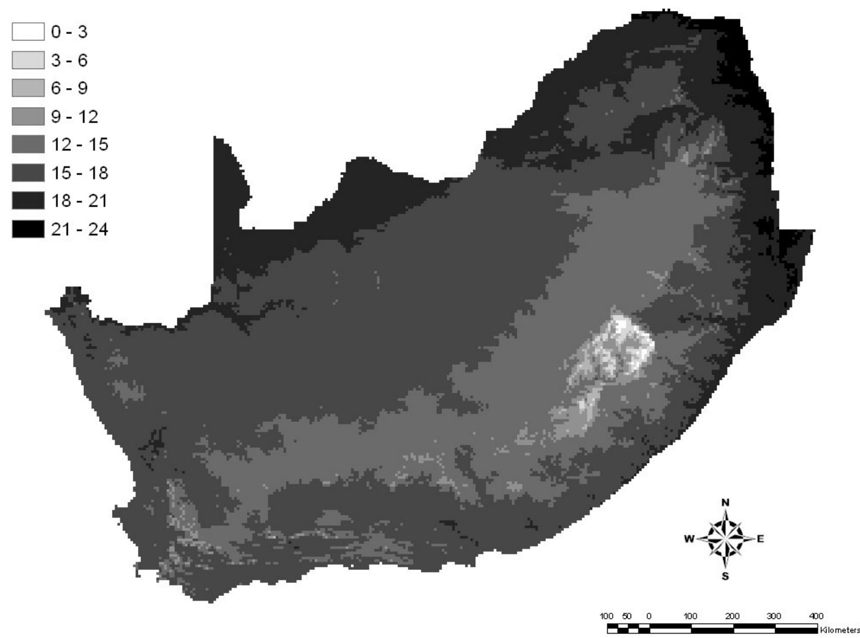


Figure 4. Mean annual temperature for South Africa (° C) (Mucina & Rutherford, 2006)

Study Area Descriptions

Vegetation units within the biomes of South Africa (Fig. 5) are described for each of the study areas according to the classifications made by Mucina & Rutherford (2006). A summary of all study areas is presented in Table 3.

Tswalu Kalahari Reserve

Tswalu Kalahari Reserve is situated in the northern region of the Northern Cape Province. The reserve falls within the eastern Kalahari Bushveld Bioregion of the Savanna Biome. The eastern electrified section (Predator Section), where data were collected, contains a mix of Koranna-Langeberg Mountain Bushveld (SVk15), Gordonia Plains Shrubland (SVk16) and Gordonia Duneveld (SVkd1). This 20 000 ha section is the only portion of the reserve that is enclosed by 120 km of electric fence. The average annual precipitation for the area is approximately 250 mm.

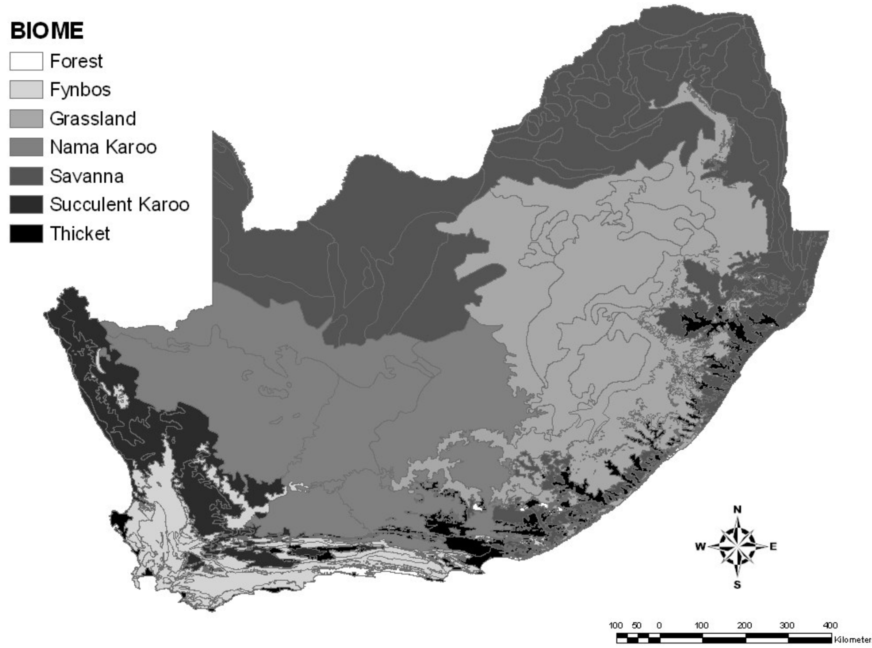


Figure 5. Vegetation biomes of South Africa (Mucina & Rutherford, 2006)

Pilanesberg National Park

Pilanesberg National Park is situated within central Bushveld Bioregion of the North West Province and is comprised entirely of the unique Pilanesberg Mountain Bushveld (SVcb5). Average annual precipitation for the area is approximately 520 mm. This 65 000 ha area is one of the North West Province's premier wildlife tourism destinations and plays host to a wide variety of mammal species.

Marakele Pty.Ltd

Marakele Pty. Ltd is situated in the Limpopo Province and the Central Bushveld Bioregion of South Africa. The 24 000 ha area contains Waterberg Mountain Bushveld (Svcb17) but is predominantly comprised of the Springbokvlakte Thornveld (Svcb15). Marakele Pty. Ltd has an average annual precipitation of 600 mm and is divided into a number of camps where buffalo and sable are bred (Table 4).

Jubatus Cheetah Reserve

Jubatus Cheetah Reserve is situated within the Limpopo Province and has an average annual precipitation of approximately 620 mm. The reserve contains both Central Sandy Bushveld (SVcb12) and Waterberg Mountain Bushveld (Svcb17) vegetation units with the latter being more predominant. The 4 500 ha reserve has been divided into four sections in order to study how predation, prey populations and area size interact.

Venetia Limpopo Reserve

The 33 000 ha Venetia Limpopo Reserve lies within the Mopane Bioregion of the Savanna Biome and falls within the Limpopo Province boundaries. The reserve contains a mix of Limpopo Ridge Bushveld (SvVp2), Musina Mopane Bushveld (SVmp1) and the Subtropical Alluvial Vegetation (Aza7) units. The average annual precipitation for Venetia is 380 mm.

Sabi Sand Game Reserve

The 65 000 ha Sabi Sand Game Reserve in the Mpumalanga Province is situated within the Lowveld Bioregion of the Savanna Biome and comprised entirely of Granite Lowveld (SVI3). Average annual precipitation for the reserve is approximately 580 mm.

Phinda Private Game Reserve

The 22 000 ha Phinda Private Game Reserve in KwaZulu-Natal falls within the Lowveld Bioregion of the Savanna Biome. The reserve has an average annual precipitation far in excess of 1000 mm and contains the following vegetation types:

- Western Maputaland Sandy Bushveld (SVI19)
- Western Maputaland Clay Bushveld (SVI20)
- Makatini Clay Thicket (SVI21)
- Subtropical Freshwater Wetlands (AZf6)
- Lowveld Riverine Forest (FOa1)
- Sand Forest (FOz8)

Table 3. Summarised study area descriptions. Vegetation types are described according to the classifications of Mucina & Rutherford (2006).

Study Area	**Province**	**Land Use Type**	**Size (Ha)**	**Electrified Fence Length (km)**	**Avg. Annual Precipitation (mm)**	**Dominant Vegetation Types**
Tswalu Kalahari Reserve	Northern Cape	Conservation Tourism	20 000	120	250	Koranna-Langeberg Mountain Bushveld (SVk15) Gordonia Plains Shrubland (SVk16) Gordonia Duneveld (SVkd1)
Pilanesberg National Park	North West	Conservation Tourism	65 000	130	520	Pilanesberg Mountain Bushveld (SVcb5)
Marakele Pty. Ltd	Limpopo	Conservation Breeding	24 000	52	600	Waterberg Mountain Bushveld (Svcb17 Springbokvlakte Thornveld (Svcb15)
Jubatus Cheetah Reserve	Limpopo	Research	4 500	64	620	Sandy Bushveld (SVcb12) Waterberg Mountain Bushveld (Svcb17)
Venetia Limpopo Reserve	Limpopo	Research Tourism	33 380	110	380	Limpopo Ridge Bushveld (SvVp2) Musina Mopane Bushveld (SVmp1) Subtropical Alluvial Vegetation (Aza7)
Sabi Sand Game Reserve	Mpumalanga	Conservation Tourism	65 000	85	580	Granite Lowveld (SVI3)
Phinda Private Game Reserve	KwaZulu-Natal	Tourism	22 000	110	1000	Western Maputaland Sandy Bushveld (SVI19) Western Maputaland Clay Bushveld (SVI20) Subtropical Freshwater Wetlands (AZf6) Lowveld Riverine Forest (FOa1) Sand Forest (FOz8)
De Aar District	Northern Cape	Stock Farming	-	22.8	300	

Potential Species Present

A list of potential species which occur in each of the study sites and susceptible to being electrocuted was compiled via visual inspection using distribution maps by Branch (1998) as well as Friedman and Daly (2004) (Table 4).

Materials and Methods

Data Collection

Historical Data

Data comprising of incidents that had occurred on participating study areas between 2004 and 2007 were incorporated and analysed separately under historical data. The quality of historical data varied greatly and as such, was subdivided into three categories for analysis.

Anecdotal Data

Anecdotal data were comprised of a number of incidents where staff from the study area recalled a species being killed on the areas' electric fence. This category provided valuable information regarding the range of species that was susceptible to being killed on electric fences in each area as well as the number of individuals that were killed between 2004 and 2007. The vast majority of these anecdotal records lacked specific categorical values (such as species measurements and height of electrified strand).

