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The development and final testing of an electrified leopard proof game fence on the farm Masequa

by

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Abstract
The leopard is one of the few large predators that still found in reasonable numbers outside formal conservations areas and standard game fences cannot constrain their movements. The objective of the study was to assess if a specially designed electrified fence can contain a wild leopard. The study was conducted in the Soutpansberg area of South Africa. The fence was constructed using 17 smooth wire strands and electrified with nine 7.5 mm diameter wires. The first wire (trip wire) was positioned 500 mm from the fence at a height of 100 mm (4 000 - 4 700 V). The next five wires were positioned on short (225 mm) offset brackets at heights of 100, 300, 500, 700 and 1 400 mm and the next two on long (450 mm) offset brackets at heights of 1 700 and 2 000 mm, with the top electric wire at a height of 2 500 mm (average 6 000 V). A captured wild female leopard was released in the experimental enclosure and observed for six days from two observation hides and the fence inspected each morning for signs and marks of attempted escapes. The leopard tried to escape mainly by digging underneath the fence and the few attempts to jump the straining post failed. These attempts reached a peak on the fifth day, whereafter the leopard started to accept the fence. It was concluded that the electrified game fence was successful in constraining the wild leopard.

Key words: *Panthera pardus*, leopard, game fence, electrified, specifications

1. Introduction

The leopard is one of the largest and most efficient predators in South Africa and one of the few that can still be found in reasonable numbers outside formal conservations areas. Due to its status among farmers as a problem animal, leopards have always been hunted in farming areas. During the period 1937 to 1955 rewards were even paid in South Africa for the killing of a leopard. In the eight years since 1947 till 1955 more than 800 leopards were killed in South Africa. During 1974 the leopard was declared a protected species in the Cape Province. The protected status of the leopard did not safeguard it from prosecution by farmers who continue to suffer stock losses. As the conflict between livestock and game farmers and the leopard continues a considerable number of leopards are still killed annually, either legally as problem animals or illegally.

Several conservation areas were established in South Africa that benefited the leopard. Due to the inefficiency of standard game fences to constrain the movement of leopards their movement remained unrestricted. Previously developed leopard proof fences were very expensive, unpractical, and not well suited for mountainous areas (Jordaan, 1989). Due to this the leopard was, and still is, classified by the various conservation authorities as an uncontrollable animal. The leopard is thus excluded from ownership, unlike most other game species that can be effectively fenced in. The need for an effective, cost effective leopard proof fence existed for range owners that would either like to keep leopards inside their property or to keep them out of their property, mainly to protect their stock and game from predation.

The opportunity to develop such a fence arose during 1997, when Mr. Johan Holtzhauzen of the farm Masequa found four leopard cups after a vehicle had killed their mother. The cubs were hand-reared by Mr. Holtzhausen. Two of the cubs did not survive the trauma, but the other two cubs, both females, did survive.

During 1999, the Centre of Wildlife Management of the University of Pretoria initiated a research project on Masequa to develop a leopard proof electrified game fence. At the time little information was available on the successful containment of leopards in a confined area. They developed a fence that successfully contained the two hand-reared female leopards. However, during the development phase and after a storm that damaged the fence a wild male managed to enter the camp and mated with one of the females. During April 1999 the female gave birth to three cups that were hand-reared as well. The weaned cubs and the adult females are kept in separate camps fenced with the developed leopard proof fence (Smit, 2001).

Since the proposed research project by the Department of Animal, Wildlife and Grassland Sciences of the University of the Free State (Smit, 2001) requires the release of the leopards on the larger 1 000 ha of the farm Masequa it was important to test the effectiveness of the fence in constraining a wild leopard. This was also required by the Northern Province Department of Environmental Affairs as a prerequisite for issuing a permit for extending the research project. The testing of the fence with a wild leopard was deemed necessary because of the difference in the behaviour of wild leopards and the more docile hand-reared leopards.

The objective of the study was to determine if the current electrified leopard proof fence can contain a wild leopard, and if not, to evaluate the reasons for the failure and to make improvements to the fence based on the way in which the leopard managed to escape.

2. The leopard (*Panthera pardus*)

The leopard is the fourth largest of the seven large cats, which include tigers, lions, leopards, cougars, jaguars, cheetahs, and snow leopards. Its scientific name is *Panthera pardus* and forms part of the family Felidae and order Carnivora. Leopards are exceptionally strong, and the lithe cats are capable of climbing trees while carrying prey up to three times their own weight. Because of its powerful limbs, the leopard can easily leap forward more than 6 meters and upward more than 3 meters. The leopard can also descend trees headfirst (though it lacks the specially adapted ankles of the clouded leopard). Along with the jaguar, the leopard is considered the strongest of the wild cats. The leopard and jaguar are judged to be roughly 10 times stronger than a human athlete of the same weight is. By comparison, other wild cats are about five times stronger than an athlete of the same weight.

The lion, cheetah, and leopard were once widespread in southern Africa, but only the leopard has maintained ground in some parts of its once-wide range. The number of leopards in South Africa is unknown, but it is estimated that there may be fewer than 2 500. It is difficult to ascertain leopard numbers and it is unlikely that exact figures will ever be obtained, except in limited, closed areas. Although still widespread in Botswana, Zimbabwe, the bushveld areas of South Africa and in the southern and south-western Cape, they are mainly restricted to mountain ranges (Stuart, 1988). If it is important to preserve leopard populations large enough to be viable in the long term, the area needed would be very large because of the big home ranges of leopards. The concept of a leopard sanctuary is not new, and a sanctuary in the southern Cape was proposed a decade ago. The basic motivation for such a sanctuary is that there is conflict with stock farming in or next to the area (Norton & Greenblo, 1984). Thus, despite the leopard being more resilient than other carnivore species, there is concern regarding its future welfare.

2.1 Description and behaviour

The leopard has an elongated body set on relatively short and stocky legs. The paws are broad. Its ears are short and rounded. They have a very short and sleek coat. Their colour varies from light tawny to deep rusty yellow, with a lighter underside. They have dark spots on their face, head, throat, chest, and legs. The rest of their body is covered in "rosettes". Many people get the jaguar and leopard confused. The jaguar is more stocky, taller, and heavyset than the leopard (Alberton, 1998). Leopards can also be all black, a condition known as "melanism", which is common amongst the spotted cats. Black leopards (the so-called "black panthers") occur most frequently in humid forest habitats (Kingdon, 1977), but are merely a colour variation, not a subspecies. The leopard's dark rosettes help it to blend into the foliage while stalking their prey. Like human fingerprints, each individual leopard's spots are unique (Brakefield, 1993).

Pocock (1932) found the following trends in coloration for leopards in Africa:
1. Savannah leopards - rufous to ochraceous coloured.
2. Desert leopards - pale cream too yellow brown in colour, with those from cooler regions being greyer.
3. Rainforest leopards - dark, deep gold coloured.
4. High mountain leopards - even darker in colour than 3 above.

