

Scat analysis and aspects of defecation in northern Cape leopards

J. du P. Bothma*

Centre for Wildlife Management, University of Pretoria, Pretoria 0002, Republic of South Africa

E.A.N. le Riche

Kalahari Gemsbok National Park, Private Bag X5890, Gemsbokpark 8815, Republic of South Africa

Received 3 August 1993; accepted 3 May 1994

Leopard scats from the Augrabies Falls and Kalahari Gemsbok National Parks, South Africa were analysed microscopically. The data supported the known biases for using scats as prey-use indicators. The Kalahari data proved the reliability of the tracking technique used there by several researchers for prey-use studies. Aspects of leopard defecation discussed include the spacing and timing of defecations, and the infrequent use of scrapes to cover faeces.

Misanalises vir luiperds in die Nasionale Augrabies-watervalpark en die Nasionale Kalahari-gemsbokpark is mikroskopies gedoen. Die resultate ondersteun die bekende sydigheid vir die gebruik van mismonsters as prooi-aanwysers in roofdiere. Die gegewens uit die Kalahari bevestig die betroubaarheid van die spoorsny-tegniek wat al daar deur verskeie navorsers gebruik is om prooibenuiting by roofdiere te bepaal. Ander aspekte wat behandel word, sluit die spasiëring in tyd en ruimte van ontlasting en die seldsame toekrap van mis deur luiperds in die Kalahari in.

Keywords: Augrabies, defecation, Kalahari, leopards, North Cape Province, *Panthera pardus*, scats

* To whom correspondence should be addressed

Introduction

Scat analysis and defecation studies provide useful information on the ecology and behavioural ecology of mammals (Riney 1957; Putman 1984). For example, such analyses may reveal information on the feeding habits of wild cats which may not be possible when using other techniques such as locating and identifying kills (e.g. Grobler & Wilson 1972; Smith 1978; Maehr, Belden, Land & Wilkens 1990). Known biases resulting from differential digestion, however, require information on food passage rates (Hiscocks & Bowland 1989), while the possible role of faeces in scent-marking (Gorman & Towbridge 1989) may be ecologically and behaviourally important.

This paper aims to augment prey-use studies of Kalahari leopards *Panthera pardus* (Bothma & Le Riche 1984; 1986) with some scat analyses, particularly to determine the presence or absence of small mammals in the diet of North Cape leopards, and provides data on various aspects of defecation of Kalahari leopards hitherto unpublished.

Study area

Analyses of leopard scats from the Augrabies Falls National Park and the Kalahari Gemsbok National Park were carried out. Defecation rates and other aspects were studied only in the Kalahari. The Augrabies Falls National Park and the adjacent Riemvasmaak area straddle the Orange River in the extremely arid North Cape. It is a region of cold winters and hot summers with rocky outcrops on sandveld flats. The study in the Kalahari was done in the northern part of the Kalahari Gemsbok National Park. The study area there is an open, arid sandveld savanna with a mean annual rainfall of about 240 mm, hot summers and cold winters. Further details on the latter study area appear in Bothma & Le Riche (1984) and Van Rooyen, Van Rensburg, Theron & Bothma (1984; 1988).

Methods and Material

In the Augrabies, scats were collected when they were found. Positive identification of their leopard origin was made from spoor and other signs. Kalahari scats were collected while visually tracking leopard spoor using the technique of Bothma & Le Riche (1984). With this technique, the timing and nature of previous kills are known relative to scat deposition. This allows for the calculation of food passage rates. Scats were labelled and air-dried.

Scat analysis was done macroscopically using reference material from the Transvaal Museum, and microscopically using Hardy microtome (Hardy 1933) hair sections mounted in collodion (Dreyer 1966; Keogh 1979). The slides were subsequently dipped in chloroform (2 min), phenol xylol (5 min) and xylol (5 min). The coverslip was affixed with Depex solution. A Leitz Ortholux microscope with a camera attachment was used to photograph hair sections under a 10× or 25× magnification using the principle of Köhler illumination. The photographic reference material is housed in the Centre for Wildlife Management, University of Pretoria. The reference collection contains material of most large South African mammals, not just those from the Kalahari area.

Where microscopic analysis failed to yield identification to species level, macroscopic prey remains and hair characteristics, such as scale shape and pattern, medullary form and pigment distribution, were used to eliminate choices. The reference collection was compiled by Hildyard (1983).

