APPENDIX I.
COMMON AND SCIENTIFIC NAMES OF ALL SPECIES MENTIONED IN THE TEXT
and larger mammals occuring at Phinda (marked*).

Mammals	
Order Primata	
chacma baboon*	*Papio ursinus*
vervet monkey*	*Cercopithecus aethiops*
thick-tailed bushbaby*	*Otolemur crassicaudatus*
Order Lagomorpha	
Cape hare*	*Lepus capensis*
Order Rodentia	
cane rat, greater*	*Thryonomys swinderianus*
Cape porcupine*	*Hystrix africaeaustralis*
tree squirrel*	*Paraxerus cepapi*
Order Tubilendata	
aardvark*	*Orycteropus afer*
Order Carnivora	
African wild dog	*Lycaon pictus*
black-backed jackal*	*Canis mesomelas*
gray wolf	*Canis lupus*
side-striped jackal*	*Canis adustus*
red wolf	*Canis rufus*
swift fox	*Vulpes velox*
American black bear	*Ursus americanus*
brown bear	*Ursus arctos*
Cape clawless otter*	*Aonyx capensis*
black footed ferret	*Mustela nigripes*
honey badger*	*Mellivora capensis*
Eurasian badger	*Meles meles*
striped polecat*	*Ictonyx striatus*
genet, large-spotted*	*Genetta tigrina*
mongoose, banded*	*Mungos mungo*
mongoose, dwarf*	*Helogale parvula*
mongoose, slender*	*Galerella sanguinea*
mongoose, water*	*Atilax paludinosus*
mongoose, white-tailed*	*Ichneumia albicauda*
cheetah*	*Acinonyx jubatus*
caracal*	*Felis caracal*
mountain lion	*Felis concolor*
serval*	*Felis serval*
Eurasian lynx	*Lynx lynx*
leopard*	*Panthera pardus*
lion*	*Panthera leo*
brown hyaena*	*Hyaena brunnea*
spotted hyaena*	*Crocuta crocuta*

Order Proboscidia	
elephant*	*Loxodonta africana*
Order Perissodactyla	
Burchell's zebra *	*Equus burchelli*
white rhinocerous*	*Ceratotherium simum*
Order Artiodactyla	
warthog*	*Phacochoerus aethiopicus*
bushpig*	*Potanochoerus porcus*
giraffe*	*Giraffa camelopardalis*
white-tailed deer	*Odocoileus virginianus*
pronghorn antelope	*Antilocapra americana*
caribou	*Rangifer tarandus*
bison	*Bison bison*
bushbuck*	*Tragelaphus scriptus*
greater kudu*	*Tragelaphus strepsiceros*
nyala*	*Tragelaphus angasii*
eland*	*Taurotragus oryx*
buffalo	*Syncerus kaffir*
domestic cow	*Bos taurus*
waterbuck*	*Kobus ellipsiprymnus*
southern reedbuck*	*Redunca arundinum*
white-earred kob	*Kobus kob leucotis*
gemsbok	*Oryx gazella*
sable antelope	*Hippotragus niger*
roan antelope	*Hippotragus equinus*
red hartebeest*	*Alcelaphus buselaphus*
blesbok*	*Damaliscus dorcas phillipsi*
blue wildebeest*	*Connochaetes taurinus*
steenbok*	*Raphicerus campestris*
suni*	*Neotragus moschatus*
duiker, common*	*Sylvicapra grimmia*
duiker, red*	*Cephalopus natalensis*
impala*	*Aepyceros melampus*
Thomson's gazelle	*Gazella thomsoni*
Grant's gazelle	*Gazella granti*
springbok	*Antidorcas marsupialis*
Spanish Ibex	*Capra pyrenaica*
Birds	
Order Aves	
ostrich	*Stuthio camelus*
wattled plover	*Vanellus senegallus*
crested guinea fowl	*Guttera pucherani*
Reptiles	
Order Reptilia	
leopard tortoise	*Geochelone pardalis*
serrated hinged terrapin	*Pelusios sinuatus*
Nile crocodile	*Crocodylus niloticus*

APPENDIX II

IMPLANTED AND EXTERNAL RADIO-TRACKING TRANSMITTERS: A COMPARISON OF PERFORMANCE IN DIFFERENT HABITAT TYPES IN LIONS.

