ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

SOME ASPECTS OF CARNIVORE ECOLOGY AND EPIDEMIOLOGY IN THE BALE MOUNTAINS, ETHIOPIA

ERMIAS ADMASU BEYENE

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ECOLOGICAL AND SYSTEMATIC ZOOLOGY, ADDIS ABABA UNIVERSITY

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ABSTRACT

The generalist pathogens of carnivores particularly rabies and canine distemper caused significant mortality to an endangered carnivore, Ethiopian wolf (*Canis simensis*), in the Bale Mountains, Ethiopia. For a full understanding of the epidemiology of these pathogens, the ecology and behaviour of both the hosts and the pathogens must be known. However, appropriate data to quantify the likelihood of transmission between hosts in most ecological studies are lacking. Furthermore, when considering carnivore pathogens, the ecology and behaviour of many smaller carnivores such as civets and mongooses are relatively unknown. Thus, there is a clear need for an intensive study of the behaviour and ecology of a guild of wild carnivores in the Bale Mountains.

Carnivore ecology and epidemiology were studied in the Bale Mountains, Ethiopia. Eight golden jackals (*Canis aureus*), five white-tailed mongooses (*Ichneumia albicauda*), one marsh mongoose (*Atilax plaudinosus*), one African civet (*Civitictis civetta*) and one common genet (*Genetta genetta*) were radio-tracked from November 1998 to March 2001. A total of 950 animal locations were obtained. The average home range size for female jackals was 36 km^2 and for males 35 km^2, range from 7.87 to 64.76 km^2. The home range size for adult males' white-tailed mongooses averaged 3 km^2, range from 1.11 to 4.27 km^2, and the adult female used an area of 2.63 km^2. The only tracked marsh mongoose, African civet and common genet used an area of 3.93, 11.06 and 1.71 km^2 respectively. Home ranges overlapped greatly both within and between species although territoriality among male white-tailed mongooses was demonstrated. Golden jackals and white-tailed mongooses were observed most of the time alone. Male -female pairs were the most frequently observed social groups in both species. Inter-specific interaction among wild carnivores, and between wild carnivores and domestic dogs were observed. The frequency of contacts was higher among

domestic dogs, golden jackals, white-tailed mongooses and spotted hyaenas. The pattern of habitat use during denning activity and foraging activity by the radiotracked species was different. Golden jackals used densely covered forests and bushes as denning sites where as they used all habitats during foraging. White-tailed mongooses used underground dens and empty houses for resting but the species intensified its foraging activity in grasslands. The marsh mongoose exclusively used underground dens along the riverbank as denning sites whereas it used riverside habitats as foraging areas. The civet exclusively rested in dense bushes where as the genet largely found resting in trees. Scavenging by the civet and the genet was frequently observed. The microhabitats were particularly important both as denning sites and foraging areas for most species, except for the genet and civet, which exhibited a similar pattern of use of microhabitats and area habitats. The mean density of golden jackals in the highlands and lowlands around the Bale Mountains National Park were the same (1.4 indiv. /km^2). The mean density of domestic dogs was 6.39 and 2.15 individuals/km^2 in the highlands and lowlands respectively. The population abundance of golden jackals, spotted hyaena and white-tailed mongoose was relatively high. Analysis of Sera sampled from wild carnivores around the Bale Mountains National Park from 1998-1999 suggests that the carnivore species had been exposed to canine viruses. Large proportion of the sampled golden jackals and Ethiopian wolves were seropositive to canine distemper, canine adenovirus and canine parvovirus. The study established that there is a potential for disease transmission between wild carnivores, and from domestic dogs to wild carnivores.

1.0 INTRODUCTION

1.1. Disease and Conservation Biology

Infections by pathogens are common in both wild and captive animals (Primack, 1998). Despite the potential importance of disease in the population dynamics of endangered species, it has until recently received little attention in conservation biology (Scott, 1988). Population declines due to pathogens have been reported in different species such as harbour seals (*Phoca vitulina*) - phocine distemper virus (Dietz *et al.*, 1989), lions (*Leo leo*) - canine distemper virus, CDV (Roelke-Parker *et al.*, 1996), buffalo (*Syncerus caffer*) - rinderpest (Kock *et al.*, 1995), Australian frogs - unknown virus (Laurance, 1997), in endangered populations of Black-footed ferrets (*Mustela nigripes*), CDV (Throne & Williams, 1988), African wild dogs (*Lycaon pictus*) - rabies (Gascoyne *et al.*, 1993; and Arctic foxes (*Alopex lagopus*) - mange (Goltsman *et al.*, 1996).

Pathogens can have a direct effect on population persistence by causing weakened physiological condition and a lower probability of survival and reproduction (Laurenson *et al.*, 1997; Primack, 1998). They can also indirectly affect by influencing behaviour, movement, and social systems (Laurenson *et al.*, 1997). In many of the earlier mentioned examples, an outbreak of disease has been evident when a generalist pathogen, which infects a range of host species, spreads from a reservoir host into a new susceptible species (Dobson & Miller, 1989). Generalist pathogens present the single greatest threat to small populations and endangered species because pathogens that specialise on few host species can not be maintained in rare isolated populations (Laurenson, *et al.*, 1997; Primack, 1998). Despite the various harmful effects of pathogens, they work within a framework of constraints largely determined by the virulence of a disease and the population density of the host species (Primack, 1998). Nonetheless, it is often difficult for biologists to predict the virulence of a disease, particularly if the environmental factors and the population are altered by the activities of people.

The principles of epidemiology have three important implications for the management of a disease in species of conservation concern. First, a high rate of contact between the host and the parasite promotes the spread of disease. Second, indirect effects of habitat destruction through deterioration of habitat quality and food availability, leading to lowered nutritional status, weaker animals and increased susceptibility to infection, can increase an organism's susceptibility to disease. Third, the occurrence of contact between two species that would rarely or never encounter in the wild enhances the transmission of disease from one species to another (Macdonald, 1996).