A considerably larger sample than the 40 scats collected over a 49-day period during research visits in six years (1979, 1980, 1982, 1983, 1984 and 1985) in the Kalahari, and the 17 scats from the Augrabies reported on here, were originally analysed, but some microscopic slides were lost to breakage before they could be examined.

For passage rate studies, data were classified into summer (September to April) and winter (May to August) samples based on the arguments of Bothma & Le Riche (1994) and the expected influence of climate on the basal metabolism of leopards (McNab 1989). For adult male leopards, data for 902,9 km of tracking over a period of 54 days in summer, and 623,1 km of tracking for 33 days in winter, were used. For adult females, the summer data involved 363,6 km of tracking for 30 days, and 83,9 km for 10 days in winter. The total study period involved in these studies to date covers the years 1971–1992. Not all the data collected were, however, useful for all types of analysis presented here and individual sample sizes are given where relevant. The statistical test for randomness used was the Runs test. Tests for differences between sexes and seasons were based on standard *t*-tests.

Results

Scat analysis

In the Augrabies Falls National Park, dassie *Procavia capensis* remains were present in nine (54%) of the scats, with springhare *Pedetes capensis* and gemsbok *Oryx gazella* remains in two scats each, and silver fox *Vulpes chama* remains in one scat. Two scats yielded no identifiable remains and two contained leopard hair, presumably from grooming. Of the 40 scats from the Kalahari, porcupine *Hystrix africae australis* remains were found in 12 (30%), duiker *Sylvicapra grimmia* and gemsbok remains in 10 (25%) each, springhare and black-backed jackal *Canis mesomelas* remains in six (15%) each, plant material, including the gemsbok cucumber *Acanthosycios naudianus*, in four (10%), steenbok *Raphicerus campestris*, springbok *Antidorcas marsupialis* and leopard hair in two scats each, and aardvark *Orycteropus afer* remains in one scat. No macroscopic or microscopic evidence of small rodents were found in any scat from the Augrabies Falls or the Kalahari Gemsbok National Parks.

Defecation rates

Most prey items first appeared in a scat on the day after a kill (ingestion), while some prey items appeared in subsequent scats for several days after ingestion (Table 1). The mean interval between defecations for male leopards in summer was 0,8 days ($SD = 1,03$ days; $n = 21$) and in winter 0,4 days ($SD = 0,58$ days; $n = 24$). This difference was not significant ($t = 1,51$; $df = 42$; $p > 0,05$). For female leopards the mean interval between defecations was 1,4 days ($SD = 1,51$ days; $n = 10$) in summer and 0,7 days ($SD = 0,58$ days; $n = 3$) in winter. This difference was also not significant ($t = 0,888$; $df = 11$; $p > 0,05$). Based on these results the seasonally, combined mean interval between defecations for male leopards was 0,6 days ($SD = 0,84$ days; $n = 45$) and for females 1,2 days ($SD = 1,36$ days; $n = 13$). This difference was significant ($t = 2,12$; $df = 56$; $p < 0,05$). On a frequency basis, the known interval between successive defecations for male leopards was 0 (same day) in 26 (58%) defecations, one day in 14 (31%), two days in four (9%) and four days in one of the defecations. For females, it was 0 in four days (31%) of the defecations, one day in six (46%), two days in one and four days in two defecations.

Table 1 The timing of the appearance of the same prey item in leopard scats in the southern Kalahari relative to the known dates of the kill (ingestion)

Known kill	Appearance in scats: days since kill					
	0*	1	2	3	4	5
Porcupine		x		x	x	x
Porcupine		x				
Porcupine			x			
Porcupine		x				
Duiker	x	x				
Duiker			x	x		
Duiker		x				
Duiker		x				
Steenbok		x				
Gemsbok calf					x	
Gemsbok calf	x	x				
Gemsbok calf			x			
Gemsbok calf		x				
Aardvark			x	x		
Black-backed jackal		x				
Black-backed jackal		x	x			
Black-backed jackal		x				