Karoo Data

Historical data collection in the Karoo involved walking the electrified fencelines of five participating farms. A number of tortoise carapaces had accumulated along these fencelines since the electric fences were installed in 2003. A GPS location was taken at each point where a carapace was found against the fenceline. Many of the carapaces had disintegrated as a result of prolonged exposure to sunlight and weathering processes, however, the plastron was placed back together and measured whenever possible. Remaining scutes were used in species identification and the height of the bottom strand was measured in mm. The Karoo data provides valuable information regarding the height of the electrified strand where mortality occurred, species prone to being electrocuted, the broad age class of individuals killed and the frequency of mortalities over a number of kms.

Marakele PTY. Ltd Data

The third category of historical data is comprised of historical records of electric fence associated mortality collected between January 2004 and May 2007. These data were analysed separately due to the amount of detail recorded. Each data point reflected the date of the incident, the species involved as well as the voltage of the electrified strand on which the mortality occurred. This information provided a month-by-month assessment of which species were being killed, how many individuals were being killed, as well as the height of the electrified strand on which individuals were killed, over a period of 36 months.

2007-2008 Study Data

The conservation areas involved in the study all had existing fence patrol teams that were responsible for monitoring and maintaining the integrity of the electric fencing infrastructure. In order to collect data over the period of one year from as broad an area as possible, these teams were integrated into the data collection process.

A comprehensive workshop was conducted at each site during which an overall summary of the aims and objectives of the research project were presented to the staff at each respective study site. The teams were taken through a thorough explanation and demonstration of the data collection techniques and identification of potential species present in the area. The identification of species was often merely an exercise of educating the teams as to the common names, as the local knowledge and identification of these species already existed. A local translator was used in instances where teams included individuals not fluent in English or Afrikaans. Teams were provided with data collection packs comprising of field data sheets, a 3 m measuring tape, a 300 mm plastic ruler, a pen, a small metal probe and a disposable camera. Images recorded by the teams on a disposable camera were used to verify correct species identification as well as to build up a visual database of mortality records.

Table 4. Potential species present in each of the study areas (Compiled from a visual inspection of distribution maps presented by Branch (1998) and Friedman & Daly (2004)).

	Tswalu Kalahari Reserve	Pilanesberg National Park	Marakele Pty. Ltd.	Jubatus Cheetah Reserve	Venetia Limpopo Reserve	Sabi Sand Game Reserve	Phinda Resource Reserve	De Aar & Middelberg (Karoo)
Tortoises								
Homopus boulengeri								x
Homopus femoralis								x
Kinixys belliana							x	
Kinixys lobatsiana				x				
Kinixys natalensis						x	x	
Kinixys spekii			x		x	x	x	
Psammobates oculferus	x		x					
Psammobates tentorius								x
Stigmochelys pardalis	x	x	x	x	x	x	x	x
Chameleons								
Bradypodion karooicum								x
Bradypodion nemorale							x	
Chameleo dilepis	x	x	x	x	x	x	x	
Monitors								
Varanus albigularis	x	x	x	x	x	x	x	x
Varanus niloticus		x	x	x	x	x	x	
Snakes								
Bitis a. arietans	x	x	x	x	x	x	x	x
Dendroaspis polylepis		x	x	x	x	x	x	
Hemachatus heamachatus							x	x
Naja annulifera		x	x	x	x	x	x	
Naja mossambica		x	x	x	x	x	x	
Naja nivea	x							x
Psammophis subtaeniatus		x	x	x	x	x		
Python natalensis		x	x	x	x	x	x	
Thelotornis capensis		x	x	x	x	x	x	
Small & Medium Mammals								
Canis mesomelas	x	x	x	x	x	x	x	x
Galago moholi		x	x	x	x	x		
Mannis temminckii	x	x	x		x	x	x	
Mellivora capensis	x	x	x	x	x	x	x	x
Orycteropus afer	x	x	x	x	x	x	x	x
Otolemur crassicaudatus						x	x	
Phacochoerus africanus		x	x		x	x	x	

A number of variables were recorded where each kill had been recorded along the fence line. Fence-line variables to be recorded at each point of contact and mortality included either distance from starting point or fence section reference number, voltage (in KW), as well as the height of the electrified strand above ground level (in mm) with which contact was made. In order to detect whether relief of the area contributed to observed mortality rates along fence-lines, points where mortalities were recorded were classified as being either a gully/drainage line, crest or flat. The date of the incident or estimated date of death was also recorded.

Tortoises were sometimes found alive but in contact with an electrified strand. In such instances, they were removed from the fence and the appropriate measurements were taken before returning the individual to the veld. The data sheet allowed for the recording of such individuals to be marked as still alive.

Snakes and monitor lizards were sexed using a blunt probe of appropriate size (Schaefer, 1934). The probe was inserted caudally, at the lateral margins, into the cloacal opening of the animal. In a male snake, the hemipenal pockets allowed the probe to move caudally for some distance. Snout vent length (SVL) measurements (in mm) were taken as a straight line along the belly, from the tip of the snout to the posterior edge of the anal plate for all snakes and monitors (as described by Branch, 1998). In addition to this, the total length of snakes and monitors were also recorded in mm (i.e. from the snout to the tip of the tail).

For tortoises, midline carapace length (MCL) midline plastron length (MPL) and maximum shell height (MSH) were measured in mm. MCL was measured by placing the carapace of the tortoise against a flat surface, then placing a plastic ruler perpendicular to the flat surface (resting on the top of the carapace) and reading the corresponding measurement for the end of the carapace. MPL was measured by inverting the tortoise before using a plastic ruler to measure the distance from the posterior edge of the plastron to the tip of the gular horn. MSH was taken using a plastic ruler to measure the distance between the ground and the highest point of the carapace.

The scutes of all carapaces, whether disarticulated or intact, were used to aid in species identification as well as age estimates (estimated by counting growth rings).

Chapter 2

Electric fence induced mortality in two regions of South Africa: An evaluation of historical data

Introduction

Recent advances in electronic technology have ensured that electric fences offer a viable alternative to barbed wire fences in most situations, with the added advantages of adaptability and significantly improved cost effectiveness (Van Rooyen *et al.,* 1989). Commercial stock farmers in the Karoo region of South Africa have taken advantage of this technological development and have supplemented their standard barbed wire fencing with low level electrified strands in order to prevent Black-Backed Jackal (*Canis mesomelas*) from entering their lands.

South Africa has also experienced rapid growth in the private game ranch sector since 1992, with the number of farms increasing from 3500 (covering 810000 ha) to 9000 (covering 6.5 million ha) in 1996 (Chadwick, 1996). Coupled with this increase has been the establishment of electrified game fences to limit human-wildlife conflict as well as to demarcate boundaries.

Concern over electric fence-related mortalities has been reported for a variety of tortoise species (Heard & Stephenson, 1987; Burger & Branch, 1994), Pangolins (*Manis temminckii*) (Jacobsen, 1991; J. Swart, pers. comm.), Southern African Pythons (*Python natalensis*) (G.J. Alexander pers. comm. 2006), Flap-necked Chameleon (*Chamaeleo dilepis*) (Cunningham & Cunningham, 2007) and Giant Bullfrogs (*Pyxicephalus adspersus*) (C.A. Yetman, pers. comm. 2006). However, there is very little literature addressing the impact of electric fence-related mortalities of wildlife in South Africa despite high number of known incidents in conservation and landowner circles.

Here, records of electric fence-associated mortality in two regions of South Africa are assessed and information regarding species prone to electrocution, trends in seasonality and estimates of mortality rates/km are presented.

Methodology

Data were collected from The Marakele Park (Pty) Ltd. (MPTY) and from a number of domestic stock farms in the De Aar and Richmond Districts (D&R) (Fig. 1, Chapter 1).

Fence patrol units from MPTY recorded all incidents of mortalities along the electric fence from December 2003 to July 2008. A data collection workshop was held in June 2007 to ensure that data had been collected rigorously (Mortality data collected prior to July 2007 were collected as part of regular perimeter fence patrols and were collected with less accompanying ecological and physical measurement information). The information recorded included the date of the incident, species identification and voltage measurements in Kilovolts (KV). Only incidents that had occurred between January 2004 and January 2008 were included in this analysis.

Data were collected in the D&R region during August 2007. A total of 37.6 km of electrified fence-lines on five farms was walked in search of carapaces that had accumulated since the installation of electrified strands in 2003. A GPS location and the height of the electrified strand where each incident had occurred was recorded (measured in mm) where a carapace was found against the fence-line. Many of the carapaces had disintegrated as a result of prolonged exposure to sunlight and weathering processes. Where this was the case, the plastron was placed back together and measured to the nearest mm wherever possible. Disarticulated scutes were used to aid in species identification as well as age estimates (estimated by counting growth rings). Tortoises were placed into three size classes based on these age estimates; Large (> 6 years of age), Medium (2-6 years of age), and Small (< 2 years of age). Mortality rates km^{-1} were calculated for each of the three size classes by dividing the total number of individuals in each category by the total sampling distance of 37.6 kms. These values were calculated for each fence-line surveyed.

The historical data collected in MPTY provided species identification as well as the month in which each mortality had occurred. This made for easy calculation of the km^{-1} mortality rate for this area. The total number of reptile mortalities for each of the four years was divided by the total distance of electric fencing surveyed (52 km). The calculation of this measurement in the D&R region was complicated by the fact that data were only collected on one occasion, four years after the installation of the electric fencing infrastructure. Thus, the total number of carapaces recorded was divided by the total distance of fencing surveyed (37.6 km) and then divided by the number of years that the fences had been in place in order to obtain an estimate of mortality rates $km^{-1}.yr^{-1}$. This measure is thus likely to underestimate of the actual mortality rate since some carcases may have been removed from the fence line by predators or deteriorated to the extent that they were not detected.

