The landscape ecology of leopards (*Panthera pardus*) in northern KwaZulu-Natal, South Africa: A preliminary project report.

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Introduction.

The leopard (*Panthera pardus*) is one of the most widely distributed large cats in the world, with a range that includes much of Africa and Asia as well as relict populations scattered through the Middle East and south-eastern Europe. As a result of their wide geographic range, leopards are often assumed to warrant low conservation priority. Indeed, at the species level, the leopard is classified on the IUCN Red List as "Least Concern," and conservation evaluations at the sub-species and population level were last made in 1996 (Nowell, 2002). While the leopard is certainly resistant to human pressure, it is the most persecuted large felid species in the world. Trophy hunting is legal in many countries based on very limited data and destruction of leopards by farmers, pastoralists and illegal hunters ('poachers') is extremely widespread.

The assumption that leopards are 'safe' may be unwarranted in many regions. The species is elusive, solitary and largely nocturnal which makes empirical data collection difficult and their conservation status is often assumed on the basis that they are able to persist where other large cats such as lions and cheetahs cannot. However, on its own, the presence of leopards in an area does not necessarily mean that a viable population occurs.

Despite numerous studies on the ecology and behaviour of leopards, the species has never been comprehensively researched under differing levels of human persecution. Accordingly, and as a result of increasing hunting of leopards in adjacent areas, we initiated a study of the landscape ecology of leopards in and around Phinda. Leopards are fully protected in Phinda (and nearby conservation areas such as Mkuze Game Reserve) but are heavily persecuted once they move onto privately-owned game and livestock farms which abut Phinda's boundaries. Increasing persecution of leopards outside Phinda and other reserves in the region since 1997 has raised concerns that:

1. protected areas are providing a source population for hunting in adjacent areas,
2. properties engaging in hunting are drawing entirely on 'overflow' from protected populations rather than fostering populations on those properties, and
3. levels of persecution *outside* protected areas may be so high that protected populations are unable to increase and may be diminishing.

This is the first study of leopards comparing a protected population adjacent to regions where the species is heavily persecuted, and will be the first examination of leopard ecology under such widely divergent land-uses. This is also the first comprehensive study of the species in KwaZulu-Natal.

The project is the chief scientific initiative of the Munywana Leopard Conservancy, an agreement between local stake-holders in the region that aims to establish a unified accord on consumptive and non-consumptive use of leopards in the region. As well as Phinda, the following properties are currently signatories to the Conservancy agreement: Bumbeni Game Ranch, Kube-Yini Game Reserve, Pumalanga Game Reserve, Zuka Ranch and Zulu Nyala Game Reserve. Additionally, the project is endorsed by the KZN Wildlife Conservation Service and the Natal Game Ranchers Association.

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As the research has been very recently initiated, we have only preliminary data and this paper is intended as an introductory report on the project. Subsequent issues of the Ecological Journal will contain more detailed papers as comprehensive data is collected and analysed.

Objectives:
The specific aims of the study are:

1. to determine the population status of the leopard in northern KwaZulu-Natal,
2. to determine ranging patterns and habitat use by leopards across land-types which are extremely variable with respect to their human uses,
3. to assess the mortality rate and the factors contributing to mortality of leopards occupying different land-types, comparing protected populations with hunted populations,
4. to establish the reproductive parameters (especially the number of surviving cubs) in protected and persecuted populations,
5. to investigate the genetic characteristics of the population, particularly the relatedness among individuals,
6. to investigate the feeding ecology of leopards in the region,
7. to establish a management plan for leopards for KwaZulu-Natal which ensures viable populations of the species are protected in the province while also permitting regulated utilisation by landowners.

To investigate these questions, we began capturing leopards in April 2002 to fit with radio-collars.

Methods.
Leopards are caught by two methods; i) free-darting over a bait or kill, and ii) using baited cage-traps with a drop-door mechanism.

To date, free-darting has proved the more successful method but is very labour-intensive. Most of the leopards in Phinda and surrounding properties are not well habituated to vehicles and are extremely wary when approaching baits. Even when successfully 'anchored' to a bait, they often respond instantly to any noise or activity; one adult female dodged the dart in reaction to the discharge of the dart-gun, a response measured at around 0.25 of a second. Cage-trapping requires less effort but leopards are similarly wary about entering them and it may take many nights of trapping to succeed. To date, only a sub-adult female and an emaciated male have been caught in traps.