* 0 = day of kill

For male leopards the mean distance moved between successive defecations in summer was 15,0 km ($SD = 14,07$ km; $n = 28$) and 10,9 km ($SD = 11,07$ km; $n = 48$) in winter. There was no significant seasonal difference ($t = 1,40$; $df = 74$; $p > 0,05$). The mean distance which females moved between successive defecations in summer was 22,6 km ($SD = 19,8$ km; $n = 13$) and in winter 15,6 km ($SD = 14,74$ km; $n = 4$), also not significant ($t = 0,64$; $df = 15$; $p > 0,05$). The seasonally combined mean distance moved between successive defecations for male leopards was 12,4 km ($SD = 12,33$ km; $n = 76$) and for females 21,0 km ($SD = 18,55$ km; $n = 17$). This difference was significant ($t = -2,339$; $df = 91$; $p < 0,05$). The distances moved between successive defecations by male leopards were random in both seasons ($p > 0,05$). Due to small sample sizes, the scats of females were not tested for randomness.

The first defecation after a kill occurred at a mean interval of 1,2 days ($SD = 0,73$ days; $n = 17$) after the kill in summer for male leopards and at 0,9 days ($SD = 0,69$ days; $n = 13$) in winter. This difference was not significant ($t = 1,25$; $df = 28$; $p > 0,05$). The seasonally combined mean interval was 1,0 days ($SD = 0,72$ days; $n = 30$) for the first defecation after a kill for male leopards. On a frequency distribution basis, six (20%) of the first defecations after a kill occurred on the same day as the kill, 18 (60%) on the day thereafter, five (17%) on the second day and one on the third day after the kill in male leopards ($n = 30$). In female leopards, the first defecation after a kill occurred after a mean interval of 1,1 days ($SD = 0,92$ days; $n = 14$) in summer, and 2,0 days ($SD = 1,0$ day; $n = 3$) in winter. This difference was not significant ($t = -1,52$; $df = 15$; $p > 0,05$). The seasonally combined mean interval for the first defecation after a kill was 1,2 days ($SD = 0,97$ days; $n = 17$) for female leopards. On a frequency distribution basis, four

(24%) of the first defecations by female leopards after a kill occurred on the same day as the kill, seven (41%) on the first day thereafter, four (24%) on the second day and two on the third day after a kill ($n = 17$).

On a seasonally combined basis the timing of the first defecation after a kill for males was not significantly different from that of females ($t = 0,81$; $df = 45$; $p > 0,05$). Therefore all the data could be combined seasonally and for the sexes, resulting in a mean first defecation after a kill of 1,5 days ($SD = 2,90$ days; $n = 47$) for Kalahari leopards. On a combined data frequency basis the first defecation occurred on the same day as the kill in 10 (21%) cases, on the first day thereafter in 25 (53%) cases, on the second day in nine (19%) cases and on the third day in three (6%) cases ($n = 47$).

In male leopards in summer, the first defecation after a kill occurred after a mean movement of 13,5 km ($SD = 10,45$ km; $n = 17$), and 8,0 km ($SD = 13,72$ km; $n = 13$) in winter. This difference was not significant ($t = 1,21$; $df = 28$; $p > 0,05$) and the distances moved were random ($p > 0,05$) in both seasons. Therefore, the combined seasonal mean distance moved by a male leopard from a kill to its first defecation was 11,1 km ($SD = 12,07$ km; $n = 30$).

In female leopards in summer, the first defecation after a kill occurred after a mean movement of 7,4 km ($SD = 5,88$ km; $n = 16$) and 2,7 km ($SD = 2,1$ km; $n = 3$) in winter. This difference was not significant ($t = 1,34$; $df = 17$; $p > 0,05$). The seasonally combined mean distance moved was 6,7 km ($SD = 5,69$ km; $n = 19$) and this distance was not significantly different from that of male leopards ($t = 1,48$; $df = 47$; $p > 0,05$). The mean distance moved by both sexes for both seasons combined was 9,4 km ($SD = 10,24$ km; $n = 49$) from the kill before the first defecation and the spacing of all these distances moved was random ($p > 0,05$).

By dividing the movement data for only those days on which no kill was made (kills led to the cessation of further movement) into four activity quarters, the timing of defecations relative to the onset of daily activity could also be examined. For male leopards in the summer, 21 defecations (40%) occurred during the first quarter of activity, 11 (21%) during the second, seven (13%) during the third and 13 (25%) during the last quarter of activity ($n = 52$). Thus 32 (62%) of the defecations occurred during the first half of each night's movements. In winter, 15 defecations (33%) occurred in the first, 17 (38%) in the second, seven (16%) in the third and six (13%) in the fourth quarter of activity ($n = 45$). Thus 32 (71%) of the defecations occurred in the first half of each night's movements.