Disease can also be transmitted from domestic animals to wild populations as areas are fragmented and human activities affect the landscape. In the Bale Mountains National Park, local people and their domestic dogs live inside the park and have become sympatric with the world's most endangered canid, the Ethiopian wolf (*Canis simensis*). Canid diseases such as rabies and canine distemper virus are known to occur in domestic dogs in the area (Teshome Mebatsion *et al.*, 1992) and canid diseases were recognised as a potential threat to Ethiopian wolf (Gotelli & Sillero-Zubiri, 1992; Laurenson *et al.*, 1997).

1.2. Bale Mountains National Park and the Ethiopian wolf

Little information was available on the natural history of the Bale Mountains until the 1950's. During the 1950's and 1960's scientific expeditions were made by various explorers and scientists to describe the flora and fauna of the Bale Mountains National Park (BMNP), particularly on the status and distribution of the endemic Ethiopian wolf and Mountain nyala, *Tragelaphus buxtoni* (Brown, 1964c, 1966; Malcolm, 1976, 1977; Morris and Malcolm, 1977; Yalden et al., 1980).

Yalden et al., (1976; 1977; 1980; 1984) and Hillman (1986) reported that the BMNP contains at least 46 mammal species and 160 bird species of which 17 mammals and 16 birds are endemic to Ethiopia. The herpetofauna and invertebrates remain poorly known. Fifteen of the mammal species are rodents (32 % of total), and 13 are carnivores (28 % of total). With the exception of the Ethiopian wolf, the ecology and behaviour of the carnivores have not been studied in any detail.

The first recorded account of the Ethiopian wolf in the Bale mountains is that of the Finish geographer Heimer Smeds who traveled across the Sanetti Plateau several times during the 1950's (Smeds, 1959). The first attempt to estimate the population size of the Ethiopian wolves in the BMNP was made by Dr. James Malcolm during the 1970s. Malcolm (1977) estimated that the population of the Ethiopian wolf in the Bale Mountains was between 350 and 475 individuals. Ten tears later, Malcolm (1987) re-assessed the population status of the Ethiopian wolf in the BMNP and reported that it had remained stable or even increased in numbers. In 1983, Hillman initiated the Bale Mountains Research Project to formulate a management for the BMNP (Hillman, 1987). He established a systematic monitoring program for Ethiopian wolves, which continues to the current day.

Sillero-Zubiri (1994) made a detailed study of the behavioural ecology of the Ethiopian wolf in the BMNP for more than a decade. This study focused on the biogeography, foraging strategy in relation to resource use, the role of habitat constraints in the distribution, evolution and/or maintenance of sociality, the reasons for territoriality and the function of scentmarking in territory maintenance, dispersal and philopatry, the evolution of mating systems and the costs and benefits of co-operative breeding.

The BMNP harbours 90 % of the Bale wolf population whereas the remaining 10 % exist outside the boundaries. The number was reduced about 50 % to 205-270 by 1992 from an estimated 440 adult wolves in 1990 (Sillero-Zubiri and Macdonald, 1997). The most important factor for such decline is a rabies epidemic that occurred in the early 1990's (Sillero-Zubiri and Macdonald, 1997). The wolf population further declined to 120-160 adults by 1995 (Sillero-Zubiri, 1995). Nonetheless, there are signs of subsequent recovery in the area, particularly after the launching of a dog vaccination program against rabies and canine distemper in and around BMNP (Pers. comm.)

1.3. Livestock in the Bale Mountains

Bale is known for its cattle population and the domestic cow is the most common large herbivore in the main mountain massif. Hillman (1986) estimated the total number of livestock inside the park at 10,500. Cattle roamed over the montane grassland with no attendance by shepherds. Sheep and goats looked after by children grazed in the steep valleys and ridges, and horses and donkeys are mainly found in marshes in small numbers. Smeds (1959) described pastoralists in Bale took their cattle for pasture to the highlands of the BMNP during the wet season when their lands in the lowlands had been covered by wheat crops and herds are taken to the lowlands to feed on the fallow fields during the dry season. However, the subsequent development of extensive agriculture in the surrounding plains of the park witnessed the change in the historical practice of using the mountains on a seasonal basis for pasture and that they have become permanent dwellers as predicted by Brown

(1966). This has taken place during the last two decades and has increased the human population of the park (Sillero-Zubiri, 1994).

1.4. Domestic dogs in the Bale Mountains

Farmers in the Bale Mountains keep dogs to guard their livestock from predators but most of these dogs are unattended by their owners, rather living on offal and carrion (Sillero-Zubiri and Macdonald, 1997). The highest density of dog population is found in and around Dinsho village and in the Web valley (Sillero-Zubiri, 1994). Dogs pose a threat to both wildlife and domestic animals in the BMNP. Dogs kill both antelopes and sheep in the Dinsho village (Pers. obs.). They also act as reservoir for canid diseases (Teshome Mebatsion *et al.*, 1992) and hybridise with Ethiopian wolves.

1.5. Farming system in the Bale Mountains

A biannual farming system is widely practiced by farmers inhabiting the higher altitudes of the Bale Mountains because the southern and southeastern part of Ethiopia experience a bimodal precipitation regime (Wesche, 2000). The first farming period begins in April and ends in June where as the second one occurs during the main rainy season from July to November. The dominant crop growing in the area is barely followed by wheat. In addition to these, farmers also grow oats, garlic and vegetables as minor crops.

1.6. Ecology and behaviour of jackals

The three species of jackals- golden jackals (*Canis. aureus*), black backed jackals (*C. mesomelas*) and side-stripped jackals (*C. adustus*)- occur sympatrically in Africa (Kingdon, 1977). However, golden jackals also occur in Asia (Macdonald, 1983; Pouche *et al.*, 1987).

The ability for the coexistence of the three species of jackals is niche differentiation with respect to habitat use, activity patterns and feeding ecology exhibited by each species (Macdonald, 1979; Smithers 1983; Pouche *et al.*, 1987). Studies conducted on jackals in the different parts of Africa have observed segregation of habitat use among all three species of jackals. Black-backed jackals frequently inhabit closed wooded habitats, golden jackals prefer to use open savannah country and side-striped jackals are mostly found in well-watered woodland habitats (Rosevear, 1974; Kingdon, 1977; Smithers, 1983; Moehlman, 1983, 1986; Fuller *et al.*, 1989).