Results

Marakele Pty. Ltd

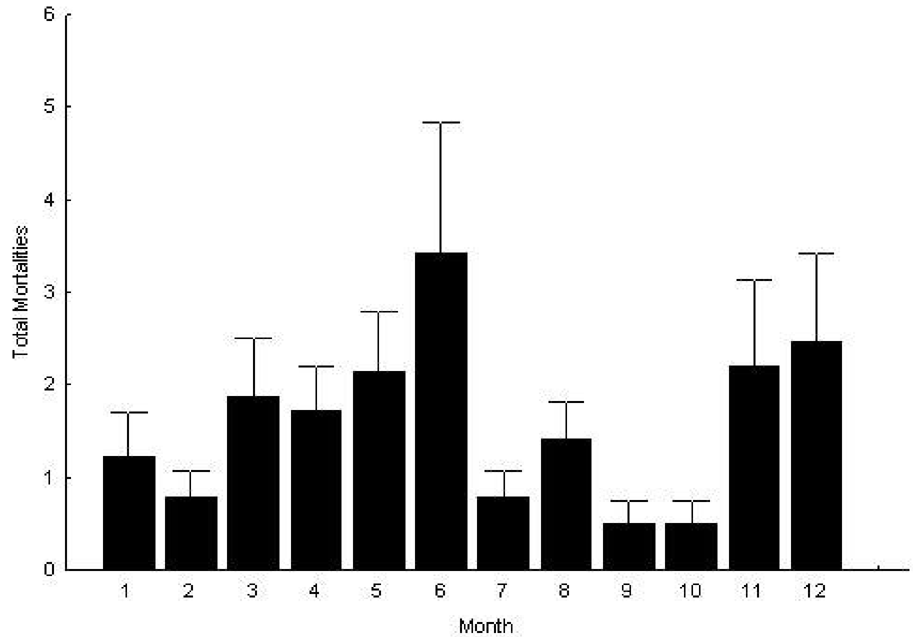
Frequency distribution plots of mammal mortalities per month over four years showed no significant differences between months (KW = 7.12, p = 0.79) with mortalities occurring throughout the year (Fig. 6A). However, the frequency distribution of reptile mortalities over the same period revealed significant differences between months (KW = 22.47, p = 0.02) with mortalities occurring exclusively between September and April (Fig. 6B).

De Aar and Richmond Districts

A total of 131 carapaces were found along the 37.6 kms of fenceline surveyed in the D&R region. Only a single species, Leopard Tortoise (*Stigmochelys pardalis*), was represented in the sample despite the fact that Tent Tortoise (*Psammobates tentorius tentorious*) and Greater Padloper (*Homopus femoralis*) occur in the region. There was a significant difference in mortality rate km^{-1} between the three size classes (ANOVA, p = 0.033; Fig. 3). A Tukey HSD post hoc test revealed that individuals in the adult age category suffered a significantly higher mortality rate km^{-1} of electrified fencing than individuals in the medium and small size classes (Tukey HSD, p = 0.041) (Fig. 7).

Strand heights recorded at each point where a mortality had occurred in the D&R region varied between 60 mm and 220 mm ($\bar{x}$ = 141.5 mm, n = 131) with the average strand height for participating farms varying between 40 mm and 250 mm, depending on the degree of topographical variation.

A



B

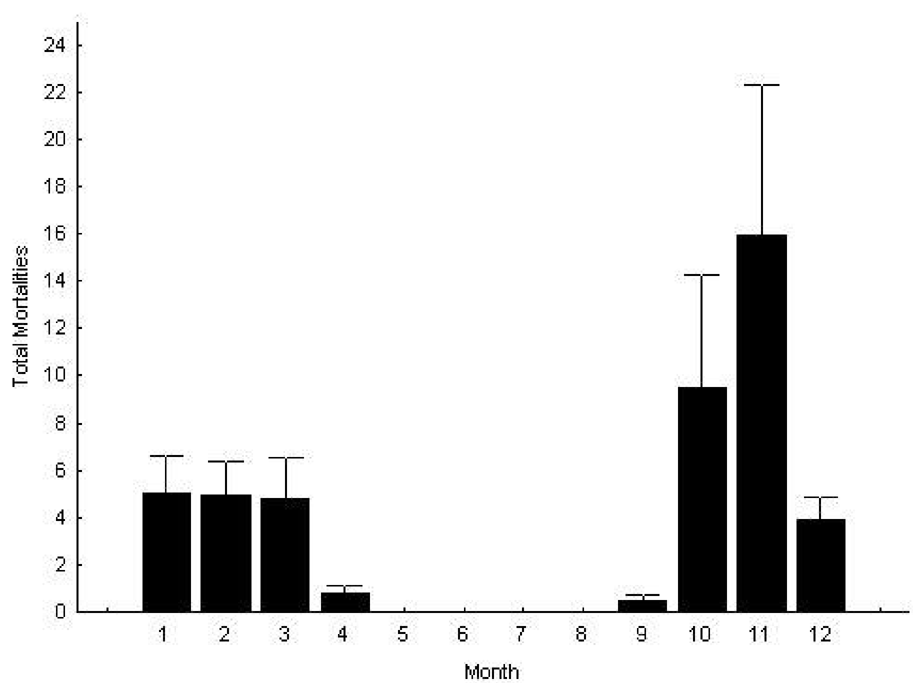


Figure 6. Mean monthly distribution of (A) mammal mortalities and (B) reptile mortalities along the electrified perimeter of Marakele Pty. Ltd over a four year period.

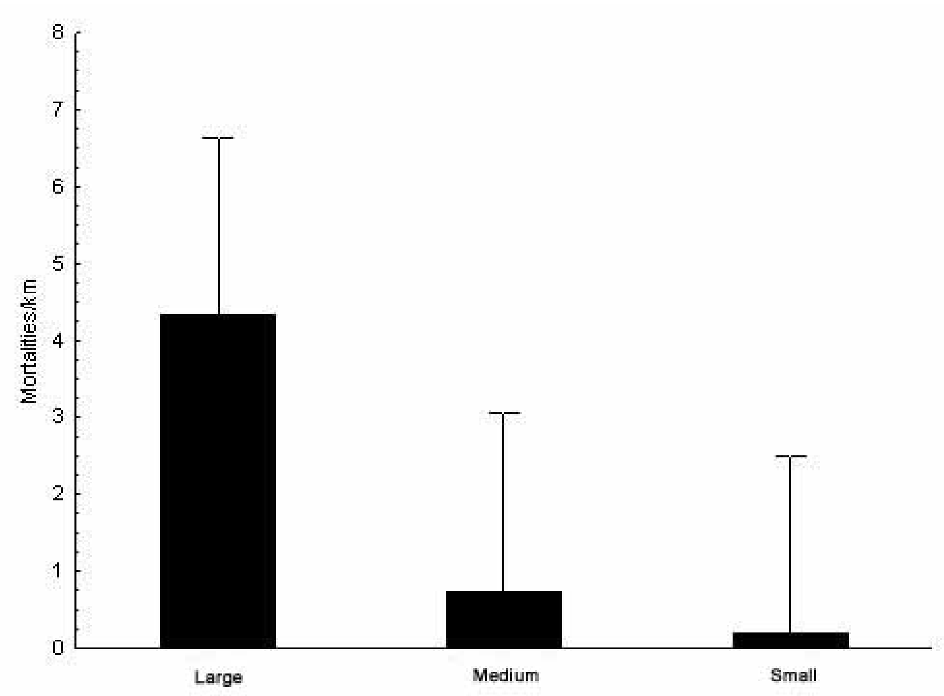


Figure 7. Frequency distribution of mortalities.km^{-1} by size class for Leopard Tortoise (*Stigmochelys pardalis*) in the De Aar and Richmond regions of the Northern Cape Province, South Africa.

Mortality Rates km^{-1} of Electric Fencing per year for Reptilia

Mean mortality rates were calculated to be 0.871 and 0.538 individuals.km^{-1}.yr^{-1} for the D&R and MPTY regions respectively. In addition, mortality.km^{-1} for MPTY was 52%, 64% and 58% greater in 2007 than in 2006, 2005 and 2004 respectively. Falkena & Van Hoven (2000) estimated that South Africa had over 90000km of game fencing, the bulk of which lies in the North West, Limpopo, Mpumalanga and Natal provinces. This coincides with the distribution of *S. pardalis* making the species highly susceptible to electric fence induced mortality throughout its range. Conservatively assuming that 50% of these farms have electric fencing infrastructure, and using a mean mortality rate value of 0.70 individuals.km^{-1}.yr^{-1}, it is estimated that South Africa loses in excess of 31 500 reptiles each year.

Discussion

Electric Fence Associated Mortality in Mammals

Analysis of electric fence associated mortality of mammals in MPTY revealed two clear categories of mortalities. Mortalities are either directly associated with the fencing infrastructure or as an interaction between the hunting activity of predatory species and the fencing infrastructure.

Of the 48 records of mammal mortalities in MPTY 69% were associated with wild dog predation and are therefore considered to be an indirect result of electric fencing infrastructure. The phenomenon of Wild Dogs exploiting perimeter fencing during hunts has been observed in a number of conservation areas (Van Dyk & Slotow, 2003; Rhodes & Rhodes, 2004). Of 316 Wild Dog kills in the Venetia Limpopo Reserve where the use of fences could be assessed, 128 (40.5%) were fence-impeded, constituting 54.1% of total edible biomass captured (Davies-Mostert, unpublished data). Mammals do not usually die from the resulting shock when coming into contact with electric fences although they may become entangled in the fence when fleeing from predators (Fig. 8A).