All animals are immobilised using a tiletamine-zolazepam combination at 3-5mg/kg and fitted with sub-cutaneous passive identification transponders and VHF radio-collars. Radio-collars were chosen over implantable transmitters as implants suffer from very significant signal loss which makes regular locations impossible in wide-ranging mammals (Hunter & Skinner, 1997). Additionally, until sub-cutaneous units become available, implantation typically takes place in the intraperitoneal cavity, a procedure which entails more risk for the animal than is currently justified by the inadequate results (Hunter & Skinner, 1997).

For each captured animal, we take a variety of physical measurements (weight, total length, shoulder height, neck circumference, etc), identification photographs and tissue samples for genetic analysis. Once handling is complete, each animal is moved into cover and monitored closely until full recovery has taken place. They are left with the bait but otherwise provisioning does not occur.

Each radio-collared animal is located at least once daily and the position is recorded using a hand-held GPS receiver where a close approach is possible. If access is impossible due to thick vegetation or an animal's wariness, position is determined by radio-triangulation and plotted on a 100m x 100m grid map. When animals are observable, a wide variety of

ecological and behavioural data is noted including information on hunting attempts, kills, mating, territorial activity and so on.

Results.
To date, eleven leopards have been captured; summary details are included in Table 1.

Animal	Sex	Capture method	Age (years)	Weight (kgs)
M1	male	free-darting	6-7	59
F2	female	free-darting	4.5	37
M3	male	free-darting	10-11	79
M4	male	free-darting	13 mo	36
M5	male	free-darting	3-4	60
F6	female	free-darting	3-4	37
M7	male	cage-trap	2	26*
F8	female	free-darting	14-16 mo	27
F9	female	free-darting	3-4	32
F10	female	cage-trap	14-16 mo	24.5
F11	female	free-darting	6	N/A

*emaciated at capture.

Table 1: Leopards captured April 2002- March 2003.

At present, eight of the above animals are radio-collared (F2, M5, F6, M7, F8, F9, F10, F11). The individuals M1 and M4 are both dead. M1 was killed in a territorial fight and the sub-adult M4 was injured by another large carnivore and later died of his wounds. M3 was fitted with a collar which he promptly removed; he is a very large male with a neck circumference 4cm larger than his head circumference at the widest point, making it virtually impossible to keep a radio-collar on him. All animals have been caught on Phinda except the young male M7 which was caught on a neighbouring property, Mziki Pumalanga.

Discussion
It is too early in the project to draw any meaningful conclusions about the population so instead we've presented a brief profile of each study animal below. For each, their project identification number (such as M1, F2 etc) is accompanied by their Phinda name which is derived from the uppermost line of whisker spots (right cheek/left cheek).

M1 (6:2)
The first project animal, caught in April 2002. He removed his collar two days later and was captured again in October 2002. On this occasion, when his recovery was essentially complete, another male M3 arrived at the capture site (a kill made by M1) and attacked him. Both animals were darted and M1 underwent surgery for severe lacerations to the neck. M3 was collared at this time but removed it the following day. M1 spent a month in captivity at Phinda to convalesce before escaping back into the reserve proper. Despite a pronounced limp on his front left leg, he did not seem significantly disadvantaged. He returned to his territory without incident, was clearly foraging successfully and was seen mating with at least 3 different females between November 2002 and December 2002. In January 2003, he was killed by another male, most likely M5.

F2 (4:3).
Caught in April, 2002. At the time, she had two dependent cubs (M4 and an unidentified female, but see F8 and F10 below) aged approximately 6-7 months. This female is relaxed with vehicles and provides regular viewing. As of December 2002, she has become increasingly elusive, perhaps as a result of pregnancy; her last recorded mating was in early

November 2002. At the time of writing, her movements have become very localised and we suspect she has given birth. Her putative birth site is inaccessible so it may be some weeks before we have confirmation of cubs.

M3 (3:3)
A very large male (79kgs at capture), he was darted during his attack on M1 in October 2002 but due to his huge neck, no further effort has been made to collar him. This animal is well-known to Phinda rangers and also to surrounding properties who rely on him for superb viewing. He has been present in the area for perhaps as long as 11 years (Walker, 1999) and frequently disappears from Phinda for months at a time but unless an alternative to conventional radio-collars can be found, there is no way to rigorously monitor his movements. We consider him at high risk of being shot as he traverses numerous properties which persecute leopards.