Temporal and spatial variation on the food habits of all the three species of jackals were also reported in different areas. Black-backed jackals and side-striped jackals were dependent both on animal and plant materials in Southern Africa (Smithers, 1983). In the Serengeti, when large ungulates and dung beetles are abundant, two species of jackals (golden jackals and black-backed jackals) show similar food habits but during August-December, they differed in their diets in areas where they overlap (Wyman, 1967).

All the three species of jackals were more active during sunrise and sunset but inter-specific variation in activity patterns has been reported in different areas by different researchers. A study by Fuller *et al* (1989) on a private ranch in Nakuru, Kenya, revealed that golden jackals were less active at mid-night than black-backed jackals and side-striped jackals. Golden jackals were observed to be active during the middle of the day in the area. In Bangladesh, Golden jackals were nocturnal in areas where the human population was high (Pouche *et al.*, 1987).

Variations exist on the social behaviour of jackals. Due to the selective pressure acting on different classes of individuals within each society, the social system of jackals is dynamic in nature (Betram, 1976). However, there is lack of information to define the limits of flexibility for the social systems of each species of jackals (Moehlman, 1986). Golden jackals and black-backed jackals show similarity in most respects of their social system. They are monogamous, territorial, and yearling offsprings serve as helpers (Moehlman, 1986; Estes, 1991). But alloparental behaviour is more pronounced in the black backed jackal (Moehlman, 1986). The other species, side-striped jackal, is relatively unknown. It occurs in well-spaced pairs and family units up to six. However, numbers from eight to twelve have been counted at kills or scavenging offal outside towns (Estes, 1991). Nothing is known about the alloparental behaviour of yearling offsprings.

Golden jackals have a comparatively close and peaceful family relationship. They are capable of forming different and larger social groups under special conditions in which an abundant, localised source of food is available (Macdonald, 1983). In Israel where food was provisioned for the jackals, Macdonald (1979a) reported groups of 10 to 20 golden jackals, with several breeding individuals. Moehlman (1986) described the Serengeti golden jackals as monogamous, with non-breeding adults up to four in the family group that care for their younger siblings. The capacity for maintaining large groups might have evolved as an adaptation for the exploitation of patchy food resources through co-operative defence (Macdonald, 1979a).

1.7. Ecology and behaviour of mongooses

Mongooses are widely distributed in the Old World tropics, especially in Africa. Four genera - *Galidia*, *Galidictis*, *Mungotictis* and *Salanoia* - are endemic to Madagascar, and all the remaining genera are represented in Africa. Eleven of the seventeen genera and seventeen of the thirty-six species are found only in Africa, making the continent the land of the mongoose (Estes, 1991). One genus, *Herpestes*, is widely distributed in Asia, and *Herpestes auropunctatus* has been introduced into the West Indies and several other Pacific islands.

Mongooses are opportunistic feeders. Most will take a variety of small prey both invertebrate and vertebrate. In few species of mongooses, plant materials also constitute a major portion of the diet. Study on the winter diet of the small Indian mongoose (*Herpestes auropunctatus*) on the northern Mediterranean Island reveals the importance of plants in the composition of the diet (Cavallini and Serafini, 1995). Vertebrates (46 % by volume, mostly murine rodents) and plant matter (43 % by volume, mostly fruits) dominated the diet (Cavallini and Serafini, 1995). The main diets of the seventeen genera of mongooses are reviewed by Rood (1986). The relative proportions of dietary items in each species of mongooses frequently vary temporally and spatially. For example, the *Herpestes* species preferred small vertebrates, especially rodents when available (Ewer, 1973; Rood and Waser, 1978; Gorman, 1979; Nellis and Everard, 1983). However, in areas where there are few small vertebrates, invertebrates predominate in the diet (Gorman, 1975).

Defining the social unit of some mongoose species is difficult. Most mongooses are either solitary or group-living. However, there are some species of mongooses that do not fit to those categories. The four Malagasy mongooses and *Cynictis pencillata* from South Africa are considered as living in " pairs ". Since the male is an integral part of the social unit, they are often seen in pairs or family groups. However, they frequently forage alone and might be classified as solitary (Rood, 1986). Waser and Jones (1983) observations on *Cynictis* and *Mungotictis* suggest that individuals may be members of social units that are more complex than a simple family unit. Earle (1981) reported *Cynictis* colonies of about eight individuals including a dominant male and female. Most species of mongooses are solitary, but eight species in four genera - *Helogale*, *Crossarchus*, *Mungos* and *Suricata* - travel and den in cohesive groups (Rood, 1986). Such groups contain several adult males and females. Of the many species grouped under the four genera, the social structure of the dwarf mongoose, *Helogale parvula*, is well documented (Rood, 1983).

Rood (1986) divides all species of mongooses into seven ecological categories. The ecological traits used for classification are

(1) Size: - large (adult weight > 2 kg) or small (adult weight < 2 kg);

(2) Time of Activity: - primarily diurnal or primarily nocturnal, and

(3) Diet: - primarily insectivorous or primarily a small vertebrate feeder.

Group-living mongooses are all small, diurnal, and insectivorous. No solitary species but three pair-living forms (*Cynictis*, *Mungotictis* and *Salaonia*) combines these traits. All the group living mongooses, but *Crossarchus* and many solitary species, live in open habitats. While the group living species share ecological traits, the solitary forms show great variability. The reason for great flexibility in the ecological features of the solitary species is mainly due to adaptive radiation in the widely distributed genus *Herpestes* (Rood, 1986). The fourteen species of *Herpestes* all feed primarily on small vertebrates, but they vary in habitats, body size and activity cycle. Six species are small, diurnal and vertebrate feeders. The remaining solitary mongooses, which can be classified as *Ichneumia*, *Rhynchogale*, *Bdeogale*, *Paracynictis*, and *Atilax*, are all nocturnal. All except *Atilax* are insectivorous.

Studies on the food habits of individual mongoose species indicate the importance of beetles in the diet of most insectivorous forms (Lynch, 1980; Waser, 1980; Rood, 1983; Waser and Waser, 1985; Ray, 1997). The large herds of African ungulates attract high abundance of dung beetles. These are important food source for the mongooses (Rood, 1986).