Mortality records not related to wild dogs but rather to the direct impact of electric fencing in MPTY accounted for 31% of mammal mortalities. The direct impact of electric fences on mammals in MPTY was found to be limited to smaller species such as Vervet Monkey (*Simia aethiops*) which attempt to climb fences, or species such as Porcupine (*Hystrix africaeaustralis*), Spotted Hyena (*Crocuta crocuta*), Aardvark (*Orycteropus afer*), Warthog (*Phacochoerus africanus*) and Black Backed Jackal (*Canis mesomelas*) which attempt to dig beneath electric fencing infrastructure. The design of an electric fence varies according to the species that are to be controlled, with the electrified strands usually being placed at the nose height of the target species (Andersen, 1984). It is this combination of fence design and an animal's behavioural instincts which make individuals prone to electrocution.

The movement of species that crawl beneath fences are currently discouraged in many conservation areas by placing low-level electrified strands, or tripwires, on the inside of the main fence. Animals that manage to excavate beneath the fence are thus vulnerable to coming into contact with these strands and may receive a high voltage electrical impulse to the brain, which can kill them instantly (Fig. 8B).

A B

Figure 8. A) Impala (*Aepyceros melampus*) entangled in an electric fence after being chased by predators in Jubatus Cheetah Reserve. B) Warthog (*Phacochoerus africanus*) killed by a low-level tripwire in Juabtus Cheetah Reserve (Photos courtesy of Brenda De Witt).

Electric Fence Associated Mortality in Reptiles

In contrast to the lack of any seasonal pattern in mammal mortalities (Fig. 6A), the number of reptile mortalities showed significant differences between months, with no mortalities being recorded between May and August (Fig. 6B). These winter months are typically cold and result in reduced activity levels among reptiles. The low environmental temperatures result in a reduction in the metabolic rate of the reptiles, forcing them to become inactive until such time as the environmental temperatures return to a favourable level (Alexander & Marais, 2007). This behavioural trait of ectotherms can result in extended periods of reduced activity, and accounts for the lack of records during winter months.

It is ultimately a combination of behavioural traits and the instinctive reaction of an animal to external stimuli that makes it prone to electrocution. The Boomslang (*Dispholidus typus*) is primarily an arboreal species that rarely descends to the ground (Alexander & Marais, 2007) and it is this behavioural trait that makes it prone to being killed on the higher strands of electrified fences. Upon receiving an electrical impulse, snakes will often curl up in defence, remaining in contact with the electrified strand and ultimately being electrocuted (Lund & De Silva, 1994). Larger terrestrial species such as the Southern African Python (*Python natalensis*) and the Rock Monitor (*Varanus albigularis*) are more likely to accidentally come into contact with the low-level (< 100 mm) electrified trip-wires used in many conservation areas as a direct result of their large body size (Fig. 9). Incidents involving *P. natalensis* were the result of the distended body, caused by a recent meal, coming into direct contact with the lowest electrified strand.

Figure 9. *Varanus albigularis* entangled in an electric fence in Marakele Pty Ltd. (Photo courtesy of the Marakele Pty. Ltd fence patrol team).

When tortoises come into contact with an electrified strand they usually react by retracting the head and limbs into the shell and thus remain a part of the circuit, receiving regular shocks, which ultimately results in death (Fig. 10). Some individuals urinate as a direct result of stress (pers. obs), increasing the degree to which they are earthed as well as the amount of current that passes through the carapace.

The nature and extent of physical injuries incurred during electrocution depend on a number of factors such as the type and amount of current, the path and duration of current flow and the conductivity of the surface exposed to the current (Anderson, 1957). Resultant injuries or mortality may arise from the direct destruction of cells by heat, electrolysis or by the disruption of normal functioning of vital centres and organs (Anderson, 1957). In addition to the above, tortoises that remain stranded on a fenceline are also exposed to prolonged sunlight and may suffer from environmentally mediated heat stress and dehydration (Perrin & Campbell, 1981).

A B

Figure 10. *Stigmochelys pardalis* killed on electric fences in (A) Marakele Pty Ltd. and (B) a farm in the De Aar District.

The results show that individuals in the large category (6 > years of age) suffered a significantly higher mortality rate km^{-1} of electrified fencing than individuals in the medium and small size classes. The calculated average strand height of 141.5 mm for all recorded mortalities in the D&R region suggests that the electrified strands are placed too close to ground level to allow for the safe passage of adult Leopard Tortoises (*Stigmochelys pardalis*) in the region. Burger & Branch (1994) state that plastron length and shell height are highly correlated in *S. pardalis* ($r^2 = 0.992$; n = 23). Thus, older individuals are expected to have larger maximum shell height values as well as other morphometric measures and, as a result, are more prone to being electrocuted on these low level electrified strands.

Many populations of terrestrial tortoises have age and size frequencies that are skewed toward larger and older individuals and that these populations exhibit low recruitment rates of between 1 and 5 % (Meek, 1985). In a study conducted on 5500 ha of farmland in the De Aar District, McMaster & Downs (2006) attributed skewed age distributions and low recruitment rates to the high vulnerability experienced at small sizes and decreased vulnerability at larger sizes combined with a long life span. The authors also acknowledge the possible role of fences in limiting the immigration of adults out of these confined areas. Electric fences are shown here to not only limit the dispersal and movement of adults between areas, but to play a significant role in compounding natural mortality rates of adult Leopard Tortoise in the D&R region.

Mortality Rates km^{-1} for Reptilia

Based on a mean mortality rate of 0.70 individuals.km^{-1}.yr^{-1}, it is estimated that South Africa loses in excess of 31 500 reptiles each year. A number of factors could influence this figure.

No recent estimates regarding the amount of game and electric fencing in South Africa could be found. South Africa has experienced rapid growth in the private game ranch sector since Falkena & Van Hoven made the last estimate in 2000. In addition to the growth in the private game ranching sector, many domestic stock farmers are now using electric fences in an effort to control perceived problem animals such as Black-Backed Jackal (*Canis mesomelas*) and Caracal (*Felis caracal*).

The total number of mortalities recorded during the study period may be underrepresented as predators, of which there are several candidate species, may have removed carcasses from the fence-lines before they could be recorded. This may also account for the lack of records involving smaller species of reptiles that occur in the study areas that are known to be prone to electrocution.

Data collected in MPTY were potentially biased by the fact that the intensity of data collection was not consistent over the four-year period, with the intensity being increased after the workshop held in June 2007. If the increase in records during 2007 was due to better collection, and not due to some real increase in mortality rate, differences in measures between this year and the earlier year provide an estimate of under-reporting for fence teams that are not highly motivated. Trends in mortality.km^{-1}.yr^{-1} for MPTY suggest that less than half of mortalities that occurred between January 2004 and June 2007 were recorded.

Similarly, measures of the number of tortoise carapaces counted in the D&R District may be an underestimate, as farmers in this region are known to remove carapaces from fencelines, especially in areas that are visible from main roads. This action is probably a direct result of the general public having brought the plight of the tortoises to the attention of both the farmers and provincial conservation authorities. Thus, true estimates of electric fence associated mortality for this region may be far greater than the measures presented here.

The mortality rate km^{-1} calculated for both MPTY and the D&R region may be greater than the national average. This is a realistic possibility as there are a number of areas where electrified strands are placed at a greater distance above ground level. If mortality rate is influenced by strand height, then such areas may experience lower mortally rates than the MPTY and D&R regions. This would reduce the estimate of the number of reptiles killed by electric fences in South Africa each year.

Potential Implications for Conservation

Leopard Tortoises appear to be the most vulnerable species prone to electrocution, accounting for 93.5% of all reptile mortalities in this assessment. This may be attributed to their widespread distributions as well as their large body size in comparison to other tortoise species.

Large female Leopard Tortoises may lay several clutches of 6-18 eggs at monthly intervals during the summer (Branch, 1998; Alexander & Marais, 2007) which, depending on hatch rates, results in a large number of neonates in the following season. The recruitment potential of these populations is dramatically reduced if individuals from the adult and sub adult age categories are removed from the population. The impact of such high mortality rates on this long-lived, slow-growing species could have significant impacts on the subsequent recruitment potential.

Conclusion

A number of species are prone to being electrocuted on electric fences in South Africa. Of these, Leopard Tortoises appear to be the most vulnerable as a result of their body size and their instinctive reaction to external threats and stimuli. Leopard Tortoises are not listed by the IUCN as threatened, however, with the recent increase in the use of electric fences to demarcate property boundaries and to contain both domestic stock and wildlife, it is doubtful whether Leopard Tortoise populations occurring in these areas can sustain the high levels of supplementary adult mortality associated with electric fencing infrastructure.

Chapter 3

Electric Fence Induced Mortality for all study areas

July 2007-June 2008

Introduction

Fencing has taken on an increasingly important role as an aid in wildlife management in Africa, and particularly in southern Africa, over the last decade. In 1992, South Africa had approximately 3 500 privately owned game reserves (Grossman *et al.*, 1992) with this number increasing to more than 9000 by 2005 (Macdonald, 2005). Currently, private reserves cover approximately 13% of the country's total land area (Berger, 2006) compared with the 5% for all national parks combined (Falkena & Van Hoven, 2000). This dramatic increase in the area of land demarcated for the establishment of private game reserves and various other forms of agriculture has resulted in an increase in the electric fencing infrastructure of varying designs in order to achieve specific objectives.

Research into the use of fencing as a wildlife management tool in Africa has addressed the potentially significant ecological, financial and social impacts that fencing infrastructure pose. The most obvious benefit associated with both non-electrified and electrified fencing is the ability to control access to an area, so that livestock or wildlife may be confined, or given exclusive access to landscape patches (Hoare, 1992). Fences have also been used as a means of reducing conflicts between humans and wildlife (Thouless & Sakwa, 1994; Clevenger *et al.*, 2001; Ogada *et al.* 2003; Boone & Thompson Hobbs, 2004; Kassilly, 2006), and as a barrier to limit both the risk of predation and the spread of disease (Martin 2005; Mbwaia & Mbwaia, 2006). Fencing undoubtedly has many benefits for both the conservation and preservation of fauna and flora, however, it does pose some degree of risk to both wildlife and livestock.