Variation in pelage has been the chief basis for the description of numerous subspecies of leopard, 24 in Sub-Saharan Africa alone (Smithers, 1975). However, Miththapala (1992), using molecular analysis and cranial measurements, concluded that Sub-Saharan African leopards showed too little difference to warrant subspecific division and proposed that the 10 sub-Saharan subspecies she examined should be subsumed into *P. p. pardus*, the name originally applied to the North African leopard.

Exceptionally large leopard males weighing over 91 kg have been reported from the Kruger National Park (Turnbull-Kemp, 1967), where average adult weights are otherwise 58 kg for males (n=3) and 37.5 kg for females (n=5; Bailey, 1993). Male leopards from the coastal mountains of South Africa’s Cape Province are much smaller, with an average weight of 31 kg (n=27) (Stuart, 1981). Norton (1984) suggested that this is because prey species are smaller in these mountains. In the rainforests of north-eastern Gabon, one adult female weighed 26 kg, and two males weighed 34 and 41 kg (Lahm, 2001). In the rainforest of the Ivory Coast Taï National Park, on the other hand, a male leopard was captured which weighed 56 kg (Jenny, 1993). The Somali leopard that is found in Somalia and Ethiopia is the smallest of all the leopards, weighing only 23-27 kg, with males 50% larger than females. The Arabian leopard is the second smallest leopard. The Amur and Javan leopards have unusual coat patterns, with darker fur and wider spaced rosettes (Estes, 1991).

Like all cats, the leopard has large canine teeth with which to deliver a killing or throttling bite. Large jaw muscles, attached high on the skull, provide for a powerful bite. The small front incisors are used to tear away fur and flesh from bones, while the large, pointed rear carnassials close upon each other like scissors to shear off pieces of meat which the leopard swallows without chewing. Equally important as the specialised teeth is the leopard's tongue. Like a common housecat, the leopard has a rough tongue covered with hook-shaped structures called papillae. However, whereas the housecat's tongue feels merely scratchy or rough, the big cat's tongue can literally peel off the fur and skin of its prey.

The paws of a leopard are soft and padded like most cats and have retractable claws. The soft pads allow the leopard to approach prey unnoticed, and then the claws help bring down the prey in the final rush. Like all cats the leopard is a digitigrade walker, only the toes and front portion of the back foot touch the ground.

Despite its relatively small body size, the leopard is still capable of taking large prey. Its skull is massive, giving ample room for attachment of powerful jaw muscles. Its whiskers are particularly long and there are often several extra-long hairs in the eyebrows, protecting the eyes and assisting movement through vegetation in darkness (Skinner & Smithers, 1990). Its scapula is adapted for the attachment of powerful muscles that raise the thorax, enhancing its ability to climb trees (Hopwood, 1947). Leopards can live independent of water for periods of time, obtaining moisture requirements from prey (Bothma & Le Riche, 1986). The known prey of the leopard ranges from dung beetles (Fey 1964) to adult male eland (Kingdon, 1977), which can reach 900 kg (Stuart & Stuart, 1992).

Bailey (1993) found that at least 92 prey species have been documented in the leopard's diet in sub-Saharan Africa. The flexibility of the diet is illustrated by the analysis of leopard scats (Hamilton, 1976) from Kenya's Tsavo West National Park, of which 35% contained rodents, 27% birds, 27% small antelopes, 12% large antelopes, 10% hyraxes and hares, and 18% arthropods. Seidensticker (1991) and Bailey (1993) reviewed literature and concluded that leopards generally focus their hunting activity on locally abundant medium-sized ungulate species in the 20-80 kg range, while opportunistically taking other prey. For example, analysis of leopard scats from a Kruger NP study area found that 67% contained ungulate remains, of which 60% were impala, the most abundant antelope, with adult weights of 40-60 kg. Small mammal remains were found most often in scats of sub-adult leopards, especially females (Bailey, 1993). Studies have found average intervals between ungulate kills to range from seven (Bailey, 1993) to 12-13 days (Hamilton 1986). Bailey (1993) estimated average daily consumption rates at 3.5 kg for adult males and 2.8 kg for females.

The leopard has an exceptional ability to adapt to changes in prey availability and has a very broad diet. Small prey is taken where large ungulates are less common. For example, Grobler & Wilson (1972) and Norton *et al.* (1986) analysed leopard scats taken from Zimbabwe's Matopos National Park and the mountains of south-western Cape and found rock hyraxes, common in the study areas, to be the most frequently taken prey. In the Central African rainforest, Jenny (1993) found the diet to consist mainly of duikers and small primates. Jenny (1993) notes also that some individual leopards have shown a strong preference for pangolins and porcupines. In his study area, the Ivory Coast's Tai National Park, a long-term study of chimpanzees determined leopard predation to be the major cause of chimp mortality (Boesch, 1991), but Jenny (1996) believed this may have been the work of a specialist chimpanzee-killing leopard.

In the interior areas of South Africa's Kalahari Gemsbok National Park, where springbok are less abundant, Bothma & Le Riche (1984) found that 80% of leopard kills located by tracking (n=30) weighed less than 20 kg; nevertheless, 37% of all kills consisted of ungulates. By using the tracking method, they found that male leopards killed every three days on average, and females with cubs every 1.5 days. At 3 900 m in the Kilimanjaro Mountains of Tanzania, Child (1965) reported the leopard's diet to consist mainly of rodents, while Fey (1964) describes how a leopard stranded on an island in the wake of Kariba Dam subsisted primarily on fish (*Tilapia*), even though impala and common duiker were present in low numbers.

The leopard shows several behavioural adaptations which permit it to compete successfully with other large predators, the first being its dietary flexibility. Bertram (1982) studied radio-collared lions and leopards in the same area in the northern Serengeti and found that, while their ranges overlapped, leopards preyed on a wider range of animals than did lions, and there was little overlap between their diets. Secondly, leopards often cache large kills in trees. Great strength is required and there have been several observations of leopards hauling carcasses of young giraffe, estimated to weigh up to 125 kg (2-3 times the weight of the leopard) up to 5.7 m into trees (Hamilton, 1976; Scheepers & Gilchrist, 1991). This behaviour is more common in areas where competing carnivores are numerous (Schaller, 1972; Bothma & Le Riche, 1984); where they are not, leopards may still drag the carcasses of large prey some hundreds of meters from the kill site into dense vegetation or a rock crevice (Smith, 1977). Leopards may also retreat up a tree in the face of direct aggression from other large carnivores. In addition, leopards have been seen to either kill or prey on small competitors, e.g. black-backed jackal (Estes, 1967), African wild cat (Mills, 1990) and the cubs of large competitors such as lions, cheetahs, hyenas and African wild dogs (Bertram, 1982).

Leopards have also been observed to ambush terrestrial prey by leaping down from tree branches, although this behaviour is apparently opportunistic and relatively uncommon (Kruuk & Turner, 1967); like other cats, they probably generally prefer to get their footing on the ground before launching the actual attack (Leyhausen, 1979). While the diet of rainforest leopards may include arboreal animals (40% of scats from Taï NP contained arboreal species, including seven species of primate: Hoppe-Dominik, 1984), they are unlikely to forage much in trees: radio-collared leopards in Taï have only been observed to attack monkeys when on the ground (Jenny 1996).