Home range size tends to be larger in group-living than solitary mongooses but intraspecific variation is great. This is much due to differing habitats, food dispersion and population densities in different ecosystems (Rood, 1986). In open areas where food is sparsely distributed, mongoose densities are low and home ranges are large. Notable examples that show the variation in the population density of mongooses depending on the type of habitat came from studies conducted in the banded mongooses in short grass plains of Kirawira, Serengeti and Queen Elizabeth park, Uganda (Rood, 1975 cited in Rood, 1986; 1983). On the open Serengeti short grass plains where food and cover are relatively in short supply, banded mongoose densities are low (ca. $1/km^2$, ranges approximately 15 km^2, daily movement about 10 km). On Mweya Peninsula, in Queen Elizabeth Park, Uganda, food resources particularly millipedes and dung beetles, and cover are abundant. Banded mongoose densities here are high about $17/km^2$, ranges average 0.8 km^2 and the packs move approximately 2.3 km per day. Comparison of the population densities of dwarf mongooses in two different ecosystems of Tanzania, Kirawira and Sangere, revealed a similar result. Dwarf mongoose densities are considerably lower in the more open habitat of Kirawira than the Acacia-Commiphora woodland of Sangere area. Ranges are larger in Kirawira than Sangere area.

Ranges traversed by terrestrial small carnivores tend to overlap considerably depending on the population density and dispersion and abundance of food. A good explanation for such argument can be obtained by looking in detail the spacing patterns of white-tailed mongooses as an example. The social unit of the white-tailed mongooses is considered as solitary (Rood, 1986), but their spacing patterns vary depending upon the given set of ecological conditions in which they are exposed. For instance, exclusive or nearly exclusive females' ranges greatly overlapped with males' ranges along the eastern edge of Kirawira whereas in the western and central part of the study area where the population of *Ichneumia* was high, more than two adult females share ranges (Waser and Waser, 1985). In less populated areas, young either fail to stay in the natal ranges or tend to disperse into adjacent areas that are unoccupied by other members of the same species. But, when the population of mongooses in the area is high, the young may continue to use the natal range and young males and some females later disperse and become wanderers until they find a breeding opportunity (Waser and Waser, 1985).

Different people proposed several ideas for the tolerance of range overlap by small carnivores in general. Waser and Waser (1985) hypothesised that where population densities of small carnivores are relatively high, ranges tend to overlap more, particularly those of females. On a similar vein, the tolerance of overlap in home range could be made possible by richer food patches (Macdonald, 1983), or rapid renewal in resources (Waser, 1981).

1.8. Justification and Aims of the study

Infection by disease organisms can arise from microparasites such as viruses, bacteria, fungi and protozoa, and larger macroparasites such as helminth worms and parasitic arthropods (Primack, 1998). The generalist pathogens of carnivores that are of particular importance from a conservation point of view are rabies and canine distemper virus, although other pathogens such as anthrax, canine adenovirus and canine parvovirus can also cause significant mortality (Laurenson *et al.*, 1997). For a full understanding of the epidemiology of these pathogens, the ecology and behaviour of both the hosts and the pathogens must be known. For example, the likelihood of transmission between hosts is dependent on the transmission mechanism of the pathogen and thus on the type of contact between individuals, as well as the frequency of contact. However, appropriate data to quantify the likelihood of transmission between hosts in most ecological studies have not been collected. Furthermore, when considering carnivore pathogens, the behaviour and ecology of many smaller carnivores such as civets and mongooses are relatively unknown. For example, we do not know the density at which these small carnivores occur, let alone how range overlap or how frequently contacts occur between individuals. Thus, there is a clear need for an intensive study of the behaviour and ecology of a guild of sympatric carnivores. This will lead to a greater understanding of resource use, niche overlap, contact rates and the potential for inter- and intra-specific pathogen transmission.

An opportunity to conduct research on the behaviour and ecology of a guild of sympatric carnivores in an ecosystem where disease poses a major threat to an endangered carnivore exists in the Bale Mountains National Park, Ethiopia. The BMNP and its surroundings harbour a diverse guild of sympatric carnivores. Species include: spotted hyena (*Crocuta crocuta*), golden jackal (*Canis aureaus*), African civet (*Civitictis civetta*), common genet (*Genetta genetta*), white-tailed mongoose (*Ichneumia albicauda*) and sympatric domestic dogs. These are all susceptible to generalist carnivore pathogens. The BMNP, apart from being home to a diverse guild of wild carnivores, also contains the largest population of the Ethiopian wolf, the world's most endangered canid. Threats to the Ethiopian wolf include destruction of the habitat for fuel wood and subsistence agriculture and overgrazing by cattle, and direct persecution and hybridisation with domestic dogs. These factors could in the long term pave the way for local extinction. This population has recently experienced dramatic declines due to the epidemics of rabies and canine distemper. Carnivore pathogens pose the most immediate threat to this population. This study of carnivore behaviour and ecology works synergistically with an ongoing epidemiological project that commenced in November 1997 that aims to establish which species is the reservoir for rabies, canine distemper and canine adenovirus, what is the effect of vaccination on domestic dog population dynamics and what factors affect inter- and intra-species transmission?

This study is the first of its kind on small nocturnal carnivore ecology and epidemiology in the afroalpine habitat. It also enriches the available limited information in conservation biology about carnivore pathogens. Data are collected on the ecology and epidemiology of diseases of a guild of sympatric carnivores in and adjacent to the BMNP. The following questions are addressed in this research:

(1) What is the ecology of golden jackals and white-tailed mongooses with respect to habitat use, home range size, activity patterns and sociality?

(2) How is the intensity of intra- and inter-specific contact rates with respect to the transmission modes of canid pathogens?

(3) What are the densities of spotted hyena, golden jackal, African civet, common genet, and white-tailed mongoose in and adjacent to the park?

(4) By combining ecological and behavioural data from this study and serological data from the epidemiological project, assess which species are likely to act as reservoirs and transmit disease to Ethiopian wolves?

2.0. MATERIALS AND METHODS

2.1. The study area

2.1.1. Location

The study area, the Bale Mountains National Park (BMNP) is located Southeast of the Rift Valley about 400 km by road from the capital Addis Ababa (Fig. 1). The Bale Mountains includes the largest area of the afroalpine habitat on the African continent and over 4000 km above 3000 m (Sillero-Zubiri & Macdonald, 1997). At present, the park covers an area of 2200 km^2, with an altitudinal range from 1600-4377 m asl (Hillman, 1987). The highest peak is Mount Tulu Deemtu, the second highest peak next to Ras Dashen in Ethiopia (Fig. 1).