(A revised version of this section been accepted for publication in *Journal of Wildlife Research* as "Effect of habitat type on performance of intraperitoneal and external radiotransmitters in lions")

Radio-telemetry is now a widely-used effective tool for locating and studying free-ranging animals. Radio-transmitters are usually attached to the animal externally, by means of collars, harnesses and so forth. However, where a species' behaviour, morphology or habitat precludes this option, researchers have experimented with internal implantation of transmitters, usually in the intraperitoneal cavity or sub-cutaneously. Although implantation presents potential problems such as surgical trauma, anaesthesia risks, post-operative infection and pathological effects on organ function (Guyunn *et al* 1987; Herbst 1991), reported success of the procedure is high (Reid *et al* 1986; Van Vuren, 1989; Korshgen *et al* 1996).

Surgical complications aside, a very real limitation of implantable transmitters is their reduced reception range when compared to external transmitters (Green *et al,* 1986), as a result of short antennas (Korschgen *et al,* 1996) and signal absorbtion by body tissue (Kenward, 1987). Although considerable experimentation with implantable transmitters has been conducted (and is ongoing), most studies have involved birds, or small mammals and data on their performance in large mammals are sparse.

Increasingly, managers in wildlife tourism ventures are seeking to balance their need for locating animals with the negative aesthetic impact of radio-collars on the tourism experience. This is particularly pertinent for carnivore re-introduction efforts in South Africa where constant monitoring may be a requirement for release by conservation authorities (Chapter 2). Implanted transmitters are widely perceived as the solution, but a comparison between implants and radio-collars in large carnivores is lacking and hence, choices being made between telemetry options are not necessarily suitable for local requirements.

Although some studies have yielded impressive results (Ralls *et al,* 1989; McKenzie *et al* 1990), the effect of local conditions on performance is largely unknown. Vegetation, terrain, soil type and climatological conditions apparently all affect reception distance (Sargeant, 1981; Kenward, 1987), and while most researchers will vouch for sometimes unpredictable performance under changing conditions, empirical data on the effects of environmental influences are rare.

McKenzie *et al* (1990) successfully implanted leopards and spotted hyaenas in Botswana and reported maximum reception distances of 1.5km to 2.5km (depending on transmitter model) from the ground. Although they mention that terrain type can affect reception range, they provide no details on the habitat in which their trials took place. Green *et al* (1986) compared implants and collars in captive north American canids held in large enclosures, rating signal quality at a fixed distance and established that signals from implants were inferior to collars, but again, did not provide data on environmental influences.

The opportunity to explore the performance of implants in difficult conditions for telemetry arose in the present study when Phinda expressed a desire to reduce the use of radio-collars on re-introduced cats due to negative feedback from paying tourists. This section reports on the results of one experiment in which a male lion was surgically implanted with a transmitter, enabling me to compare the signal reception of the implanted lion in three habitat types with the reception of a radio-collar carried by a lioness in the same social group. I conducted performance trails in three habitat classes to establish if vegetation characteristics (particularly density) affected signal strength.

MATERIALS AND METHODS.

A detailed account of the surgical procedure is beyond the focus and expertise of this section and a qualified vet should always be retained to perform these types of operations. A brief summary is included here by way of introduction.

The subject, a 30 month old male lion, was darted with 500mg Zoletil after a holding period in captivity for three days during which he was starved. While sedated, normal saline was administered intravenously for the duration of the operation, which lasted approximately 50 minutes. A mid-ventral incision approximately 7 cm long was made through the skin and linea alba into the abdominal cavity. The transmitter (model IMP 400/L, 100 x 35mm, weight 200g; Telonics™, Mesa, Arizona) was inserted into the abdominal cavity and sutured into the omentum using No. 2-0 chromic catgut. When the transmitter was in place, the muscle layers and skin were sutured closed using No. 2 monofilament nylon. During all stages of the operation, the signal reception was constantly monitored to be sure the implant was functioning. The patient was allowed to recover in a large ($80m^2$) outdoor enclosure and released 24 hrs after the operation. Apart from licking the incision up to 3 days after surgery, he appeared indifferent to the wound and did not disturb sutures. There was no evidence of infection or trauma to the wound site following healing. He reunited with his pride the same day as release.