For female leopards in the summer, seven (33%) of the defecations occurred in the first quarter, six (29%) in the second, three (14%) in the third and five (24%) in the last quarter of activity ($n = 21$). This means that 13 (62%) of the defecations occurred in the first half of each night's movements. The winter sample of eight defecations did not allow this type of analysis.

Only two leopards, both females with small cubs, covered their faeces with sand once. In both these cases, the cubs were younger than three months and each female scraped sand over her faeces only when defecating near her cubs.

Males ($n = 97$) and females without cubs ($n = 21$) never scraped sand over their faeces and usually defecated on open sand.

Discussion

The scat analyses for leopards from the Augrabies Falls National Park confirm the findings of authors elsewhere that, when they are present, dassies are common prey for leopards (Grobler & Wilson 1972; Smith 1978; Norton, Lawson, Henley & Avery 1986). Although small carnivores regularly fall prey to leopards elsewhere (Smithers 1983; Bothma & Le Riche 1984; 1986; Grimbeek 1992), the silver fox has not yet previously been recorded as a prey item for North Cape leopards.

For the Kalahari, the scat analyses showed no real deviation from the known common prey of leopards there (Bothma & Le Riche 1984; 1986). It, however, does support the reliability of the tracking method in that no remains of rodents other than those of porcupines and springhares were found, in particular murids. If murid prey were overlooked while tracking, and if they were nearly as abundant a prey as was suggested for leopards in Tsavo (Hamilton 1976), the Matobo National Park (Grobler & Wilson 1972), the Waterberg area in the Northern Transvaal (Grimbeek 1992) and the southern Cape (Norton *et al.* 1986), then some evidence of murid remains should have been found in the Kalahari scats examined. The possibility of more use of murids by leopards in times of exceptionally high populations of rodents (Nel 1983) cannot be totally ruled out, however, but will require an intensive leopard scat analysis effort during such a period. The presence of gemsbok cucumber seeds in one scat confirms the occasional use of such plants by carnivores in the Kalahari (Eloff 1984).

No references to the frequency and spatial distribution of leopard defecations could be found. Therefore the data reported here are unique, although their relevance to other regions must still be determined. Scott (1985), who observed a female leopard for many months in East Africa, for example, only recorded two incidences of defecation.

The appearance of the remains of a specific prey animal in different scats over a period of up to five days is similar to that found with feeding trials for cheetahs (Hiscocks & Bowland 1989) and other carnivores (Bowland & Bowland 1991). This strengthens the arguments against the unweighted numerical analyses of prey remains in scats of such carnivores as reliable indicators of relative prey-use intensities (Putman 1984).

Most prey remains first appeared in the scats on the first day after being eaten (Table 1), indicating the possible absence of differential rates of digestion in leopards for different prey as speculated upon by Eisenberg & Lockhart (1972). Large prey being eaten over a period of several days (Bothma & Le Riche 1984; 1986) will affect the distances of movement recorded from prey to first defecation as the leopards do not move. However, leopards in the Kalahari seldom spend longer than a day with a given kill (Bothma & Le Riche 1984; 1986).

The data presented here are to our knowledge the first to reveal some aspects of defecation by the leopard in natural

conditions. Such data for large carnivores are rare, as seen by the virtual absence of them in the extensive work on carnivores by Gittleman (1989). In the Kalahari, all leopards defecated at random in terms of time and distance moved. Schaller (1972) found that Serengeti lions also defecated at random spatially. His observations suggested that faeces were not used for scent-marking in any special way. Muckenhirn & Eisenberg (1973) stated that leopards in Sri Lanka also do not use their faeces to scent-mark. In contrast, Asa, Mech & Seal (1985) claimed that the faeces of wolves *Canis lupus* emit volatile compounds which may be a more nasally salient signal than urine, and that wolf faeces are used for scent-marking.

The tracking equipment and technique used to date to study Kalahari leopards, in an often trackless terrain, made it impossible to verify the use of defecation by leopards to mark the edges of their range as claimed by Scott (1985). The intended future use of GPS equipment will, however, allow such an examination.