The potential negative impacts of fences include landscape fragmentation and isolation (Lovejoy *et al.,* 1984; Wilcove *et al.,* 1989), the disruption of migratory movements, dispersal patterns and accessibility of key resources (Owen & Owen, 1980; Hoare, 1992; Spinage, 1992; Albertson, 1998; Scott Wilson Resource Consultancy, 2000; Boone & Thompson Hobbs, 2004; Grag Gibson/Environmental Investigation Agency, 2004; Mbaiwa & Darkoh, 2005) as well as a reduction in habitat quantity and quality (Mbaiwa & Darkoh, 2005; Ricciuti, 1993), In addition to the above, fencing has been documented as increasing mortality rates of a number of species (Denney, 1964; Hoare, 1992), increasing potential for inbreeding within fenced land parcels (Ricciuti, 1993; Remmert, 1994); and providing smooth wire for the construction of snares by poachers (Hoare, 1992).

Electrified fences pose an additional increased risk of mortality for a number of individuals of a species as a direct result of the high voltage electrified strands that are placed at varying heights above ground level.

There is very little literature that addresses the impact of electric fence-related mortalities of wildlife in South Africa despite the high number of known incidents in conservation and landowner circles. Burger & Branch (1994) studied the impacts of an electric fence in the Thomas Baines Nature Reserve and made a number of recommendations as to how observed mortality rates could possibly be reduced. However, very little has been done since their pioneering study in 1994. The lack of literature addressing impacts of electric fencing on South African fauna is of great concern considering the degree to which the use of electric fencing has increased over the last decade.

Here, records of electric fence-induced mortality from a number of regions in South Africa are assessed in order to quantify mortality rates for both mammals and reptiles, identify trends in seasonality and identify possible means of amelioration.

Methodology

Eight study sites were located in a conservation, wildlife tourism and research areas throughout the country, as well as from livestock farms in the De Aar District of the Northern Cape (Fig. 1- Chapter 1).

Data were collected between July 2007 and June 2008. The conservation areas involved in the study all had existing fence patrol teams that were responsible for monitoring and maintaining the integrity of the electric fencing infrastructure in their particular area. These teams were integrated into the data collection process in order to collect data that would allow for the analysis of temporal variation in mortality trends.

A comprehensive workshop was conducted at each study site during which an overall summary of the aims and objectives of the research project were presented to the staff. The teams were taken through a thorough explanation and demonstration of the data collection techniques and identification of potential species present in the area. Data collection packs comprising of field data sheets, a 3 m measuring tape, a 300 mm plastic ruler, a pen, a small metal probe and a disposable camera were provided. Images recorded on the disposable camera were used to verify species identification as well as to build up a visual database of mortality records.

Variables recorded at each site where an animal was found to be in contact with the electrified fence included: date, species, sex, a number of morphological measurements (see below), voltage (in KW), the height of the electrified strand above ground level with which contact was made (to the nearest 1 mm), as well as a broad topographical classification of the relief at the site (gully/drainage line, crest or flat).

Snakes and monitor lizards were sexed using a blunt probe (Schaefer, 1934) and both snout vent length (SVL) and total length (TL) measurements were recorded in mm (as described by Branch, 1998).

For tortoises, midline carapace length (MCL), midline plastron length (MPL), and maximum shell height (MSH) were measured to the nearest 1 mm. Midline plastron length was measured by turning the tortoise onto its shell before using a plastic ruler to measure the distance from the posterior edge of the plastron to the tip of the gular horn. Tortoises were sexed by visual inspection of the tail when possible. Sex estimates for rotting carapaces were made by visually inspecting the plastron. Tortoises were sometimes found alive and in contact with an electrified strand. In such instances, they were removed from the fence and the appropriate measurements were taken before releasing the individual away from the perimeter fence.

Mortality rate km^{-1} was calculated for each study area by dividing the total number of mortalities between July 2007 and June 2008 by the total distance (in kilometres) of electric fencing.

Data analysis was limited by a number of factors. Firstly, the lack of repeated measures for a number of variables made testing for statistically significant differences between areas impossible. Secondly, the total number of mortalities and species recorded may be underrepresented for a number of reasons. Some carcasses may have been removed by predators. Farmers are known to remove carapaces from fence-lines, especially in areas where carcasses are easily visible from main roads.

This action is probably a direct result of the attention of the general public being alerted to the plight of the tortoises. Sampling may have also been biased towards larger species. Thus, true estimates of electric fence associated mortality for the region are likely to be greater than the estimates presented here. The final constraint pertains to the lack of population density estimates for species in each of the study areas. Differences in mortality rates between the areas, and in turn the electric fence designs, cannot solely be attributed to the electric fence configuration, since differences may also result from population density differences at each of the study sites.

Results

Annual Mortality Rates for Reptiles

The mean annual mortality rate for all study areas for reptiles was calculated as 0.48 individuals.km^{-1}.yr^{-1}. Mortality rates showed great geographical variation with the highest rates occurring in the De Aar District, Marakele Pty. Ltd and Jubatus (Fig. 11).

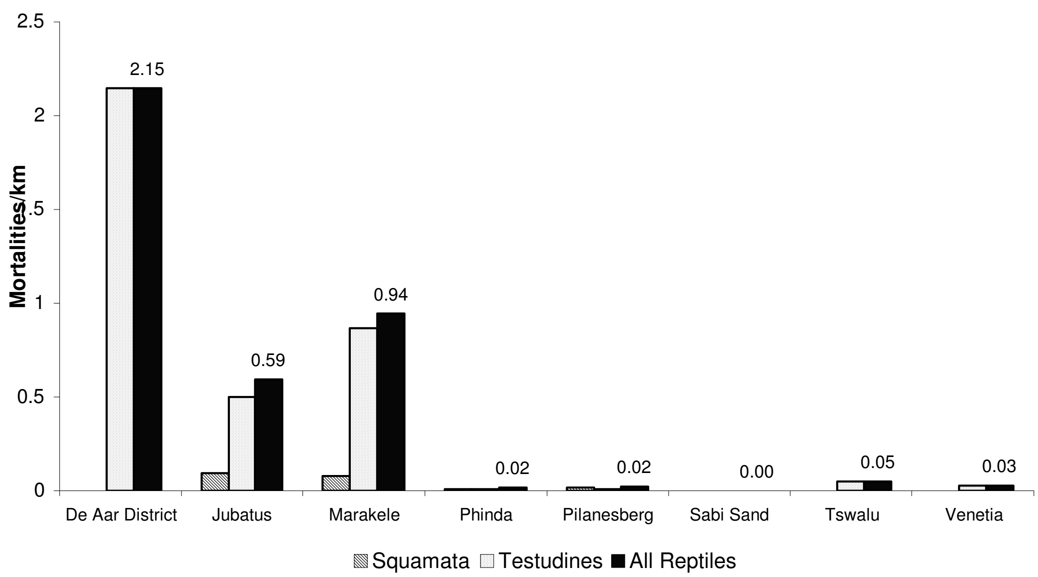


Figure 11. Annual mortality rates per km for reptiles in each study area.

Seasonality of Reptile Mortalities

A total of 150 reptile mortalities were recorded during the 12-month study period. Reptile mortalities were found to have occurred between September and April with a distinct peak in the warm summer months of October and November. Except for a single incident involving a Flap-necked Chameleon (*Chameleo dilepis*) in Natal, no mortalities were recorded during the cool winter months between May and August (Fig. 12).

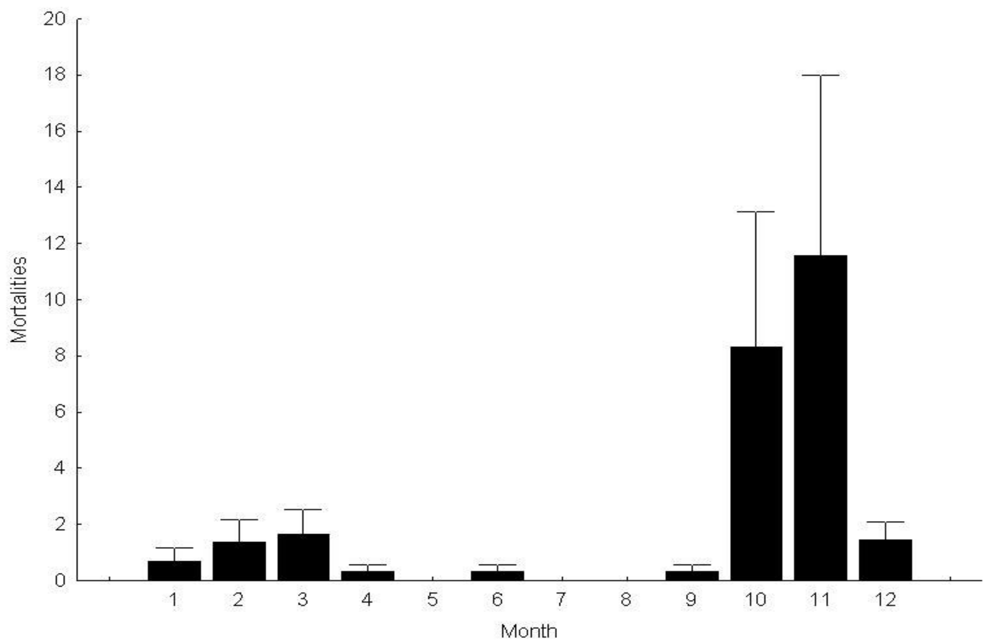


Figure 12. Frequency distribution of reptile mortalities per month for all study areas.