The implanted lion's social group included a female fitted with a radio-collar (see Chapter 2 for details on transmitter). Whenever this group was located stationary, I drove away from them along a straight compass bearing and determined the respective distances at which the signals from the implant and the collar became inaudible. Initially I checked every 100m, decreasing to the nearest 20m as signal strength weakened. Distance was measured from the vehicle's odometer or later from topographic maps when it was impossible to maintain a straight line between myself and the animals. I conducted the measurements in three different habitat types which follow descriptions in Chapter 2. The habitat types were:

i. grassland. Tall tussocked grassland essentially devoid of large woody vegetation,

ii. open woodland. *Acacia*-dominated woodland with a canopy less than 6m, with trees occurring >10m apart and a sparse sub-canopy,

iii. closed woodland. Mixed *Acacia* and *Terminalia* woodland dominated by large (7-15m high) trees and having a dense sub-canopy of smaller trees.

All measurements were taken at ground level. After I had established the maximum distance of signal reception, I drove back to the lions to ensure they had not changed location during the trial. I conducted 34 such trials between March and June 1993 when the implanted male was killed in a poacher's snare.

A very obvious difference between transmitter types in their maximum reception distance was immediately apparent (see Results) and statistical tests would be meaningless to confirm this. To examine whether this difference was affected by habitat type, I compared the difference between collar and implant performance in each habitat type using a one-way ANOVA, followed by a Newman-Keuls test, a conservative post hoc comparison of means, to determine where differences existed.

RESULTS.

The mean distance of signal reception for both transmitters in different habitat types is presented in Fig. 61 . In all habitats, the collar could be received at least three times as distant as the implant. The maximum distance the implant was received was 850m (in grassland) compared to 2800m for the collar in the same habitat (Table 41). In some trials in closed woodland particularly when the density of large trees was very high, the signal from the implant became inaudible at 100m.

The difference in performance between transmitter types increased significantly in grassland compared to the two woodland habitats ($F = 25.123$, $p = 0.0000$, $df = 2$: Newman-Keuls test, grass:open woodland, $p = 0.00013$; grass:closed woodland $p = 0.0015$; Table 41.). Although performance difference increased marginally in open woodland compared to closed woodland, it was not statistically significant (Newman-Keuls $p = 0.1302$).

	Implant		Collar		
Habitat	**mean**	**range**	**mean**	**range**	**mean difference**
Closed woodland (n = 11)	182.2	100-320	1200.0	1000-1400	1017.3
Open woodland (n = 11)	427.3	200-600	1563.7	1400-2000	1136.4
Grassland (n = 12)	683.3	500-850	2212.5	1800-2800	1529.2
All habitats combined (n = 34)	438.6		1675.0		

Table 41. Reception performance for implant and collar in three habitat types.