Leopards clearly defecated most often during the first half of a given activity cycle (night), but no clear explanation other than the onset of activity after a period of rest can be presented for this phenomenon.

There were no seasonally (climatically) different patterns and frequencies of defecation in both sexes of leopard. McNab (1989) stated that climate may influence the basal rate of metabolism of a carnivore, and hence its rate of defecation. However, he referred to constantly different climates such as arctic areas versus the tropics and not to seasonal climatic differences.

Kalahari leopards mostly defecate on the day of a kill or the day thereafter. Feeding is the probable stimulus for such defecation, particularly as felids are known to have a high rate of metabolism when feeding mainly on vertebrate prey (McNab 1989).

There were significant differences between defecation rates of males and females. In general, males defecated at shorter time and distance intervals than females. This result is not supported by the general concept that carnivores with a smaller body size should have a greater basal metabolic rate than those with a larger body size (McNab 1989) and no other explanation exists for this phenomenon as the prey base used was essentially the same for both sexes. The more extensive data now available for Kalahari leopards, continue to support the more frequent defecation rates found earlier for male leopards compared with females (Bothma & Le Riche 1986). Relative to the timing of known kills, males and females defecated similarly in terms of time intervals, but males moved further than females from a kill before defecating for the first time.

Scraping of sand over the faeces was rare in Kalahari leopards. Gorman & Towbridge (1989) maintain that domestic cats *Felis catus* and Scottish wild cats *Felis silvestris* only bury their faeces within the core areas of their ranges. It can be expected that leopards with small cubs will remain within the relative 'safety' of their core areas, although no evidence to support this can be obtained in the Kalahari areas until the GPS equipment becomes available. In East Africa leopards also seldom scrape soil over their

faeces and it is generally postulated that scraping is less common in leopards in Africa than elsewhere (Hamilton 1976). Our data support this belief.

Acknowledgements

The National Parks Board of South Africa permitted and, with the University of Pretoria, financed the research. Several technicians helped with the microscopic analyses of hair samples, as did the then Maj. J. van Rooyen of the Forensic Laboratory of the South African Police. The Transvaal Museum made reference material available and the Department of Botany, University of Pretoria allowed the use of their Leitz Ortholux microscope and camera. Mr P. Bronkhorst did the scat collection in Au-grabies. Mr A.G. Schmidt of the Centre for Wildlife Management and Prof. H.T. Groeneveld of the Department of Statistics, both at the University of Pretoria, assisted with some of the statistical analyses. Mrs L. Swanepoel and Mrs A. van Zyl typed drafts of the manuscript. We thank them all sincerely.

References

- ASA, C.S., MECH, L.D. & SEAL, U.S. 1985. The use of urine, faeces and anal-gland secretions in scent-marking by a captive wolf (*Canis lupus*) pack. *Anim. Behav.* 33: 1034–1036.
- BOTHMA, J. DU P. & LE RICHE, E.A.N. 1984. Aspects of the ecology and the behaviour of the leopard *Panthera pardus* in the Kalahari Desert. *Suppl. Koedoe* 27: 259–279.
- BOTHMA, J. DU P. & LE RICHE, E.A.N. 1986. Prey preference and hunting efficiency of the Kalahari desert leopard. In: *Cats of the World: Biology, Conservation and Management*, (eds) S.D. Miller & D.D. Everett. National Wildlife Federation, Washington D.C., pp. 389–414.
- BOTHMA, J. DU P. & LE RICHE, E.A.N. 1994. The relationship between minimum air temperature and daily distances moved by Kalahari leopards. *S. Afr. J. Wildl. Res.* 24: 18–20.
- BOWLAND, J.M. & BOWLAND, A.E. 1991. Differential passage rates of prey components through the gut of serval *Felis serval* and black-backed jackal *Canis mesomelas*. *Koedoe* 34: 37–39.
- DREYER, J.H. 1966. A study of hair morphology in the family Bovidae. *Onderstepoort J. Vet. Res.* 33: 379–472.
- ELOFF, F.C. 1984. The Kalahari ecosystem. *Suppl. Koedoe* 27: 11–20.
- EISENBERG, J.F. & LOCKHART, M. 1972. An ecological reconnaissance of Wilpattu National Park. *Smithsonian Contrib. Knowl. (Zool.)* 101: 1–118.
- GITTLEMAN, J.L. (ed.) 1989. *Carnivore behavior, ecology and evolution*. Chapman & Hall, London.
- GORMAN, M.L. & TOWBRIDGE, B.J. 1989. The role of odor in the social lives of carnivores. In: *Carnivore behavior, ecology and evolution*, (ed.) J.L. Gittleman, Chapman & Hall, London, pp. 57–88.
- GRIMBEEK, A.M. 1992. The ecology of the leopard (*Panthera pardus*) in the Waterberg. M.Sc. thesis, University of Pretoria, Pretoria.
- GROBLER, J.H. & WILSON, V.J. 1972. Food of the leopard *Panthera pardus* (Linn.) in the Rhodes Matopos National Park, Rhodesia, as determined by faecal analysis. *Arnoldia* 5(35): 1–9.