Leopards are generally most active between sunset and sunrise, when most prey are killed (Hamilton, 1976; Bailey, 1993). In the Kruger NP, Bailey (1993) found that male leopards and female leopards with cubs were relatively more active at night than solitary females. The highest rates of daytime activity were recorded for leopards using thorn thickets during the wet season, when impala also used them (Bailey, 1993). In tropical rainforest, Jenny (1996) reported that two radio-collared leopards (an adult male and female) have hunted only during the day, although they often travel at night.

Leopards have the best night vision and can easily spot and track a potential meal in nearly complete darkness. Excellent hearing and sense of smell also help locate prey under the cover of night. Among the large cats, the leopard is frequently considered to be the most intelligent and crafty. It hunts by stealth, silently approaching his prey as close as possible before dashing a few short yards to down the surprised victim. Leopards also are known to leap or drop from trees down onto an unsuspecting victim. When the leopard must chase down his meals, he can run at speeds up to 60 km/h for short periods. While this is far short of the speedy cheetah (approximately 100 km/h), where the two cats' territories overlap, they tend to prey on different species and thus occupy different niches within the same habitat.

When bringing down large animals such as antelope or gazelles, the leopard employs a throttling bite. Clamping his powerful jaws on either the throat or mouth, the prey is quickly suffocated. For smaller prey, the leopard will bite the nape, severing the spinal cord in the neck with the penetrating canines. These typical feline attacks are quite different and more precise than the mauling, swarming attack of dogs and other canines, which hunt in packs.

The climbing ability and great strength of the leopard make it a good bet that he will be able to finish a meal in peace if he has time to get the carcass to a tree. Capable of climbing while carrying three times its own weight, the leopard will often stash a carcass in the bowl of a tree. Leopards have been witnessed climbing trees with fully-grown male antelope and young giraffes in tow. This may be the most significant tactic to the survival success of the leopard since it allows him to feed for several days from a single kill. Other predators frequently lose much of their kill to scavengers and larger predators. When a leopard is unable to remove his kill to a tree for whatever reason, he will frequently feed on the richest portion (generally the meaty hindquarters) rapidly bolting his food down before abandoning his kill.

The leopard will make a meal of all sorts of wildlife, eating almost anything it can catch. Duiker, eland, gazelle, hares, impala, insects, monkeys, baboons, porcupines, rats, field mice, reptiles, rock hyrax, squirrels, warthogs, wildebeest and even porcupines are all meals for the stealthy leopard in its various ranges across the world. Where human settlement approaches the leopard's range, domestic livestock and house pets may also fall victim to the hungry leopard. Leopards have been known to eat fruit, but this is not really a viable food source for the carnivore.

Leopards have claws that are retractable, hooked, and very sharp. This enables them to climb trees almost effortlessly. However, these claws are also a deadly weapon. The sharp hooked claws can tear through their prey's flesh easily, and helps the leopard catch and hold their prey down. Because the claws are curved so much, a lot of debris and bacteria are caught underneath of them, so a scratch from a leopard can cause a severe infection and can be deadly. Leopards keep their claws sharp by clawing the bark of trees, which helps to shed the outer layer of the nail (Estes, 1991).

2.2 Social order

Though solitary, the leopard does communicate with members of his own species. Most frequently this is done through scent markings and roaring. Leopards mark the boundaries of their territories with urine, scratching, and rubbing. Chemical messages are contained in the urine sprayed on trees and rocks around their territory. Oils secreted from glands in the cheek ruffs and around the claws are left behind to tell other leopards to keep out. To the very keen nose of the leopard, these markings speak volumes. They carry information about the sex of the owner of a particular territory, and in the case of females, tell whether she is in oestrus. Very conspicuously, scent markings are placed at nose level to be noticed by other leopards.

Dominant leopards will mark their territories more frequently and are more vocal in patrolling their territories. Cats, including leopards, also have a special organ in the roof of the mouth called the Jacobson's organ. A male cat who detects the scent of a female in heat performs a distinctive action known as the flehmen response, wrinkling his nose, and opening his mouth to taste and smell the odour with his Jacobson's organ.

In the event of leopards meeting, confrontations are usually sounder than fury. Even a victorious fighter might be too injured to hunt and that is not a chance most leopards wish to take. A female leopard in oestrus will often attract multiple male suitors with an increased chance of conflicts. Though some pairs and trios of adult leopards have been observed to live and work together, these are the exception rather than the rule.

Leopards mate and then separate, leaving the female to raise her cubs alone. Females usually give birth to 1 to 3 cubs. Most cubs do not survive to maturity due to attacks by lions or hyenas, and scarcity of food. Cubs are born blind after a gestation period of 3 to 3.5 months. Their eyes open after about 10 days. During the first 2 months of their life, the cubs will remain hidden while the mother goes hunting. Cubs are weaned at 3 months. They will remain with the mother for 18 to 24 months, learning the hunting skills they will need to survive, before leaving to find their own home range. They will reach maturity at about 2.5 to 3 years. Because of the long rearing time of a litter, females usually only bear cubs every 2 years.

2.3 Biology

Reproductive Season: Probably year-round, but Bailey (1993) found a peak in leopard births during the birth season of impala, the main prey species.

Oestrus: Average 7 days.

Oestrus Cycle: Average 46 days (Sadleir, 1966).

Gestation: 96 (90-105) days (Hemmer, 1976).

Litter Size: 1.65 (range 1-4; n=59) (Eaton, 1977). According to time of first observation, when cubs may be several weeks old and some may have died - 2.13 (range 2-3; n=16) (Martin & de Meulenaer, 1988).

Cub Survival: First-year mortality estimated at 41% (Martin & de Meulenaer, 1988) to at least 50% annually (Bailey, 1993).

Sub-adult Survival: Average annual mortality of sub-adults (1.5-3.5 years old) was estimated in Kruger NP at 32%, nearly twice as high as adults, probably related to poorer hunting success. Females - 40%; males: 25% (Bailey, 1993).

Interbirth Interval: Average 15 months (Martin & de Meulenaer 1988; these data include some shorter periods after litters did not survive) to over 2 years (Schaller, 1972; Bailey, 1993).

Age at Independence: 13-18 months (Bailey, 1993; Skinner & Smithers, 1990). Siblings may remain together for several months before separating (Skinner & Smithers, 1990). Dispersal may be delayed in areas where prey is abundant, especially if resident leopards (Bailey, 1993) occupy adjacent habitat.

Age at First Reproduction: Females - 33 months (range 30-36: Weiss 1952), average 35 months (n=8: Martin & de Meulenaer, 1988); males - 2-3 years (Green, 1991).

Reproductive Rate: Bailey (1993) reported that the average proportion of adult females producing young each year in his Kruger NP study area was 28%, while noting that in some years no females gave birth, while in others up to half of the females produced young.