The influence of Strand Height on Reptile Mortality Rate

A strong relationship exists between the average number of mortalities.$km^{-1}.yr^{-1}$and the average height of the lowest electrified strand. Areas where electrified strands were placed between 100 mm and 200 mm above ground level showed noticeably higher mortality rates when compared to areas where the lowest electrified strand was placed at a height of greater than or equal to 200 mm above the ground (Fig. 13).

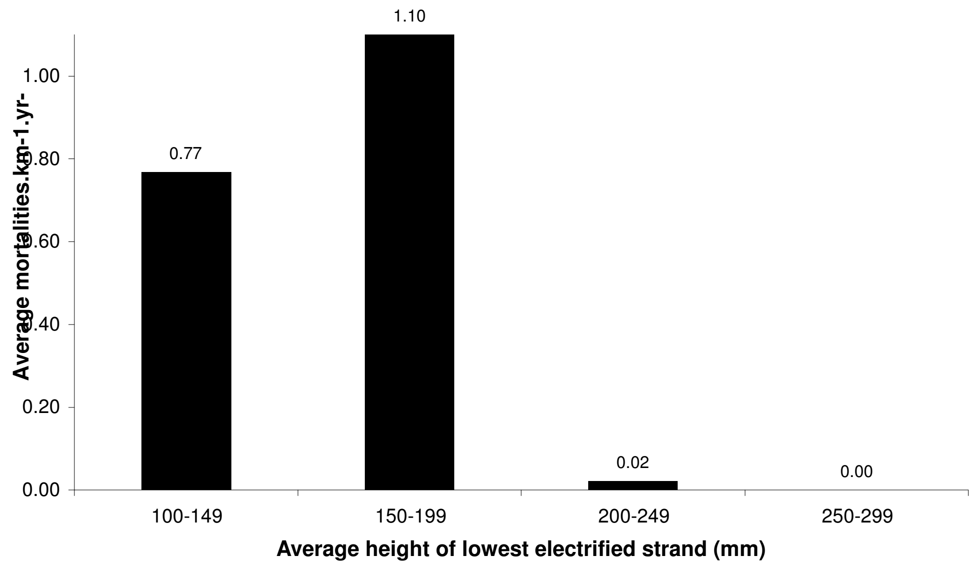


Figure 13. Average mortalities.km^{-1}.yr^{-1} for reptiles within four categories of strand height.

Electric fence Associated Mortality in Mammals

A total of 32 incidents involving individuals from five mammal species were documented during the 12-month study period. The mean annual mammal mortality rate ranged between 0 and 0.18 individuals.km^{-1}.yr^{-1} ($\bar{x}$ = 0.04 individuals.km^{-1}.yr^{-1}). The majority of incidents involved Greater Kudu (*Tragelpahus strepciceros*) (56%), Impala (*Aepyceros melampus*) (25%) and Pangolin (*Manis temminckii*) (13%). Incidents involving Red Duiker (*Cephalopus natalensis*) (3%) and Warthog (*Phacochoerus africanus*) (3%) constituted the remaining 6% (Fig. 14).

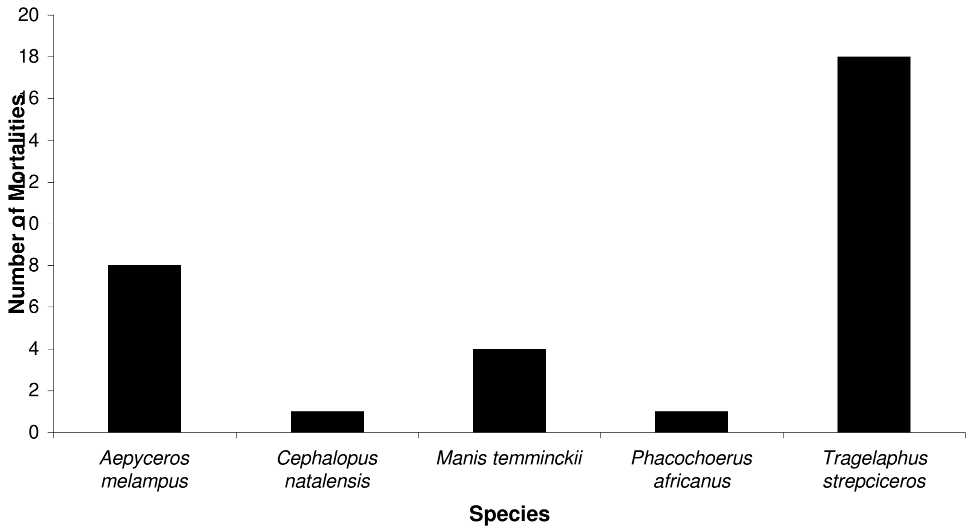


Figure 14. Mammal mortalities for all study areas between July 2007 and June 2008.

Discussion

Mortality Rate km^{-1} for Reptiles

Annual mortality rates for reptiles ranged between 0 and 2.15 individuals.km^{-1}.yr^{-1} ($\bar{x}$ = 0.475 individuals.km^{-1}.yr^{-1}) with the highest mortality rates occurring in the De Aar District (2.15 individuals.km^{-1}.yr^{-1}), Marakele Pty. Ltd (0.94 individuals.km^{-1}.yr^{-1}) and Jubatus (0.59 individuals.km^{-1}.yr^{-1}) (Fig. 11). These values are very similar to the mean mortality rates presented in Chapter 2 (0.871 and 0.538 individuals.km^{-1}.yr^{-1} for the D&R and MPTY regions respectively).

Seasonality of Reptile Mortalities

Mortality rates for reptiles showed noticeable differences between months, with only a single incident being recorded between May and September (Fig. 12). Winter months are typically cold and result in reduced activity levels among reptiles. The low environmental temperatures force ectotherms to become inactive until such time as the environmental temperatures return to a favourable level (Alexander & Marais, 2007). This behavioural trait of ectothermic organisms can result in extended periods of little or no activity and accounts for greatly reduced mortality rates during winter months.

The Influence of Strand height on Reptile Mortality Rates

Average mortality rates per km showed a marked decrease in the 200 mm and greater categories of strand height. Study sites where electrified strands were placed below 200mm include the De Aar District (2.15 individuals.km^{-1}.yr^{-1}), Marakele Pty. Ltd (0.94 individuals.km^{-1}.yr^{-1}), Jubatus (0.59 individuals.km^{-1}.yr^{-1}) and Tswalu (0.05 individuals.km^{-1}.yr^{-1}) (Fig. 13).

Strand height thus appears to have a pronounced effect on the number of individuals that are electrocuted, with mortality rates decreasing as the height of the electrified strand above ground level increases. This supports the findings of Burger & Branch (1994). The authors recommended that the lowest electrified strand of an electric fence be erected at a height of at least 250 mm above ground level in order to reduce the number of Leopard Tortoise mortalities in the Thomas Baines Nature Reserve.

Notably, Pilanesberg National Park recorded only a single chelonian mortality over the study period. This low mortality rate may be attributed to the fact that the reserve has a rock packed apron around the base of the fencing infrastructure which makes it very difficult for chelonians to come into direct contact with the bottom electrified strand.

Mammal Mortalities

Individuals from five mammal species were documented as being electrocuted on electrified fences (Fig. 14). Of greatest conservation concern are the incidents involving Pangolin (*Manis temminckii*). Four incidents of electrocution of individuals of this species occurred in Tswalu Kalahari Reserve’s predator camp in 12 months, and reports of pangolins being killed on electrified fences are commonly reported by landowners in the Mpumalanga, Limpopo, North West and Northern Cape provinces.

The natural defence of a Pangolin to external stimuli is to curl into a ball where all the vulnerable regions of the body are protected by its thick scales. When a Pangolin receives a shock from an electrified strand it assumes this defensive position and rolls around the electrified strand (Fig. 15), remaining a part of the circuit and receiving regular pulses of electricity.

Mammal mortalities involving Impala (*Aepyceros melampus*) and Greater Kudu (*Tragelaphus strepciceros*) were attributed to hunting activity of Wild Dogs (*Lycoan pictus*) in Pilanesberg National Park, Marakele Park Pty. Ltd and Venetia Limpopo

Reserve. This phenomenon of Wild Dogs exploiting perimeter fencing during hunts has been observed in a number of conservation areas (Van Dyk & Slotow, 2003; Rhodes & Rhodes, 2004; Davies-Mostert, unpublished data). A single incident involving a Warthog (*Phacochoerus africanus*) was recorded during the study period involving an individual that attempted to dig under a fence. The individual's head came into direct contact with the low-level tripwire resulting in a high voltage shock to the brain, killing the animal.

Figure 15. A Pangolin (*Manis temminckii*) curled around an electrified trip-wire in Tswalu Kalahari Reserve.

Potential Implications for Conservation

The mean mortality rate for reptiles was calculated as 0.48 individuals.km^{-1}.yr^{-1} for all participating study areas. This estimate provides a measure with which to calculate the number of mortalities occurring annually along South Africa's electrified fencelines. Falkena & Van Hoven (2000) estimated that South Africa had over 90 000 km of game fencing. Conservatively assuming that 50% of these farms have electric fencing infrastructure, and using the mean mortality rate value of 0.48 individuals.km^{-1}.yr^{-1}, it is estimated that South Africa loses in excess of 21 000 reptiles each year.

A total of 91% of reptile mortalities were attributed to a single species, Leopard Tortoise (*Stigmochelys pardalis*), which appears to be the most vulnerable species due to its large body size and widespread distribution. Adult females may be at the greatest risk due to their increased body size when compared with males of the same species (Branch, 1998). The selective removal of these large, sexually reproductive adults could have significant negative impacts for populations occurring in areas surrounded by electrified fences.