The study is based around the BMNP Head-Quarter (HQ), Dinsho, with an altitudinal range from 3000-3500 m asl and encompassed by coordinates (7 ° 3' 40'' – 7 ° 10' 28'' N and 39 ° 38' 30'' – 39 ° 50' 31'' E; Fig. 2). It encompasses an area of 153 km^2 (Northern Gaysay area = 56 km^2; the remaining area = 97 km^2). It stretches 14 km from north to south and 18 km from east to west. This had the benefit of carrying out the study without the use of a vehicle.

2.1.2. Climate

The climate of the BMNP shows considerable variation due to the great altitudinal gradient within the park and the large extent of the mountain massif (Hillman, 1986). The rainfall is characterised by eight months of wet season from March to October (Daniel Gamachu, 1977). Temperature shows altitudinal gradient within the park from -3 to 24°C at lower altitudes and from -15 to 26°C at higher altitudes in the dry season (Hillman, 1987). There is a relatively narrower range in the diurnal temperature from 5 to 20°C.

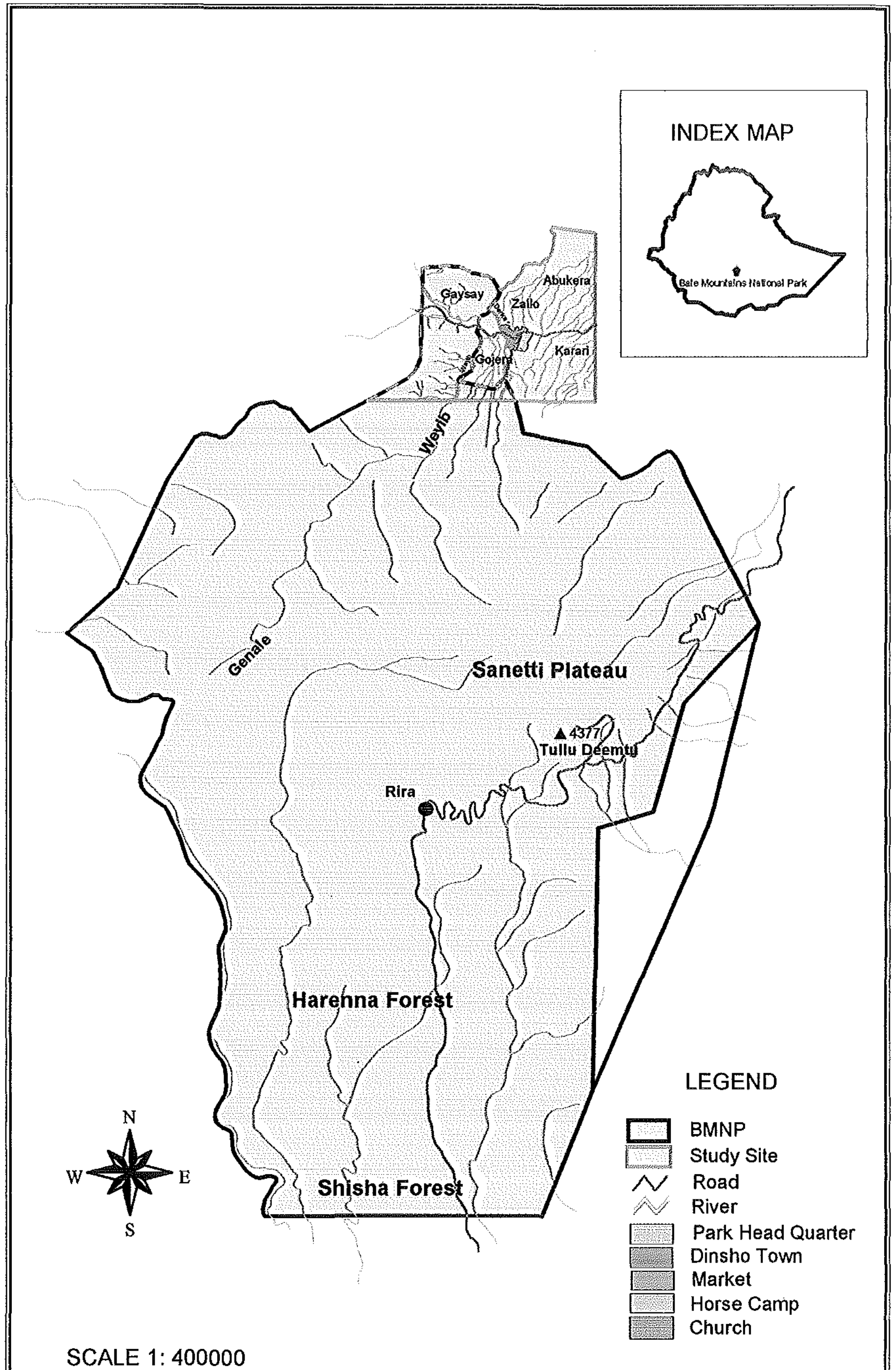

Figure 1. LOCATION MAP OF THE STUDY SITE

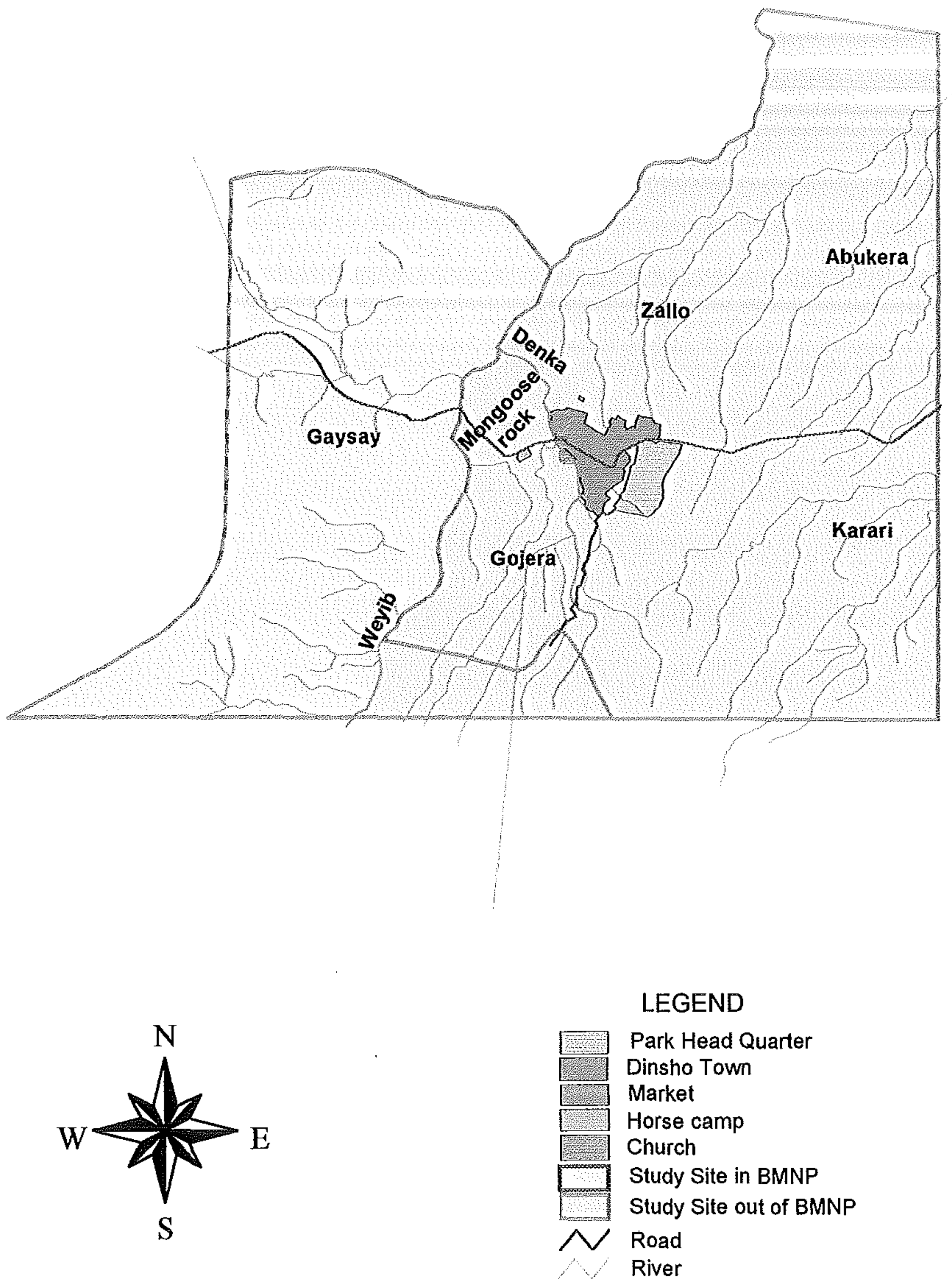

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Figure 2. MAP OF THE STUDY SITE

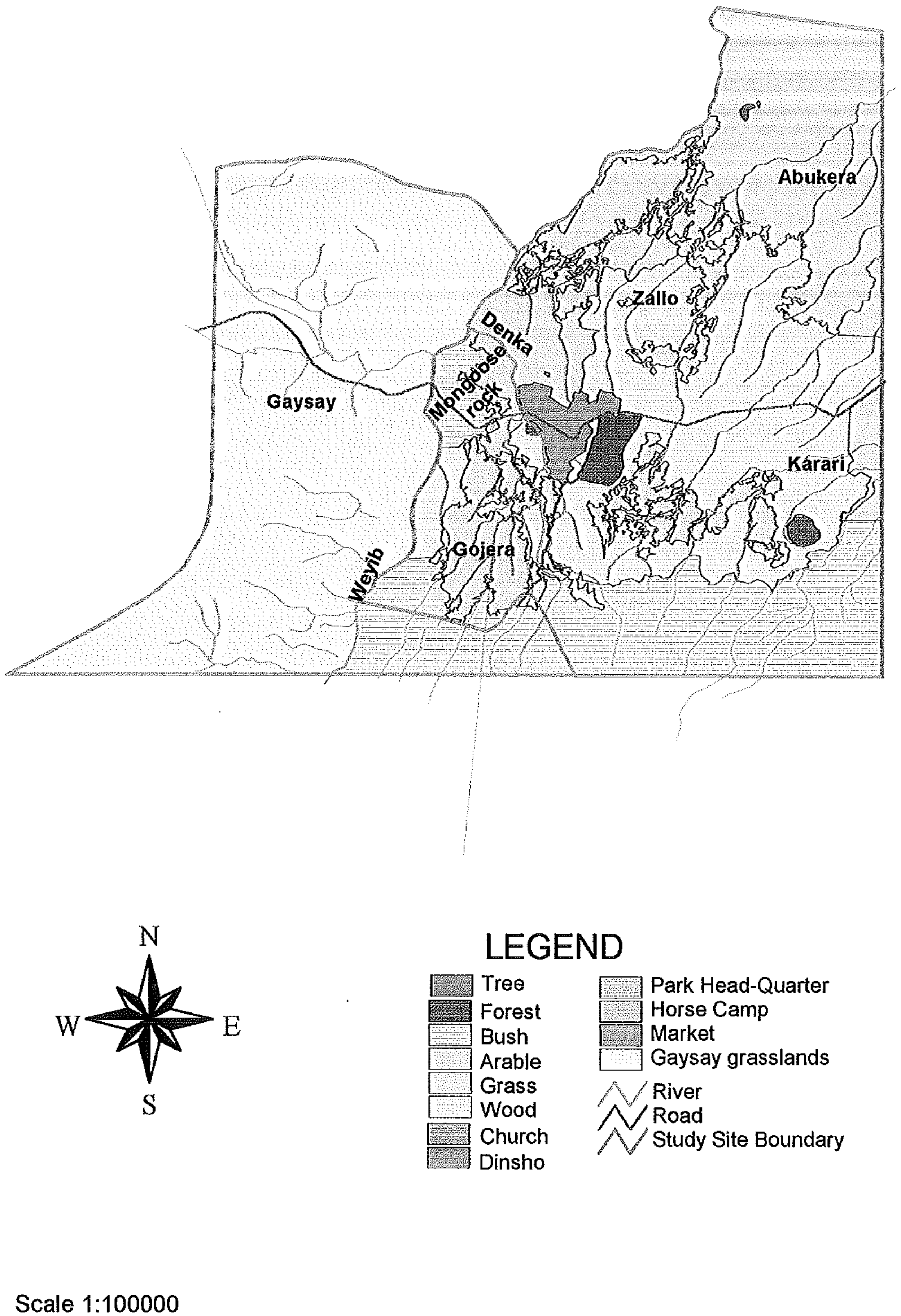

Figure 3. VEGETATION MAP OF THE STUDY SITE

2.1.3. Vegetation

The vegetation of the study site, excluding the Gaysay area, can be divided into five main habitat types following Pratt *et al* (1966):