- HAMILTON, P.H. 1976. The movements of leopards in Tsavo National Park, Kenya, as determined by radio-tracking. M.Sc. thesis, University of Nairobi, Nairobi.
- HARDY, J.I. 1933. A practical laboratory method of making thin cross-sections of fibres. *Circular U.S. Dept. Agric.* No. 378.
- HILDYARD, C.J. 1983. The identification of mammals using hair samples. B.Sc.(Hons) (Wildlife Management) Project Report, University of Pretoria, Pretoria.
- HISCOCKS, K. & BOWLAND, A.E. 1989. Passage rates of prey components through cheetahs. *Lammergeyer* 40: 18–20.
- KEOGH, H. 1979. An atlas of hair from southern African mammal species, with reference to its taxonomic and ecological significance. D.Sc. dissertation, University of Pretoria, Pretoria.
- MAEHR, D.S., BELDEN, R.C., LAND, E.D. & WILKENS, L. 1990. Food habits of panthers in southwest Florida. *J. Wildl. Manage.* 54: 420–423.
- MCNAB, B.K. 1989. Basal rate of metabolism, body size, and food habits in the Order Carnivora. In: *Carnivore behavior, ecology and evolution*, (ed.) J.L. Gittleman. Chapman & Hall, London, pp. 335–354.
- MUCKENHIRN, N.A. & EISENBERG, J.F. 1973. Home ranges and predation of the Ceylon leopard (*Panthera pardus fusca*). In: *The World's Cats*, (ed.) R.L. Eaton, Vol. 1. World Wildlife Safari, Winston, Oregon, pp. 142–175.
- NEL, J.A.J. 1983. Changes in population structure of Kalahari rodents over a decade: 1970–1980. *Ann. Mus. Roy. Afr. Centr. Sc. Zool.* 237: 173–178.
- NORTON, P.M., LAWSON, A.B., HENLEY, S.R. & AVERY, G. 1986. Prey of leopards in four mountainous areas of the south-western Cape Province. *S. Afr. J. Wildl. Res.* 16: 47–52.
- PUTMAN, R.J. 1984. Facts from faeces. *Mammal. Rev.* 14: 79–97.
- RINEY, T. 1957. The use of faeces counts in studies of several free-ranging mammals in New Zealand. *N. Z. J. Sci. & Tech.* May 1957: 507–532.
- SCHALLER, G.B. 1972. *The Serengeti Lion*. University of Chicago Press, London.
- SCOTT, J. 1985. *The leopard's tale*. Elm Tree Books, London.
- SMITH, R.M. 1978. Movement patterns and feeding behaviour of the leopard in the Rhodes Matopos National Park, Rhodesia. *Carnivore* 1(3–4): 58–69.
- SMITHERS, R.H.N. 1983. *The mammals of the southern African subregion*. University of Pretoria, Pretoria.
- VAN ROOYEN, N., VAN RENSBURG, D.J., THERON, G.K. & BOTHMA, J. DU P. 1984. A preliminary report on the dynamics of the vegetation of the Kalahari Gemsbok National Park. *Suppl. Koedoe* 27: 83–102.
- VAN ROOYEN, N., VAN RENSBURG, D.J., THERON, G.K. & BOTHMA, J. DU P. 1988. A checklist of flowering plants of the Kalahari Gemsbok National Park. *Koedoe* 31: 115–135.