Reported population density figures range from 0.017 to 0.03 tortoises per hectare, and 0.3 to 0.85 tortoises per hectare within habitat (Grobler, 1982; Mason *et al*., 2000; McMaster, 2001). Recorded home range sizes vary from mean of 58 ha in the Thicket Biome of the Eastern Cape (Mason *et al*., 2000), to a mean of 414 ha in the Nama-Karoo Biome of the Northern Cape (McMaster, 2001). Land is often divided and fenced into smaller parcels to facilitate rotational grazing management systems. These small parcels pose a real threat to tortoise populations present in the area when electric fencing is used due to the large perimeter to core ratio, increasing the likelihood of the tortoises coming into contact with an electrified strand.

Meek (1985) found that many populations of terrestrial tortoises have age and size frequencies that are skewed toward larger and older individuals and that these populations exhibit low recruitment rates of between 1 and 5 %. In a study conducted on 5500 ha of farmland without electric fencing in the De Aar District, McMaster & Downs (2006) attributed skewed age distributions and low recruitment rates to the high vulnerability experienced at small sizes and decreased vulnerability at larger sizes combined with a long life span. The authors also acknowledge the possible role of fences in limiting the immigration of adults out of these confined areas. Electrified fences are shown here to not only limit the dispersal and movement of adults between areas, but to play a significant role in compounding natural mortality rates of adult Leopard Tortoise (*Stigmochelys pardalis*) in the Nama-Karoo.

The recruitment potential of such populations is dramatically reduced if individuals from the adult and sub adult age categories are removed from the population. The impact of such high mortality rates on this long-lived, slow-growing species could be devastating in terms of a populations' ability to produce hatchlings that will survive to sexual maturity at an age of 10-15 years (Branch, 1998; Alexander & Marais, 2007).

Recommendations

The use of electric fences to control the movement of wildlife and domestic animals is gaining popularity amongst landowners. The objectives of an electric fence vary according to the type of land use and the target species to be controlled by the fence. Domestic livestock farmers in the De Aar and Middelberg region, for example, use a single electrified strand at the base of a cattle fence in order to keep predators out of the property. Conservation areas, on the other hand, use multiple electrified strands placed at varying heights in order to contain a variety of species within a protected area. The primary objective of the fences in these conservation areas is to limit human wildlife conflict by preventing wildlife from moving beyond the borders of the protected area. Any recommendations regarding possible methods of amelioration should thus take the specific needs of landowners, as well as the resource available to them, into account.

Observations made throughout the study have highlighted several important recommendations that may assist in reducing the number of electric fence associated mortalities in South Africa.

Increasing the height of the bottom electrified strand.

This modification should dramatically reduce the number of tortoise mortalities as it facilitates the safe passage of most tortoises beneath the electrified strand. Long & Robly (2004) suggest that strand heights of at least 210 mm above ground level were instrumental in preventing echidna deaths in Australia. Similarly, Burger & Branch (1994) recommended that the height of the lowest electrified strand be at least 250 mm above ground level in order to reduce the number of tortoise mortalities in the Thomas Baines Nature Reserve in the Eastern Cape Province of South Africa. The results of my study support the findings of Burger & Branch (1994) and it is therefore recommended that the lowest electrified strands be placed at a minimum of 200 mm above ground level.

Increasing the distance that the lowest electrified strand is offset from the main fence.

Throughout the study, a number of carapaces were found between the low-level tripwire and the diamond mesh fencing. These individuals may have been able to push beneath the tripwire or may have passed beneath it at a point where the distance between the ground and the wire allowed for a safe passage. Once between the fence and the tripwire, tortoises moved along the fence until they reached a point where they came into contact with an electrified strand, which was closer to the ground. By increasing the distance that the electrified strand is offset from the fence to between 400 and 500 mm and simultaneously raising the height as described in (1), the number of tortoises that are trapped between the fence and the electrified strand should be reduced dramatically.

Installing a barrier wall.

Barrier walls have been used with great success in diverting reptiles and amphibians towards culverts beneath highways and railway lines (Dodd *et al*., 2004). A similar barrier wall system may be effective in preventing the movements of a host of reptile species towards electric fencing infrastructure. Such a barrier wall would need to be easy to erect and maintain, and should be economically viable. A simple wall could be constructed using plastic sheeting or wire mesh partially buried beneath the ground and held up with wooden or metal stakes.

Duty cycle/timer switches.

Livestock farmers that utilise electrified fences as a means to control predator movements should consider the use of duty cycle switches to control the times that the electrified fence is live. Black-backed Jackal (*Canis mesomelas*) and Caracal (*Felis caracal*), most commonly perceived as problem animals, are predominantly nocturnal predators whereas chelonians are active diurnally. Electric fence associated mortality of reptiles may be greatly reduced by switching the electrified fences off during daylight hours, the peak period of reptile activity, and switching them on in the early evening, the peak activity periods of *C. mesomelas* and *F. caracal.* This solution may be ideal for domestic livestock farmers as a duty cycle or timer switch can easily be fitted to existing fence energisers. However, this solution is not viable in conservation areas where any of the big 5 species are contained.

Rock Packed Aprons.

The primary aim of wire netting aprons is to prevent animals from pushing or digging beneath a fence. Low-level electrified tripwires are currently used in a number of conservation areas to prevent animals such as *Phacochoerus africanus* and *Hysrtix africaeaustralis* from excavating beneath the fences and facilitating the movement of predators such as Lion (*Panthera leo*) and Wild Dog (*Lycoan pictus*) out into rural areas. This study has shown how mortality rates for reptiles are dramatically increased by such fencing infrastructure and the use of rock packed aprons may be a viable and more eco-friendly alternative to these damaging strands. Sinking a bonnox or diamond mesh apron at least 0.5 m beneath the surface and packing rocks against the base of the fence will serve two purposes; (1) attempts to dig beneath the fence will be restricted by both the mesh apron as well as the rocks which will fall in to replace any soil removed from the base of the fence, (2) tortoises will be prevented from making contact with the electrified strand as they are unable to negotiate their way over the rock packing at the base of the fence.

Conclusion

Individuals from a total of 15 species were recorded as being killed by electric fencing infrastructure over a 12-month period. Of these, 66.6% were reptiles and 33.3% mammals. Leopard Tortoises appear to be the most vulnerable as a result of their body size and their instinctive reaction to external threats and stimuli, however, the mortality of species such as Pangolin (*Mannis temminckii*) and Southern African Python (*Python natalensis*) is of great concern. It is highly unlikely that the estimated volume of 21 000 reptiles that are killed each year on electrified fences would be acceptable for larger more charismatic species. Possible mitigation measures include increasing the height of the bottom electrified strand to a minimum of 200 mm, increasing the distance that lowest electrified strand is offset from the fence, the use of rock packed aprons, and the installation of timer/duty cycle switches.

Chapter 4

Species Prone to Electrocution in South Africa

Introduction

Concern over electric fence-related mortalities has been reported for a variety of tortoise species (Heard & Stephenson, 1987; Burger & Branch, 1994), Pangolins (*Manis temminckii*) (Jacobsen, 1991; J. Swart, pers. comm.), Southern African Pythons (*Python natalensis*) (G.J. Alexander pers. comm. 2006), Flap-necked Chameleon (*Chamaeleo dilepis*) (Cunningham & Cunningham, 2007) and Giant Bullfrogs (*Pyxicephalus adspersus*) (C.A. Yetman, pers. comm. 2006).

A number of additional species were recorded in the data presented in Chapters 2 and 3. In this chapter I present a comprehensive species list, documenting species which may be prone to electric fence induced mortality in South Africa.

Long & Robly (2004) developed such a list for Australia during a study aimed at assessing the impacts of feral animal exclusion fencing in areas of high conservation value. The authors used survey questionnaires to evaluate which species landowners and managers had found killed on feral animal exclusion fences in Australia.

Using reports submitted by the public, species accounts from a wildlife rehabilitation organisation, and data collected by the fence patrol teams in each of the study areas, a similar species list has been compiled for South Africa. Here I present a number of species lists and discuss the factors that contribute to the assemblages of species that are prone to being electrocuted on electric fencing infrastructure.

Methodology

Data were collected from three sources. Data gathered in participating study areas between July 2007 and June 2008 were used both in calculating frequency percentages for species in each class, as well as in the compilation of species lists. Historical data obtained from Marakele Pty Ltd and the De Aar and Middelberg region were combined with anecdotal data and reports sent in by the general public as a result of media coverage, and through discussions with FreeMe manager, N. Wright. These data were used solely in the compilation of species lists and not in determining frequency percentages for species.

All species accounts were categorised by class. The species list for mammals is subdivided, with mortalities classified as being a direct result of the electric fence, or indirectly through an interaction between predatory activity and the electric fence. Based on the rate of recurrence and the volume of incidents reported from all three data sources, species were assigned into one of three categories (1) Frequent, (2) Infrequent, (3) Occasional.

Results

Electric fence induced mortality in mammals

A total of six incidents involving four mammal species were recorded as being killed as a direct result of electric fencing in all participating study areas between July 2007 and June 2008. 66% of these mortalities involved Pangolin (*Manis temminckii*) with Warthog (*Phacochoerus africanus*) and Red Duiker (*Cephalopus natalensis*) comprising 17% each.

Combined with the historical and anecdotal data, a total of 22 mammal species have been reported as being killed on electric fencing infrastructure. Of these, 16 (72.7%) were a direct result of electric fencing, whilst the remaining 6 (27.3%) species were killed as a result of an interaction between predatory behaviour and electric fencing infrastructure (Table 5).