Sex Ratio of Resident Adults: 1 male: 1.8 females (Bailey, 1993; Hamilton, 1981).

Age at Last Reproduction: Average 8.5 years at one zoo (females: Eaton, 1977), but up to 19 years in both sexes (Shoemaker, 1993).

Adult Mortality: Average 19% annual mortality for adult leopards in Kruger National Park. Old males 30%; prime males 17%; old females 17%; prime females 10%. The proportion attributable to starvation was 64% (Bailey, 1993).

Longevity: Probably 10-15 years (Turnbull-Kemp, 1967, Martin & de Meulenaer, 1988); generally, 12-15 years, but up to 20 years (Shoemaker, 1993).

2.4 Habitat and distribution

The leopard lives in the forests, mountains, and grasslands in sub-Saharan Africa (Sahara Desert) and west of the Kalahari. They are in China, Asia, India, Iran, Pakistan, Indonesia, and Nepal. It is quite abundant, although they are hunted for their skins.

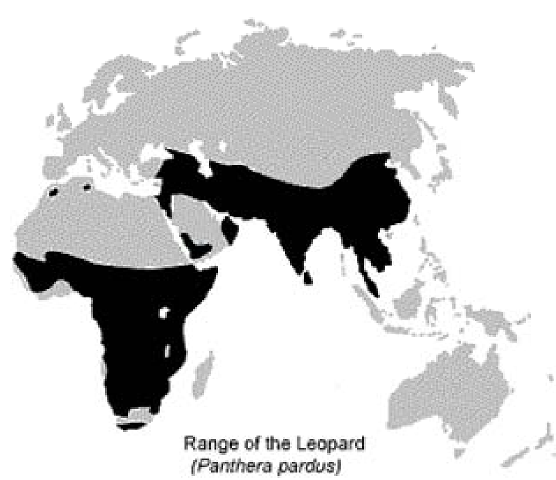

Figure 1. World distribution range of leopards *(Panthera pardus)*.

Leopards are the most adaptable of the big cats. Because of their solitary and secretive nature, most leopards go unnoticed, and so are not bothered. Even if humans encroach on a leopard's territory, it "retaliates" by changing its dietary habits to include the human's livestock or dogs. However, leopards are easy to hunt because they can easily be scared into the trees by dogs. Leopards also follow the same arboreal pathways, so if it is studied enough, it can easily be traced. Brush fires also adversely affect the leopard, taking away necessary cover in which to hunt (Estes, 1991).

Leopards occur in most of sub-Sahara Africa. They are found in all habitats with annual rainfall above 50 mm (Monod, 1965), and can penetrate areas with less than this amount of rainfall along river courses: e.g., leopards are found along the Orange River in the Richtersveld National Park (South Africa), which lies at the southernmost extension of the Namib Desert (Stuart & Stuart, 1989). Of all the African cats, the leopard is the only species which occupies both rainforest and arid desert habitats. Leopards range exceptionally up to 5 700 m, where a carcass was discovered on the rim of Mt Kilimanjaro’s Kibo Crater in 1926 (Guggisberg, 1975). They are abundant on the highest slopes of the Ruwenzori and Virunga volcanoes, and have been observed to drink thermal water (37°C) in Zaire’s Virunga National Park (Verschuren, 1993).

The leopard appears to be very successful at adapting to alter natural habitat and settled environments in the absence of intense persecution. There are many records of their presence near major cities (Turnbull-Kemp, 1967; Guggisberg, 1975; Tello, 1986; Martin & de Meulenaer, 1988). Hamilton (1986) reported their presence in western Kenya in extensively cultivated districts with more than 150 persons/km^2, the largest livestock populations in the country, little natural habitat, and prey, and where 20 years ago they had been considered extirpated. However, leopards appear to have become rare throughout much of West Africa (Martin & de Meulenaer, 1988). According to Myers (1976), leopards have completely disappeared from most of the Western Sahel.

The leopard currently has the largest distribution of all wild cats, ranging through most of sub-Saharan Africa, parts of the Middle East, and much of southern Asia.

The leopard is the most adaptable of the large cats, capable of bringing down a wider variety of prey. Because of this, the leopard is found in open savannas, forests jungles, cold mountainous regions, and even on the outskirts of urban areas. These different habitats present a variety of challenges for the leopard.

2.5 Population status

Status: endangered. Before the twentieth century, the range of the leopard was much more extensive. Western and northern Africa, the non-desert regions of the Middle East, and even more of Asia were home to the leopard. Although the leopards appears tolerant of habitat modification and occurs in the vicinity of settled areas, density is certainly reduced when compared to occurrence in natural habitat, perhaps as low as 1/10 or even 1/100 (Martin & de Meulenaer, 1988), and the leopards become more vulnerable to exploitation and population fragmentation.

Statistics are:
Panthera pardus pardus - African Leopard - 500 000 in the wild
Panthera pardus nimr - middle eastern - Nearly extinct
Panthera pardus jarvisi - middle eastern - Nearly extinct
Panthera pardus saxicolor - Persian leopard - Nearly extinct
Panthera pardus orientalis - Amur Leopard (also called Korean or Manchurian Leopard) - Critically endangered, an estimated 30 to 50 remaining in the wild.
Panthera pardus japonensis - Northern Chinese Leopard - Endangered: 2 500 in the wild, 100 in captivity.

The fur trade was a major threat to the leopard in some areas during the 1960s and 1970s, before the market collapse due to the changing public opinion and the imposition of international trade controls under CITES. There was a peak in 1944 in Uganda alone where 2 344 permits for skins were sold. Hamilton (1981) reported that poaching for fur trade substantially reduced the leopard population in Kenya and considers the species to be particularly vulnerable to baited trapping, as leopards patrol small home ranges along regularly used trails.

The use of poisoned bait is also an important threat (Myers, 1976). Martin & de Meulenaer (1988) simulated the effects of high harvests on leopards in East Africa during this period (they estimated 30 000 leopards killed between 1968-69) and concurred with Hamilton (1981) that hunting had severally depressed populations there. However, their model also indicated that even very high off takes, of the order of 61 000 animals a year, had produced only a slight decline in the total Sub-Saharan population. They consider the leopard to be generally resilient to harvest up to a critical threshold, which varies with density.

2.6 Evolutionary History

Not surprisingly, the closest relative of the leopard is the very similar-looking jaguar. Palaeontologists believe the ancestor of the modern leopard and jaguar crossed the Siberian-Alaskan Ice Bridge about 100 000 years ago. After the connection between the two continents was gone, the isolated groups began the slow evolutionary divergence. Leopards and other modern cats are not descended from the sabre tooth "tigers".

3. Game fences

3.1 Normal game fences

The construction of game fences is always influence by the type of game, the nature of the terrain, the type and availability of material and the financial cost. There is no ideal construction of a game fence, but there are some guidelines that can help a game rancher. The situation must be evaluated first, and the nature conservation authorities must be consulted for the minimum requirements of game fences.