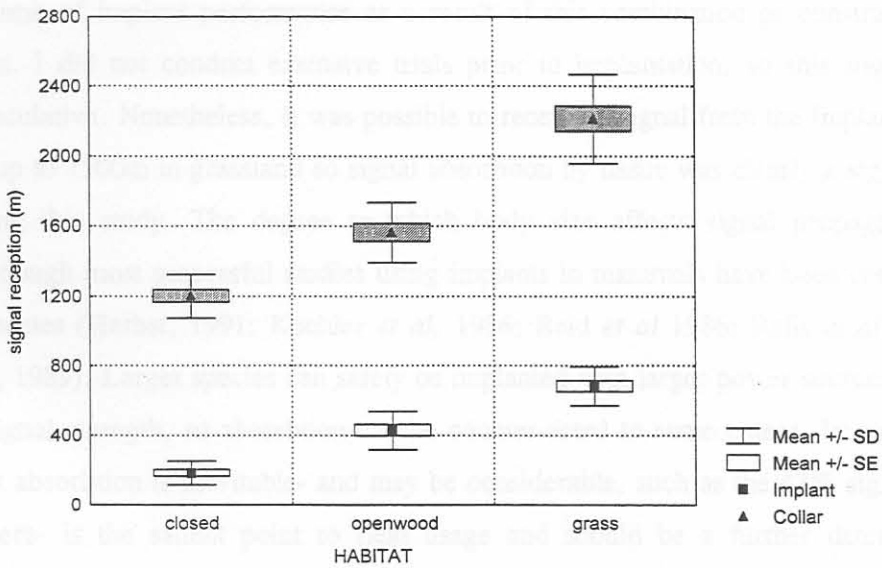

Figure 61: Implant versus collar performance in three habitat types.

DISCUSSION

This study, albeit brief, suggested that signal loss in implanted transmitters may negate their practicability in some radio-tracking scenarios. Even the maximum reception range of 850m in optimum habitat (grassland) would not be sufficient to regularly locate animals with a large home range and large daily movements such as in lions. In denser habitat where this range is considerably reduced, such as both types of woodland at Phinda, it would be almost impossible to predictably locate animals carrying implants. Phinda has an extensive road network which facilitated 'sweeping' an area for radio-tagged animals in habitat impossible to drive. However, this method was dependent on the radio signal being able to penetrate stands of vegetation in which roads existed approximately every two kilometres. Implanted animals would not be detected in a situation such as this unless they happened to be resting close to a road.

It is interesting that the disparity between transmitter performance increased as habitat became more open (Table 41). It is unclear why the mean difference in transmitter performance was not consistent across habitat types. However, implants suffer two sources of signal depletion regardless of environmental factors: transmission path loss as a result of a shortened, coiled antenna (Korschgen *et al* 1996) and signal absorbtion by body tissue (Kenward 1987). The increasing difference between the two transmitters probably reflects the upper limit of implant performance as a result of this combination of constraints on transmission. I did not conduct extensive trials prior to implantation, so this suggestion remains speculative. Nonetheless, it was possible to receive a signal from the implant prior to surgery up to 1500m in grassland so signal absorbtion by tissue was clearly a significant factor during this study. The degree to which body size affects signal propagation is unknown, though most successful studies using implants in mammals have been conducted on small species (Herbst, 1991; Koehler *et al,* 1986; Reid *et al* 1986; Ralls *et al*, 1989; Van Vuren, 1989). Larger species can safely be implanted with larger power sources which improves signal strength, so absorbtion can be counter-acted to some extent. In any case, the fact that absorbtion is inevitable- and may be considerable, such as the 43% signal loss observed here- is the salient point to field usage and should be a further deterrent to deploying implants where dense vegetation could exacerbate these inherent limitations. Where habitat is very open, it may be feasible to use implants to locate animals: however, these results suggest open habitat is ideal for maximum performance of external transmitters, arguing that resources may be better invested in conventional radio-collars.

Some innovative techniques have attempted to reduce poor performance in internal transmitters. Korschgen *et al* (1996) successfully implanted ducks and exited a long external antenna through the caudal abdominal wall and skin, improving signal range. It is unlikely that most mammal species which groom themselves and show interest in novel objects would tolerate this. Conspecifics or cubs of radio-collared lions and cheetahs invariably bit off the external antenna on collars until design was modified so that the antenna was hidden between two layers of collar belting. Additionally, given that the main concern here is physical appearance of animals, it is highly unlikely that visible external whip antennas would be considered an improvement by tourists.