1) *Hagenia/Juniperous* closed woodland
2) *Hagenia/Juniperous* open woodland
3) Open montane grassland
4) *Artemesia/Hypericum* bush and *Erica* moorland
5) Farmland

2.1.3.1. *Hagenia/Juniperous* closed and open woodland

Remnants of the original *Hagenia/Juniperous* forest of the Bale Mountains, which covers 1.5 km^2 area, are found on few protected areas within the study site such as Park HQ, Muna Muno sacred place and church (Appendix 1; Fig. 3). An open *Juniperous* woodland greatly modified by agriculture and cutting wood for fuel occurs partly in Gojera and partly in Karari regions and covers 57 km^2 (Appendix 1).

2.1.3.2. Open montane grassland

This portion of the area is observed at the present time as small relicts of the characteristic montane grassland of the Bale Mountains interspersed by arable land (Fig. 3). This is due to interference by human activities to obtain more land for agriculture. It covers an area of 12 km^2 (Appendix 1).

2.1.3.3. *Artemesia/Hypericum* bush and *Erica* moorland

This type of habitat is mainly found in the southern part of the study area (Fig. 3) and covers an area of 24 km^2 (Appendix 1). It comprises predominantly *Artemesia*, *Hypericum*, *Euphorbia* bushes and *Erica* moorland.

2.1.3.4. Farmland

Farmland comprises a large portion of the area (34 km^2; Appendix 1).

2.2. Preliminary study

Prior to the onset of the present study, carnivore trapping and radiotracking methods were tested and refined by Dr. Karen Laurenson and Dr. Simon Thirgood during January-April, 1998. The project became fully operational during October 1998. During this preliminary study, one white-tailed mongoose, one caracal, and one African civet were captured and instrumented with radio-transmitters. Unfortunately, all except the white-tailed mongoose subsequently disappeared.

2.3. Trapping and radiotagging

Trapping was carried out in two sessions: the first session took place during October-November, 1998 and the second one in March 1999. Individuals were trapped from three different sites in the study area: Gaysay area, Mongoose Rock and Park HQ. Two types of traps were used depending upon the species: double-door cage traps (Longmeadow Traps, UK, 160x40x37 cm) for mongooses, civets and genets and rubber-padded steel leg-hold traps (Victor soft catch, Woodstream Corp. Lititz, PA, U.S.A) for jackals. The cage traps were kept with the doors open for one day and prebaited on the next day. The baits used were boiled eggs mixed with peanut butter and small scraps of sheep meat. The cage traps were set to catch the small carnivores one-day after prebaiting.

Both the cage and leg-hold traps were set late in the afternoon around 6:00 p.m. The cage traps were checked only once early in the morning between 6:00 a.m. and 7:00 am. The leg-hold traps were checked every three hours during the night (2100; 2400; 0300; 0600). The longer the animal stayed in the trap, the more likely to hurt itself trying to escape. During each time interval, leg-hold traps sprung without catching were set again.

To ensure that the animals caught in the cage traps did not panic and to aid the immobilisation, the traps were covered from outside with blankets and then the animal was pushed into one side of the trap. The animals trapped in the cage traps were then anaesthetised while they were in the trap. The small carnivores captured in the soft leg-hold traps were also covered with blankets before handling.

The animals were anaesthetised by injecting subcutaneously a combination of Domitor and Ketamine using hand-held syringes. The dosage varied depending on the size and type of species. For medium-sized carnivores (jackals, caracals and civets) the dosage ranged from 0.8-1.5 ml, and for smaller ones such as genets and mongooses, it ranged from 0.3-0.9 ml. While handling the animals, species type, sex and age (on the basis of tooth wear and body mass) were determined, and body measurements (HB-TL-HF-EL-HG-CR) and body mass were taken.

The animals were equipped with neck mounted radio-collars (Biotrack Ltd., UK) transmitting on 173 MHz. The size of the collars varied depending upon species. Large collars were used for civets and jackals while small size collars were used for mongooses and genets. The complete system weighs < 5 % of the animal for which it is designed to ensure that there are no adverse effects. Care was taken not to make the collar too loose or too tight as it might come off or affect the behaviour of the animal respectively. After handling the animals, a reversal drug, Antisedan (Pfizer) at approximately 0.15 mg/kg was injected intramuscularly to reverse the effects of Domitor and aid rapid recovery. None of the animals were dead due to the anaesthetising.

2.4. Radiotracking

During tracking periods, each animal was located at least three times each week. During nightime tracking, the individual carnivore was followed for a maximum of three hours. The individual animal was followed by detecting the radio signal emitted from the radio-transmitter attached to the collar and fitted on the neck of the animal using a hand-held receiver (Telonics, TR 4, Mesa, Arizona, U.S.A) and a 3-element Yagi antenna (Biotrack, UK). Follow of the direction of the signal was carried on foot until a strong signal was detected where a locational fix was taken using a hand-held GPS (Global Positioning System) (Garmin 48; 1200E. 151st Street, Olathe, Kansas 66062, U.S.A). When visual contact was difficult, estimation of the animal's position was determined using a compass. Attempt was made to evenly spread the timing on each individual followed from dusk until dawn. When following, an attempt was made to keep in continuous contact with the individual either visually using a spot light or with the radio. Care was taken not to disturb the tracked individual. During the daytime, resting sites or dens were located only once except for few occasions where animals were observed to have become active in the day time, in which case more than one fixes were taken for the individual. Start time and stop time of each follow was recorded. As far as possible, data on location fixes, visibility, activity on fix, habitat use (point and area habitat) and sociality was recorded every fifteen minutes. While the individual was in visual contact, the duration of visibility (frequency) and any behaviour with reference to the transmission modes of canid pathogens were recorded.