The height of a game fence will depend on the game species that need to be fenced in. Game can, according to their behaviour, escape by jumping over the fence, crawling under it, or running through it. According to this game can be divided into five categories namely: fence jumpers (kudu, eland), fence crawlers (oryx, sable antelope, nyala), fence breakers (buffalo, rhinoceros), non-jumpers (springbok, blesbok) and species that move freely through fences (warthog, predators). Fence heights of approximately 2.25 to 2.4 m are necessary for game that jumps fences. This fence must consist out of 17 or 21 wires. In areas where there are animals that dig holes underneath the fences, like warthogs, a farmer can gain an advantage by constructing diamond mesh or jackal-proof wire at the base of the fence. It can also prevent the presence of unwanted species, like some but not all predators.

Straining posts are used as anchors for the fence and they must be strong enough not to bent or break. They must resist the weight of the fence. The distance between straining posts depend on the terrain and will vary from plains to mountainous areas. On the plains they can be 300 to 500 m apart. In mountains this distance may vary from 50 to 300 m. Straining posts must be anchored in the ground.

Droppers (100-125 mm in diameter) are another essential for fences and divide the distance between straining posts in equal lengths. The boundary fence is then fastened to every dropper. The distance between droppers vary from 25 to 50 m and this ensures elasticity. Droppers (60 mm diameter) are used to divide the distance between two droppers and strengthen the fence. The distance between these droppers may vary between 1 to 3 m.

Different types of wire may be used and there are certain recommendations for different climatic conditions. Smooth wire is not so expensive as barbed wire and is easy to work with. However, smooth wire is used to make snares, while barbed wire is more visible for the game and cannot be used for snares (Bothma, 1995).

When a fence is electrified it is usually for elephants, hippopotamus, baboons, and predators. When an electrical fence is constructed the area of the farm and the type of animal that wants to be contained is important. A strong amplifier is necessary. The greater the fright the animal gets when it is shocked the quicker it learns. The number of amplifiers depends on the distance of the fence as well as the number of wires. The amplifier must be strong enough to supply 4 000 V at any part of the fence. The amplifier must be underneath a roof. The wire that is used with an electrified fence must be approximate 2.24 mm in diameter to carry the electricity. Isolators that are used on a game ranch must be fire resistant and made from porcelain or fibreglass. It is important to have a digital voltmeter near to test the electricity on the wires.

3.2 Development of an electrified leopard proof fence

There is little information available on the successful containment of a leopard in a restricted area. The current fencing requirements for keeping predators are used for both lions and leopards. This fence can effectively contain lions but is not so effective for leopards (Orban, 2000). There are high costs involved in erecting a fence according to these specifications and the need for a more cost-effective fence existed for farmers to keep leopards in or out.

The provincial fencing requirements described in the ordinance of the Limpopo Province have not changed since its conception in 1983. The fencing specifications require that the camp must have a double fence, where the first fence is 1.8 m high and 0.3 m anchored in the ground. There must be 7 wires with a spacing of 0.3 m in between. The outside fence must be 3.5 m high and consist of 8 wires that are spaced 0.5 m between each other. There must be a 0.6 m overhang on each side of this fence as well. It is necessary that both fences are covered with diamond mesh or chain mail constructed fencing material (Van Schalkwyk, 1994).

Most existing game fences have a height of either 1.8 m or 2.4 m. Such a fence can be constructed from smooth wire, Bonnox, Veldspan or a combination. Standard game fences cannot constrain predators. By using the currently accepted game fence construction and specifications on electrification for keeping lions, an attempt was made by the Centre of Wildlife Management of the University of Pretoria to find a more cost-efficient alternative through slight modification (Orban, 2000).

A project was initiated by the Centre of Wildlife Management of the University of Pretoria in 1999 with two domesticated female leopards to test different fencing constraints to determine its effectiveness in keeping the leopards within an enclosure.

A relatively small camp fenced using a 17 smooth wire strand construction and initially electrified according to specifications for keeping lions, was erected within the larger camp, fenced according to the current specifications for keeping predators in captivity. This fence had nine wires: one electric wire on top of the game fence; one electric wire (trip wire) 130 mm from the ground and 500 mm from the fence. Five electric wires on short (225 mm) offset brackets at 200, 400, 600, 800 and 1 400 mm from the ground. The top wires were placed on long (450 mm) offset brackets at a height of 1 800 mm and 2 100 mm from the ground, respectively. The top electric wire was at a height of 2 500 mm. In addition to the electric fence specifications for the larger camp, it was necessary to secure the gate and posts using electrical windings. This was considered necessary as the two leopards used in the research initially escaped from the larger camp by climbing the straining posts. This was considered a weakness in the design and was rectified (Orban, 2000).

After several weeks of evaluation and following several modifications to the placement of electrical wires and with an increase in the power supply to 6 500 V, the leopards was successfully contained (Orban, 2000). This study was conducted during 1999.

3.3 Expenses in constructing an electrified leopard proof fence

The expenses in constructing electrified game fences are high and it is important that the right material is used. In Table 1 the prices for the constructing of an electrified leopard proof fence as described by Orban (2000) are shown. When an existing game fence is electrified for the containment of leopards the following material will be needed: Five short offset brackets with plastic isolators and two long offset brackets per 20 m, energiser, battery, float charger, free standing shock box, steel wire (9 strands), high-tension cable and a digital voltmeter.

When buying an energiser, it is better to buy the 1.25 Super. This energiser has a backup battery for use during power failures. One energiser is known as a station and can supply 6 000 V up to 9 000 V to a fence with nine electrical wires and 21 smooth wires for 8 km; it uses a 100-hour ampere battery; meaning it can supply power of one ampere for a hundred hours to the fence when there is a power failure. The float charger keeps the battery on full charge and protects it from overcharging. The high-tension cable transfers the power from the shock box to the fence and back. For every station that is erected there must be a lightning conductor. This is important otherwise lightning can destroy the shock box and the energiser.

Table 1 Estimated cost of the leopard proof electrification of an existing game fence.

Description of material	Unit cost (R)	R / km	R for 8 km
Short offset brackets (5 wires)	5.35/20 m	267.50	2 140.00
Long offset brackets (2 wires)	2.28/20 m	114.00	912.00
Energiser (1.25 Super):			2 185.38
Installation			350.00
Float Charger			424.15
Installation			40.00
Free-standing Shockbox			561.43
Installation			180.00
Battery (100h amp)			1 105.62
Installation			60.00
Steel wire (9 strands)	0.16/ m	1 440	11 520.00
Installation		300	2 400.00
High-tension cable (100m/8 km)	2.50/ m		250.00
Installation			80.00
Lightning-conductor			51.30
Installation			80.00
Digital voltmeter			689.47
TOTAL			**R 23 029.35**
Average cost per km - R 2 878.67			

A digital voltmeter is important to measure the power on the wires at any place and time. This can help to detect a problem of low volts on the wires.

The prices of the material in Table 1 are from MEPS suppliers as on October 2001[1].