The use of an aircraft can significantly improve reception in implants (McKenzie *et al* 1990) and radio-tracking from the air is widely undertaken for wide-ranging species (Kenward, 1987). If this option is regularly available, implants may be an effective means to locate radio-tagged individuals in the sorts of conditions described here. Nonetheless, cost and effort needs to be weighed against this gain. External transmitter reception will likely be far superior than implant reception, reducing time in the air which is the main expense and probably allowing for more accurate and/or more frequent locations. By way of example, although I was not able to assess implant signal strength from an aircraft during these trials, at a later date I received the signal from the same radio-collar tested here at distance of more than 20km while in a Cessna Grand Caravan flying at approximately 500ft: McKenzie *et al* (1990) reported a maximum of 6km for implants from aerial searches.

Having said this, these results need to be interpreted cautiously. The study was brief because of the implanted lion's premature death and a longer comparison would permit investigation of other potential environmental influences such as humidity, cloud cover and electrical storms (Kenward, 1987). Furthermore, a greater sample of both types of transmitters would be more compelling. Given that only one implant was available for the trials, I was not able to ascertain whether this particular unit was functioning optimally in comparison with other implants, though field personnel more experienced than myself in use of this equipment suggested it was 'normal'. Although I did not conduct extensive trials of its performance prior to implantation, it was possible to receive a signal up to 1500m in grassland. Some diminishment in signal strength once implanted can be expected because tissue absorbs some signal radiation and McKenzie *et al* (1990) have suggested that leaving the unit free floating in the abdominal cavity as opposed to lateral attachment of the implant (the method employed here), may improve signal strength.

In conclusion, serious thought needs to be given to deployment of implants in wide ranging mammals such as large felids, particularly where the sole concern is appearance and where environmental conditions may limit their use. Where managers are not faced with limitations arising from a species behaviour, morphology or habitat, the potential risks of invasive surgery combined with the far greater performance of external transmitters argues against intraperitoneal implants. Furthermore, there is no evidence that radio-collars affect behaviour of large cats: indeed lions and cheetahs seem largely oblivious to collars from the moment they recover from sedation after being fitted. Although the aesthetic impact of collars is undeniably negative, perhaps managers of wildlife tourism operations would better be served by allocating resources to educating tourists about the reasons for collars and the drawbacks to alternatives. The development of effective, less invasive, inconspicuous telemetry such as sub-cutaneous implants for large mammals would render many of the problems of both collars and implants obsolete. Encouragingly, research on these options is underway[1].

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APPENDIX III.

A CASE OF CANNIBALISM IN MALE CHEETAHS.

(This section published as: Hunter, L.T.B. & J.D. Skinner, 1995. "A case of cannibalism in male cheetahs" *Afr. J. Ecol.* 33:169-171. I observed a second incident of cannibalism by the same male cheetahs, virtually identical to the case described here, which occured while this manuscript was *in press*).

Among large felids, individuals appear to establish territories which may be rigourously defended from conspecifics of the same sex (see Packer, 1986 and Gittleman, 1989 for references). Contests over these territories can be fierce and occasionally result in the death of combatants (Schaller, 1967, 1972; Caro *et al* 1987a,b). Although the consumption of a killed conspecific after such an encounter would possibly benefit the victor/s by replenishing energy expended during the fight, cannibalism in these clashes appears to be rare. In the incident described, the victorious pair of cheetahs utilised the carcass of a killed male in the manner of a typical kill.

STUDY SITE AND SUBJECTS

The present research is part of an ongoing project examining the behavioural ecology of reintroduced cheetahs and lions in the Phinda Resource Reserve (hereafter Phinda), a privately owned reserve of 17600 Ha in northern Natal Province, South Africa. The area is within the historical range of cheetahs, the last of which were extirpated in 1941 (Rautenbach *et al* 1980). Between March 1992 and May 1993, Phinda released five male and seven female cheetahs wild caught in Namibia and Botswana. Two of the males (representing all five males by their association in coalitions) and a single female have been radio-collared (Telonics, Arizona) and monitored since their release.