Electric fence induced mortality in reptiles

150 reptile mortalities from 10 species were recorded in all study areas between July 2007 and June 2008. Leopard Tortoise (*Stigmochelys pardalis*) comprised 86 % of all mortalities with Lobatse Hinged Tortoise (*Kinexys lobatsiana*) and Rock Monitors (*Varanus albigularis*) comprising 3.3% each. Southern African Python (*Python natalensis*) and comprised 2%, followed by Marsh Terrapin (*Pelomedusa subrufa*) with 1.3 %. Flap Necked Chameleon (*Chameleo dilepis*), Boomslang (*Dispholidus typus*), Olive Grass Snake (*Psammophis mossambicus*) and Stripe-bellied Sand Snake (*Psammophis subtaeniatus*) each comprised a further 0.7% of the total mortalities.

When combined with anecdotal and historical data, individuals from a total of 14 reptile species were recorded as being prone to electric fence induced mortality (Table 6).

Table 5. Mammal mortalities associated with electric fencing infrastructure in South Africa.

		Rate of Recurrence		
Species	**Common Name**	**Frequent**	**Infrequent**	**Occasional**
Direct result of electric fencing				
Atelerix frontalis	South African Hedgehog			*x*
Canis mesomelas	Black-backed Jackal			*x*
Cephalopus natalensis	Red Duiker			*x*
Crocuta crocuta	Spotted Hyena			*x*
Galago moholi	Lesser Bushbaby		*x*	
Genetta genetta	Small Spotted Genet		*x*	
Hystrix africaeaustralis	Porcupine	*x*		
Manis temminckii	Pangolin	*x*		
Mellivora capensis	Honey Badger		*x*	
Oreotragus oreotragus	Klipspringer			*x*
Orycteropus afer	Aardvark		*x*	
Oryx gazella	Gemsbok			*x*
Otolemur crassicaudatus	Thick Tailed Bushbaby		*x*	
Phacochoerus africanus	Warthog		*x*	
Potamochoerus larvatus	Bushpig			*x*
Simia aethiops	Vervet Monkey		*x*	
Indirect result (Interaction between predatory species and electric fencing)				
Aepyceros melampus	Impala	*x*		
Connochaetes taurinus	Blue Wildebeest	*x*		
Equus burchellii	Burchells Zebra			*x*
Kobus elipsiprymnus	Waterbuck			*x*
Tragelaphus scriptus	Bushbuck			*x*
Tragelaphus strepsiceros	Greater Kudu	*x*		

Table 6. Reptile mortalities associated with electric fencing infrastructure in South Africa.

		Rate of Recurrence		
Species	**Common Name**	**Frequent**	**Infrequent**	**Occasional**
Chameleo dilepis	Flap Necked Chameleon		*x*	
Dendroaspis polylepis	Black Mamba			*x*
Dispholidus typus	Boomslang			*x*
Kinixys belliana	Bells Hinged Tortoise		*x*	
Kinixys lobatsiana	Lobatse Hinged Tortoise	*x*		
Pelomedusa subrufa	Marsh Terrapin		*x*	
Philothamnus	Spotted Bush Snake			*x*
Psammobates oculiferus	Kalahari Tent Tortoise			*x*
Psammophis mossambicus	Olive Grass Snake			*x*
Psammophis subtaeniatus	Stripe-bellied Sand Snake			*x*
Python natalensis	Southern African Python	*x*		
Stigmochelys pardalis	Leopard Tortoise	*x*		
Thelotornis capensis	Southern Vine Snake			*x*
Varanus albigularus	Rock Monitor	*x*		

Electric fence induced mortality in amphibians

No species-specific frequencies could be calculated for amphibians as all incidents were reported by the general public and present in the 2007-2008 data. A total of three amphibian species were recorded as being prone to electric fence induced mortality (Table 7). Of great concern is the presence of the Leopard Toad (*Bufo pantherinus*), which is listed as endangered (Minter & Harrison, 2004).

Table 7. Amphibian mortalities associated with electric fencing infrastructure in South Africa.

		Rate of Recurrence		
Species	**Common Name**	**Frequent**	**Infrequent**	**Occasional**
Bufo pantherinus	Leopard Toad			*x*
Pyxicephalus adspersus	Giant Bullfrog		*x*	
Bufo rangeri	Raucous Toad		*x*	

Discussion

Species Prone to Electrocution in South Africa

Individuals from 33 species and three classes were recorded as being directly killed by electric fencing infrastructure in South Africa. In addition to these, a further six species of mammals were recorded as being killed via the interaction between predatory activity and an electric fence. Leopard Tortoises (*Stigmochelys pardalis*), Pangolin (*Manis temminckii*), Southern African Python (*Python natalensis*), Rock Monitors (*Varanus albigularis*), Lobatse Hinged Tortoise (*Kinexys lobatsiana*) and Porcupine (*Hystrix africaeaustralis*) appear to be the species killed most frequently by electric fences.

The species lists presented here could be further extended to include species that are similar to those that have already been recorded as being killed by electric fences. Flap-necked Chameleons (*Chameleo dilepis*), for example, has been shown to be prone to electrocution. Similar species of Dwarf Chameleon (*Bradypodion* sp.) occurring in areas where electric fences are used, whether in urban or rural environments, may also be prone to being electrocuted on such infrastructure. This logic can be extended to include species of the *Varanus* and *Genetta* genera.

The role of behavioural traits

It is ultimately a combination of behavioural traits and the instinctive reaction of an animal to external stimuli that makes it prone to electrocution. Species such as Flap Necked Chameleon (*Chameleo dilepis*), Boomslang (*Dispholidus typus*), Thicktailed Bushbaby (*Otolemur crassicaudatus*), and Lesser Bushbaby (*Galago moholi*) have an arboreal nature. This results in tendency to climb fences, and as a consequence, individuals of these species are prone to being killed on the higher strands of electrified fences.

Larger, more terrestrial species of such as Southern African Python (*Python natalensis*), Rock Monitor (*Varanus albigularis*), Leopard Tortoise (*Stigmochelys pardalis*), Pangolin (*Manis temminckii*), and Porcupine (*Hystrix africaeaustralis*) are more likely to come into contact with the low-level (< 150 mm) electrified tripwires used in many conservation areas.

Instinctive reactions to external stimuli

Pangolin (*Manis temminckii*) and a number of snake species were found curled around electrified strands. This is thought to be as a direct result of their instinctive reaction to external stimuli. Upon receiving an electrical impulse, snakes will often curl in defence, thus remaining in contact with the electrified strand and ultimately being electrocuted (Lund & De Silva, 1994).

When tortoises come into contact with an electrified strand they generally react by retracting the head and limbs into the shell. Some tortoises were observed as having urinated, possibly as a direct result of stress, moistening the soil around them and increasing the degree to which they are earthed (Pers. obs). This increases the amount of current that is passed through the carapace.

The nature and extent of physical injuries incurred during electrocution depend on a number of factors such as the type and amount of current, the path and duration of current flow, and the conductivity of the surface exposed to the current (Anderson, 1957). Anderson (1957) also states that resultant injuries or ultimate mortality may arise from the direct destruction of cells by heat, electrolysis or by the disruption of normal functioning of vital centres and organs. In addition to the direct impacts caused by the high voltage electrified strands, Chelonians that remain stranded on a fence-line are subjected to prolonged exposure to sunlight. This may result in additional effects of environmentally mediated heat stress and dehydration (Perrin & Campbell, 1981).

Potential implications for conservation

The species lists presented above provide a reference with which to assess the possible impacts of new electric fencing infrastructure. By compiling a list of potential species present in an area, and cross-referencing this list with the species lists presented here, landowners and fencing companies may be able to identify potential threats to species during the planning phase of erecting electric fencing infrastructure.

Electrocution by electric fences was sighted as one of the major threats to the reintroduction of Babcock's Leopard Tortoises (*Stigmochelys pardalis babcocki*) into the wild areas of KwaZulu-Natal (KZN Wildlife, 2004). Recommendations were made to raise the height of the lowest electrified strand in order to prevent electric fence induced mortalities of the species. Similar threats should be identified timeously and may be resolved by using the proposed means of amelioration presented (Chapter 2).

Conservation areas and domestic stock farms are not the only areas where electric fences are used. Electric fences have become increasingly popular amongst urban South African homeowners. Electric strands placed around buildings and on top of perimeter walls are a common means of increasing the security of ones home. These fences have the potential to kill chameleons, geckos, skinks, snakes and lizards.

The way forward

Electric fence designs currently in use in conservation and stock farming have been shown to compound natural mortality rates in a variety of species. Concern over this negative impact is growing amongst conservation minded landowners and members of the public. This study provides a reference for identifying which species are prone to electrocution as well as a number of possible means of amelioration (Chapter 3).

The next phase of this project (conducted by the Endangered Wildlife Trust) involves the experimental testing of the proposed means of mitigating electric fence induced mortalities. The results of these experimental trials will then be compared with the results presented here in order to obtain a true measure of whether the experimental designs were successful in reducing mortality rates km^{-1}, as well as the number of species that are affected.

Conclusion

Individuals from 33 species were recorded as being killed as a direct result of electric fencing infrastructure in South Africa. Electric fences may, in reality, kill individuals of more species, as smaller species may not have been detected due to sampling bias. The species lists presented offer a valuable reference for landowners wanting to erect electric fencing infrastructure as it alerts them to the possible species which may be negatively impacted upon.

The specifications of electric fences vary greatly between the study areas, making it very difficult to generalise about the true extent of their impacts in South Africa. However, this may not be too different from the real state of affairs in the country. Current electric fencing legislation is out-dated and the requirements and recommendations made to landowners vary greatly between provinces. Thus, there is a need for the development of legislation that governs the standards of electric fencing infrastructure on a national scale. The results presented here, in conjunction with the recommendations made in Chapter 3, could be used in developing future norms and standards around electric fencing in South Africa.

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