The installation fees are according to Johnthon Electric's at Louis Trichardt.

[1] Editor's Note: The prices for material have not been updated to current values.

4. Testing the electrified game fence with a wild leopard

4.1 Procedure

4.1.1 Study area

The study was conducted on the farm, Masequa, located in the Soutpansberg area approximately 30 km north of Louis Trichardt in the Northern Province of South Africa. The farm lies between 22°21'36'' and 22°52'48'' south and 29°53'19'' and 29°56'28'' east at an elevation between 760 and 1 210 m above sea level. The geology of the area is mainly sandstone and conglomerates of the Wylliespoort formation (Soutpansberg group). The soil varies from sandy-loam soils to shallow rocky outcrops on dry, hot, northern slopes.

The savanna vegetation is described as Soutpansberg Arid Mountain Bushveld (Low & Rebello, 1998). The tree layer is diverse with *Vachellia tortilis* and *Senegalia nigrescens* being prominent, as well as broad-leaf species like *Combretum*, *Commiphora* and *Grewia* species. The *V. tortilis* and *S. nigrescens* trees are dominant on the lower slopes and the broad-leaved species on the higher ground. The most important grass species are *Aristida spp*., *Cenchrus ciliaris*, *Digitaria eriantha* and *Panicum maximum.* The area represents prime leopard habitat and free roaming leopards still occur in the area.

The rainy season usually extends from October to March, inclusive, but rainfall is irregularly distributed and unpredictable. The average rainfall is 748 mm per year. The average summer temperature is 31.6°C, but can reach up to 42°C. The area experience moderate winter temperatures with an average minimum of 7.9°C.

The farm was mainly used for cattle farming since 1906 but did not have any inside camps. Sometime in the past a small area in the lower lying areas was used for the cultivation of certain crops. Game roams the farm freely and the farm is known for its big kudu bulls.

4.1.2 Description of the fence used in the current study

The electrified leopard proof fence was constructed around an area of 2.2 ha. This enclosure was constructed inside a bigger camp of about 25 ha, which was electrified as well and with diamond mesh at the bottom instead of smooth wire. Two types of droppers were used in the construction of the inner fence, one 12 mm thick and 2.4 m long and the other was 3 m long Y-type pole. The construction of the fence differed between the north and east side. The main droppers on the northern side were 30 m apart, while on the eastern side it did not have main droppers but consisted of straining posts that were 135 m apart.

The game fence of the inner (experimental) enclosure consisted of 21 smooth wires (2.2 mm diameter) and was 2.5 m high (Figure 1). The first wire was 70 mm from the ground and the second one 140 mm. The next ten wires were spaced 100 mm apart. Wires thirteen to eighteen were 150 mm apart and the last two wires were 200 mm apart. The twenty-first wire was an electrified wire and was 100 mm from the last non-electrified wire.

The experimental fence was equipped with nine electric wires (7.5 mm diameter), positioned slightly differently from the original configuration described by (Orban, 2000) (Figure 2). The most important difference was the slightly lower positioning of the electric wires, based on the observation that the most likely method of escape of a leopard is by crawling underneath the fence. The first wire (trip wire) was positioned 500 mm away from the game fence at an average height of 100 mm above the ground (allowed range: 75 - 130 mm). This wire carried an electrical current of 4 000 – 4 700 V. The next five wires were positioned on the game fence on short (225 mm) offset brackets at 100, 300, 500, 700 and 1 400 mm above ground level. The next two wires were placed on long (450 mm) offset brackets at a height of 1 700 mm and 2 000 mm above ground level, respectively. The top electric wire was at a height of 2 500 mm

(Figure 2). The wires carried an average electrical current of 6 000 V (effective range: 3 000 - 9 900 V).

To address the potential weakness of the electric fence at the straining posts and in the corners, offspring wires was attached to each electric wire on each straining post. Such an offspring wire should not be closer than 200 mm or further than 250 mm from the post (Figure 3). An offspring wire was also attached to the top electric wire on top of each straining post (Figure 3). A backup battery (sealed dry sell) with the capacity to maintain the required electrical current for at least 14 hours in case of a power failure was used.

Figure 1 Electrified game fence with 21 smooth wires and nine electric wires used in the experiment.