RESULTS

The observations are presented here as a detailed case history. A resident two-male coalition of cheetahs was located at 0650h well within the borders of their territory pursuing some impalas They were lost for 15 minutes and then relocated 1700m away where they had caught another male cheetah which they were attacking with savage throttling and repeated mauling of the hindquarters. No movement or response was seen by the third male from the moment of arriving at the scene and it was possibly already dead. Nonetheless, both of the attacking males bore bite wounds to the cheeks and ears, indicating the third male had attempted to defend itself. Two game guards on fence patrol had witnessed the actual attack and reported that after an initial brief skirmish lasting only 2-3 minutes, they had lost sight of the cheetahs in the long grass, most probably the point at which the intruding male was overcome by the two attackers.

Both males maintained their respective holds on the third animal without rest for 15 minutes from first contact, before moving 5m away from the third cheetah which was clearly dead at this stage. After resting for less than a minute, they approached the dead cheetah aggressively and then attacked the carcass again, savagely throttling the throat and repeatedly tearing at the hind-quarters and genitals. The throttling motion at the throat was performed in the same way with which a prey animal is killed: however, the action was much more forceful and prolonged than observed during the killing of ungulates (Hunter *pers. obs.*). The pattern of a brief rest followed by renewed attack on the carcass was repeated for 45 minutes in which the carcass was "re-attacked" five times.

At 0802h, one of the males began lapping blood from the wounds and then proceeded to open the carcass at the right flank and fed on it for 25 minutes. The second male then approached the carcass and fed for 10 minutes before also moving off to rest. At this point, the carcass was removed for identification purposes. The entire muscle mass of the right hind leg had been eaten and the abdominal cavity opened. The intestines had not been eaten. In normal feeding patterns, cheetahs intersperse feeding periods with short rests close to the kill until it is finished (Hunter *pers obs.*) which probably would have occurred here if there had been no intervention.

DISCUSSION

The behaviour presented here is interesting as cannibalism is rarely observed in large felids, except in cases of infanticide (Packer & Pusey, 1982). The motivation for the consumption of the killed male in this incident is unclear. Pienaar (1969) mentions records of cannibalism in cheetahs in the Kruger National Park, suggesting these stem from fights over carcasses. This does not appear to be the reason in this case as the attacking animals were hunting before encountering the third male and there were no carcasses in the area. Although fights over a resource such as territory or an oetrous female have been known to result in the death of competing cheetahs (Stevenson-Hamilton 1945, Kuenkel 1978, Caro *et al* 1987b, Skinner *et al* 1991), such instances have not been recorded resulting in cannibalism. Similarly, extreme hunger does not appear to be the likely cause here as the victorious males had together consumed a subadult impala killed less than 48 hours prior to the incident.

Although the resident pair were hunting when they encountered the third male, there seems little doubt that the intruding cheetah was attacked as a competitor rather than a prey item. The repeated mauling of the animal long after it was dead and the aggression of the attackers are behaviours not seen when cheetahs deal with prey (Eaton 1970c and Hunter, *pers obs*). Accordingly, the possibility of the cheetah pair actually hunting their own species (as appears to occur occasionally in some primates, see Goodall 1986) seems very unlikely. This is particularly so when one considers that observed interactions between these two males and females (including a female with large dependent male cubs) were devoid of any atypical aggression. Accordingly, the possibilty that the reintroduction process contributed to the cannibalistic behaviour seems unlikely. The two attacking males had been resident in their territory for 15 months at the time of the incident and during this time, had displayed no behaviour indicating disturbance or trauma resulting from the reintroduction.

It is possible that the extensive nature of the wounds inflicted on the hindquarters stimulated the cheetahs to begin feeding. In normal cheetah feeding patterns, the carcass is almost always opened at the hindquarters (Leyhausen, 1979). The mauling of the hindquarters had left large tears in the skin and muscle layer from which blood was flowing freely. Just prior to initiating feeding, one of the males had begun to lap the blood, which may have then stimulated him to open the carcass. Unfortunately, no records exist on the extent and location of wounding in other male cheetahs killed in intraspecific fighting, so one cannot make a comparison between this case and others in which cannibalism has not occurred. Until this data becomes available, the motivation for this behaviour will remain unclear.