M4 (3:3 cub)
The male cub of F2, collared in October 2002 as he began to spend increased time away from her. Between October 2002 and January 2003, his home range was entirely contained within that of his mother's, a typical pattern for recently independent animals. He had begun making wider excursions to the southern limits of her range when he was badly injured by another predator, possibly a spotted hyaena (evidence of a fight between a leopard and hyaena was found close to his location). He was darted and underwent treatment in the field but died of his wounds five days later in January 2003.

M5 (1:2)
Collared in December 2002. This is a young but large male, 60 kgs at capture (which compares with the adult male M1 twice his age). M5 was the probable killer of M1 and has occupied his territory since that death. He is very relaxed with vehicles and currently provides the majority of the leopard sightings at Phinda. Initial data indicates that M5 spends approximately 10-20% of his time outside Phinda on properties which persecute leopards; accordingly, he is at considerable risk.

F6 (2:2)
Collared in December 2002. This female is shy during the day and reasonably approachable at night but her likely pregnancy is escalating her elusive behaviour (as for F2). Her last oestrous was December 2002 when she was observed mating with M1 and M5; she may also have mated M3. If she does indeed have cubs, they will be captured when old enough to handle and tissue samples will confirm the sire. She traverses at least one property which hunts leopards.

M7 (3:3, usually called Pumalanga male)
M7 is the only animal to date which has not been captured on Phinda. Prior to capture, he had evidently spent some time taking refuge under a lodge in adjacent Mziki-Pumalanga. We set a cage-trap and caught him that night. He was in very poor condition at capture and had injuries consistent with an attack from an adult male. M7 is a young male, almost certainly still dispersing, a period in which they are presumably very vulnerable to attack by territorial adults. At the time of writing, he seems to have made a full recovery and spends most of his time on Pumalanga and the adjoining property, Bumbeni.

F8 (2:1) and F10 (2:2).
These two young females were both caught in February 2003. They are being discussed together here because the preliminary information we have on them is very similar. Both individuals are of a very similar age and size, and their ranges overlap extensively. Having said this, we don't think they are from the same litter. It is very likely that one of them is the daughter of F2 and sister of M4 but we will know this only when the genetic analyses have been completed.

F9 (3:2).
An adult female, caught February 2003. She occupies the far north-east of Phinda and almost certainly moves into the adjacent Mnqobogazi community. We currently know very little about her except that she is seen quite regularly during the day by foot patrols along the north-eastern fenceline; virtually all such sightings entail her resting in trees, unconcerned with their presence.

F11 (2:2)
The most recent addition to the project, caught in March 2003. She is also the first animal to be captured in Phinda South. The density of leopards seems to differ radically between the north and south of the property, with the majority of sightings and tracks (and, as a result, research activity) concentrated in the North. At this stage, there is no clear explanation for the pattern but F11's inclusion in the project is an important step in examining the question and we hope to capture more animals in Phinda South in the near future. Although F11 has only been added to the project very recently, we have already discovered that she has two cubs about 4 months old. At the time of writing, she is keeping them on an adjacent property which hunts leopards; we hope that she moves them onto Phinda soon.

Conclusions and the future.

Despite early obstacles and some deaths, the project is now proceeding well, with data being collected daily for all eight collared animals. As a high proportion of the study animals are females and young animals, we expect to collect accurate data on reproduction and the dispersal of sub-adults. We are also beginning to gain an insight into mortality in this population. The early deaths of two study individuals represent a considerable loss for the project (given they are so difficult to catch) but both arose from natural causes and have provided revealing data. Usually, the most we could say is that these animals simply disappeared; being able to accurately document the process will allow us to eventually estimate the natural mortality rates of different sex/age classes of leopards at Phinda. This is critical information if we wish to establish how the additional pressure of persecution is affecting the population.

During 2003, the priority will remain focused on intensive data collection of radio-collared animals. We will also continue to catch and radio-collar additional animals until we have a balanced spread of age/sex classes under daily monitoring. Finally, we will deploy digital camera-traps which are triggered remotely when animals break an infra-red beam. This will provide us with data on shy and transient individuals which are otherwise impossible to monitor and will ultimately furnish a very accurate estimation of leopard density in the region. The research will run until at least the end of 2005.

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