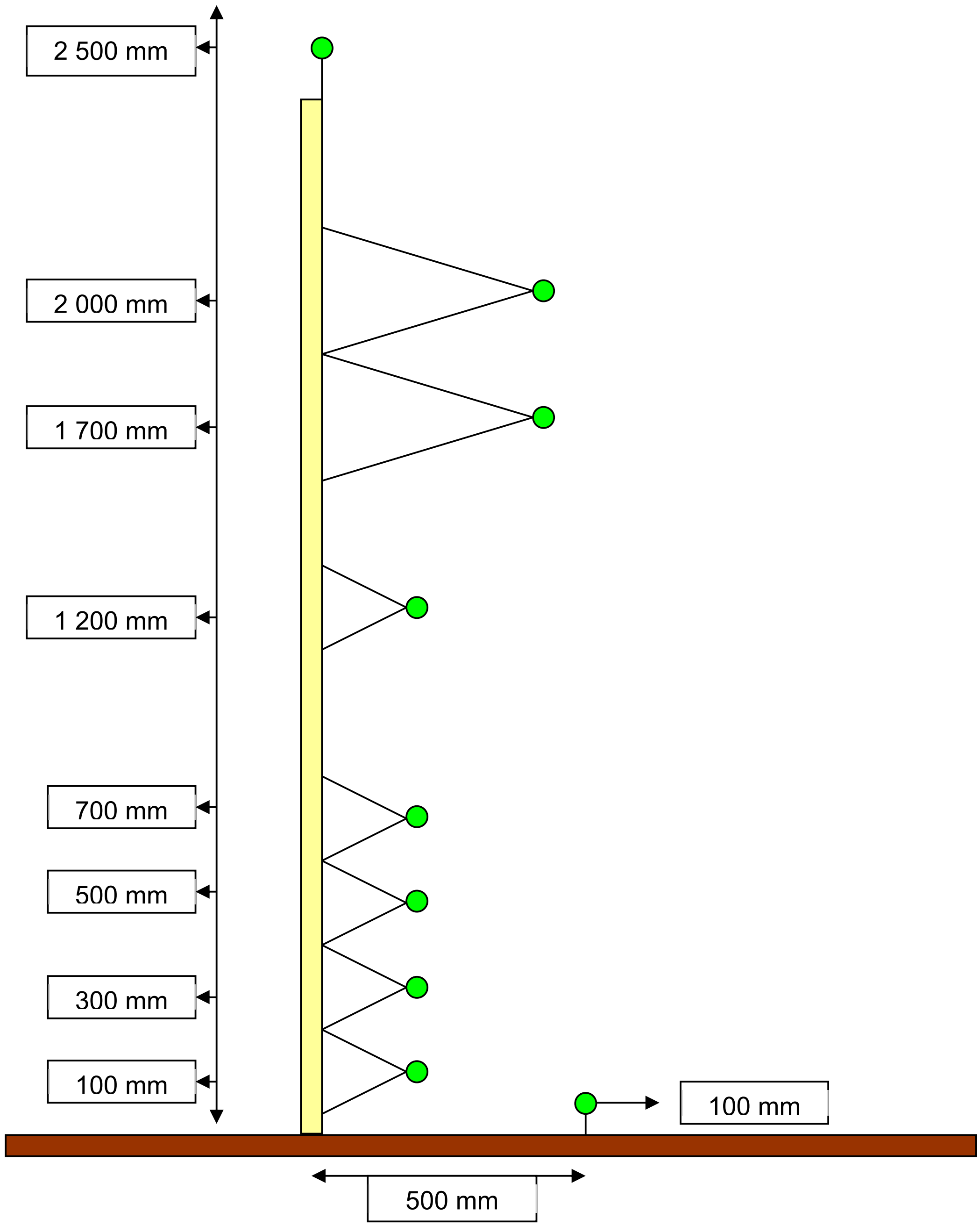

Figure 2 Schematic illustration of the electrified fence, indicating the positioning of the electric wires on the game fence.

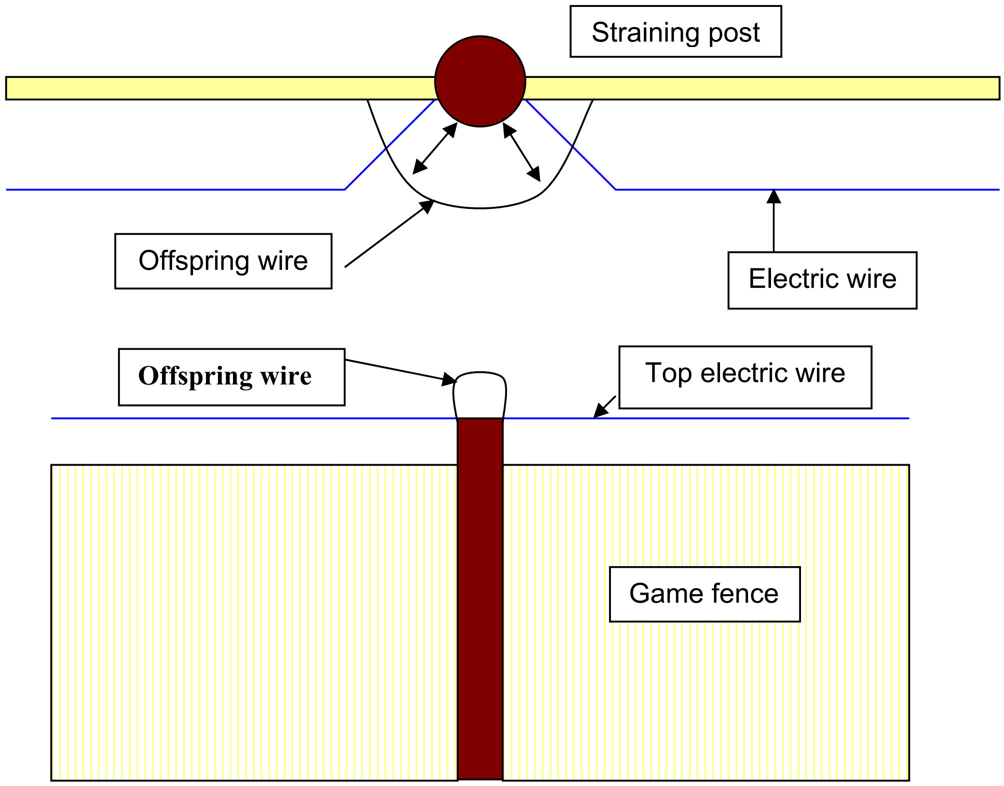

Figure 3 Positioning of the offspring wires at each straining post (offspring wire should not be closer than 200 mm or further than 250 mm from the post).

4.1.3 Description of the wild leopard

The Limpopo Province Department of Environmental Affairs provided a wild leopard from their problem animal control programme. A female leopard was captured on 20 May 2001 in the Phalaborwa district. It was assumed that she did not have any prior experience with this type of electrified fence. While final preparations were made with the experimental fence, she was kept in a cage from 20-28 May at De Wildt. During her time in the cage she was in close contact with humans. She was a relatively old female because she only had one canine and the hair behind her ear had already been worn of. She was fed on the morning of 28 May. Officials of the Department darted her with Zoletil 100 (5 mg/kg) to be transported to Masequa. The leopard was released in the experimental enclosure at 14h30 that afternoon. At the time of release, she was still tranquillised. A holding pen was placed inside the enclosure for the recapture of the leopard when the study was completed, and a lump of meat was placed inside the holding pen. The leopard was observed for six days from 28 May until 2 June 2001.

4.1.4 Observations

At the north-eastern corner of the experimental enclosure an observation hide was constructed as well as on the south-western corner. The hides were covered by shade netting (Figure 4). Blankets were attached to the inside of the hides, which concealed the movement of the observers to the leopard. Observations by two observers were made from the hides from 06h30 until 11h00 and again from 15h00 until 18h00. The fence was inspected each morning and any signs and marks of attempted escapes were recorded.

Data recorded included (i) the nature of the attempts, (ii) frequency of attempts, (iii) the relationship between the attempts and the time spend in the enclosure, (iv) the success of the attempts, and (v) whether or not the leopard managed to escape. These observations were supplemented with visual observations of any other behaviour.

Figure 4 A hide on the north-eastern corner of the enclosure, before the blanket covering was fastened on the inside.

4.2 Results

Day 1:
The leopard arrived on 28 May on the farm Masequa but was drugged and sleeping. She was released in the enclosure at 14h30, still sleeping and in the cage in which that she was transported. Observations were made from 14h30 till dark. The leopard was not seen.

Day 2:
The power bracket was off from approximate 05h00 until 06h00 but the batteries that are used in case of a power failure went on. Observations of other animals near and around the enclosure were also made. At 06h55 one of the hand-reared leopards roar and at 07h35 there was a bird alarm for about 2 minutes inside the enclosure. At 08h00 baboons alarmed in the mountain and at 08h25 and 09h37 there were bird alarms outside the enclosure. There was another bird alarm inside the enclosure, while we were walking around the fence at 15h00. At 17h17 there was another bird alarm outside the camp.

The following three observations were made while walking around the enclosure to look for any marks of escaping or attempts of escaping:

- The first attempt was at the south-eastern straining post. Two of the offspring wires that were around the post to prevent the leopard from climbing over at the straining

post, where pushed apart. It looked as if the leopard jumped against the fence pushing the wires apart.
- The other two attempts were drag marks on the ground underneath the first electrical wire.

<u>Day 3</u>:
It was decided not to go to the hides. The wind blew and the leopard would certainly smell us. It was hoped that by staying away she would calm down and maybe investigate the fence or try to escape.

<u>Day 4</u>:
At 07h10 guinea fowls signal an alarm outside the enclosure. At 07h54 there was a bird alarm and they flew out. The following observations were made at 11h00 when walking round the enclosure:
- Several footprints were observed near the waterhole. We could distinguish between old footprints of day 3 and fresh footprints of the previous night.
- There was one other footprint mark near the east fence.
- Scratch marks on a tree about 6 m from the east fence.
- Feeding marks were visible on the meat that was placed in the holding pen.
- Another attempt was observed at the gate of the enclosure. The gate was closed with strings of wire and they were extended to their maximum length as it was suspected that the leopard must have pushed against the gate.

<u>Day 5</u>:
At 07h25 there was a bird alarm in the enclosure and again at 07h30 for about 3 minutes. The next observations were made:
- The first visual observation of the leopard was at 07h13. It moved out of the bush and touches the trip wire with its front leg. The leopard moved forward placed both front legs over the trip wire and peer through the game fence. The leopard then placed one of her hind legs over the trip wire walked for a few steps like this and disappears back into the bush.
- At 07h16 she reappeared, sat 3 m from the fence and stared at it. She then walked west a few steps and stared at the fence. The leopard walked by the south-western hide and disappears in the bush at 07h:22.
- At 8: 56 the leopard again walked out of the bush towards the fence. She bends down and peeked through the fence, walked east and into the bush again.
- At 09h00 she appeared for the last time at the south- eastern corner. She stared at the fence, again walked a few steps, stare again at the fence and the walked into the bush at 09h02.
- Three digging marks at the eastern side of the fence were observed. They were about 25 cm from the trip wire.
- Three other separate footprints were found near the fence.
- New feeding marks on the meat in the holding pen and the meat were moved again.

<u>Day 6</u>:
Two more digging marks were found when the observations around the fence were made.

The leopard was caught on day eight in the holding pen in the enclosure. The Limpopo Province Department of Environmental Affairs released the female leopard elsewhere.

All the attempts to escape were plotted (Figures 5 and 6). The results show that the leopard tried to escape mainly by digging underneath the fence. These attempts reached a peak on day 5 and are lower again on day 6 (Figure 5). All the different attempts of escape during the observation period are illustrated in Figure 6. Other attempts included scratch marks on a tree, moved gate and the electrical wires of a straining post that was pushed apart.

4.3 Discussion

The leopard initially remained in hiding after her release (Figure 6). As she became more acquainted with her new surroundings there were a build-up of attempts to escape (Figure 5), which reached a peak on the fifth day.

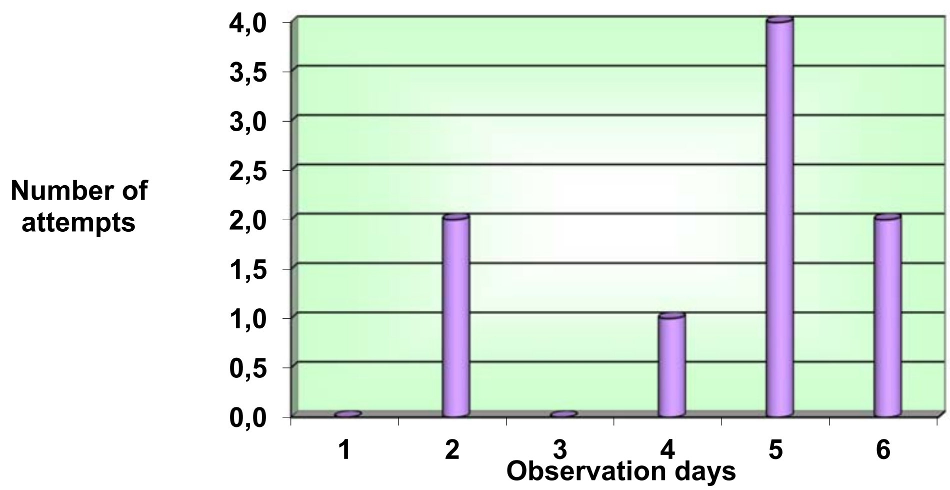

Figure 5 **Number of attempts to escape by digging underneath the fence.**

It can be concluded that after the fifth day the leopard started to accept the fence and realise that she could not escape. The few attempts to jump the straining post failed and the electrical wires surrounding the post constrained her successfully (Figure 6). Attempts to dig underneath the fence was the most frequent (Figure 6) and the leopard probable had some experience digging underneath fences.

The purpose of the meat that was placed inside the cage used for her transport was mainly to see whether the leopard was still in the enclosure. The leopard was apparently not afraid of the cage, because she went inside to eat daily.

The few visual observation of the leopard did not come as a surprise since the leopard is nocturnal. Based on the few visual observations of her behaviour she was investigating the fence thoroughly for any opening. It seemed that she was looking for a place where the wires were not so close to each other or a place where the electrical wires where high from the ground.

In conclusion of the study it can be said the developed electrified game fence was successful in constraining the hand-reared leopards as well as a wild leopard.

5. Acknowledgements

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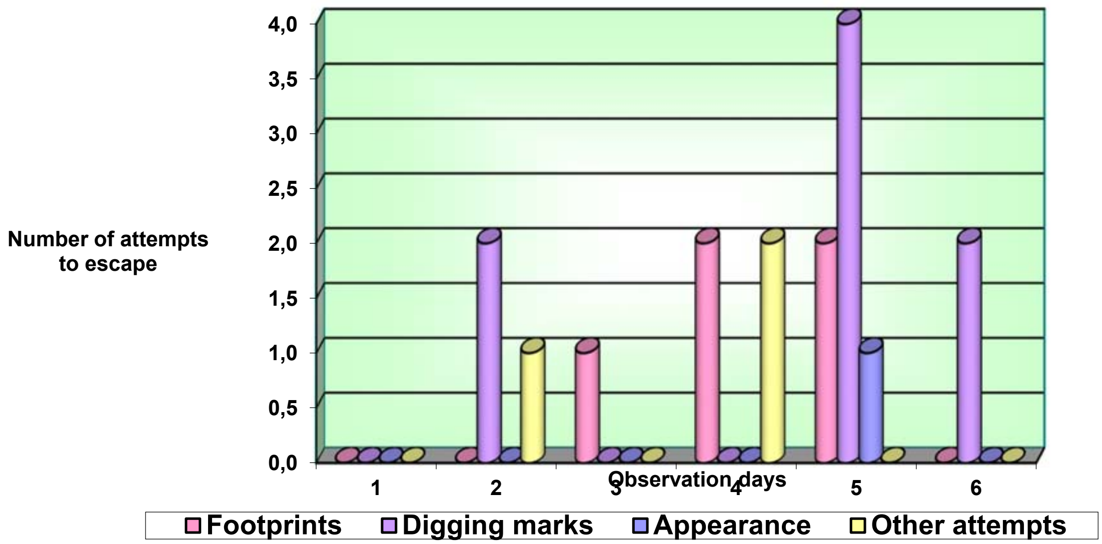

Figure 6 **The different attempts of escaping from the enclosure during captivity**

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