2.5. Home range analysis

Minimum Convex Polygon (MCP) was used to estimate the home range size of the animals (Mohr, 1947). The minimum convex polygon estimates the home range size of the animals by connecting the outer most points of the animal's locations (Harris *et al.*, 1990). Harmonic Mean (HM) method has been developed for the accurate calculation of centres of activity, representation of range use. In cases when a number of locations are large enough, harmonic mean, with 95 % of locations to exclude possible outliners, was used to determine home range size (Harris *et al.*, 1990).

For home range calculation, the tracked individuals of each species were divided into two classes on the basis of age (subadult and adult). A home range analysis computer program called TRACKER was used to calculate the home range size, core of activity and range overlap of the radio-tracked individuals. Life time range (i.e. calculated for the entire period of radiotracking) for each radiotracked individual was calculated using 100 % MCP and 95 % HM methods. Harmonic mean method (with 50 % of locations) was used to determine the size of core areas.

Range overlap between pairs of Intra- and inter-specific individuals tracked for the same period was calculated to examine the extent of sharing the same resource and the rate of contact between these guild of wild carnivores with the potential for transmission of canid diseases.

2.6. Social interactions

When the tracked individual was in close proximity to another individual (detected either visually or with the receiver) of the same species or different species, the group size and proximity to the nearest neighbour was recorded. Distance estimated to the nearest neighbour was grouped under four classes: (1) together; (2) near - less than 20 m; (3) medium - between 20 and 100 m; (4) far - greater than 100 m. The frequency of locating animals together and in various lengths of distance was calculated to estimate the rate of social contacts (both intra- and inter-specific). In addition to these, while the animal was in visual contact with the observer, any behaviour observed, especially with reference to the transmission modes of canid pathogens, was recorded. Moreover, the percentage of range overlap between individuals tracked for the same period was used to identify the formation of social groupings or families among members of the same species and to determine the potential for social contacts between individuals of the different species.

2.7. Habitat use and selection

Habitat distribution of the study area was made using GIS (Geographic Information System) after conducting UTM/UPS readings of the different habitat types on the ground. The vegetation map was then superimposed on the digitised topographical map of the study site. Two methods were used to predict habitat utilisation of the given individual.

(1) Two types of data on habitat use (micro-habitat and macro-habitat) were collected during tracking the animals. Micro- habitat type (defined as habitat type found within 3 m radius from each location fix) was recorded only when visual contact with the individual was possible. Macro- habitat type (defined as habitat type found within 20 m radius from each location fix) was recorded both during visual contact and non-contact with the animal. For each habitat category, the type, height and cover/density of the vegetation were recorded.

The pattern of habitat use during resting (defined as the period during which the animal became inactive) and activity (defined as the period during which the animal was active) was determined. A resting site corresponded to a location of an animal during resting. Inactive animals were distinguished from active animals by a constant signal strength and same position for > 45 minutes.

(2) An index of habitat selection was calculated using Jacobs Index (1974) from the following formula. The index identifies whether a given population prefers to or avoids a certain habitat:

S = (U-A) / {(U+A) - [2 x (U x A)]} where S = Selection

U = proportion of use of habitat type x

A = Proportion of habitat type x available in the home range of the animal

Habitat availability within individual home ranges was calculated by dividing the area occupied by habitat type x to the total area occupied by the different habitats available in the home range of the animal. Gayay area was not considered for calculation of selectivity because none of the animals crossed the Web River. A cartesian grid over the vegetation map was used to count the distribution of fixes in the different habitats found in the animal's home range. Selection is defined as the relative difference between the use and availability of a habitat type and gives an index of habitat selection (Jacobs, 1974). The value of S ranges from -1 to +1, values between -1 and 0 indicate avoidance of that habitat, and values between 0 and +1 indicate preference for that habitat.

2.8. Density Estimation

2.8.1. Trapping Index

Accurate record of trap nights and success for both leg-hold and cage traps were kept. The following suggestions were made for the leg-hold traps:

1) If the traps were sprung without catching and again triggered, it is considered as sprung.

2) If the traps were sprung without catching and nothing happens after setting again, it is considered as sprung.

3) If the traps were sprung without catching and catch after setting again, it is considered as catch.

The number of captures and recaptures in the three different sites of capture were used as an index of abundance of the carnivores when measured against effort.

2.8.2. Extrapolation from radiotracking data

Data on home range boundaries for the population of the study species allowed calculation of the species' population density in the study area. All fixes of the radiotracked individuals of the same species were combined together and then the combined home range size was calculated by connecting the outermost points of the fixes. Density was computed by dividing the number of all the radiotracked individuals of the same species including any observations of uncollared individuals by the combined home range size.

2.8.3. Opportunistic sightings

Information on any carnivore encountered, especially with reference to the transmission modes of canid diseases, during tracking and non-tracking period was recorded. Parameters recorded were date and time of observation, species, and age and sex if possible, location fix, activity and habitat type on fix. These data can also be used to get an index of abundance of the carnivores when calculated against effort.

2.8.4. Density estimation by Distance sampling

Transect lines were traversed in a vehicle during the night both in the highlands and lowlands of the Bale region. The vehicle was driven slowly (about 20 km per hour) along the predetermined routes with two observers on the back of the car flashing spotlights on either side of the road.

The following routes were covered which could be grouped as follows (Fig. 4):

Highlands	Dinsho – Garamba
	Dinsho – Homa
Lowlands	Homa – Goba
	Homa – Agarfa

For each transect route, start time, species and direction of species sighted, habitat type (point and area habitat), and perpendicular distance of the animal from the transect line were recorded. Estimation of perpendicular distance of the individual animal sighting from the transect line was practised with measured distances. Two way (i.e. forward and backward) counting of carnivore sightings was conducted with half hour break after one way drive assuming that carnivores are not fixed at the initial sighting position for long and none are counted twice.

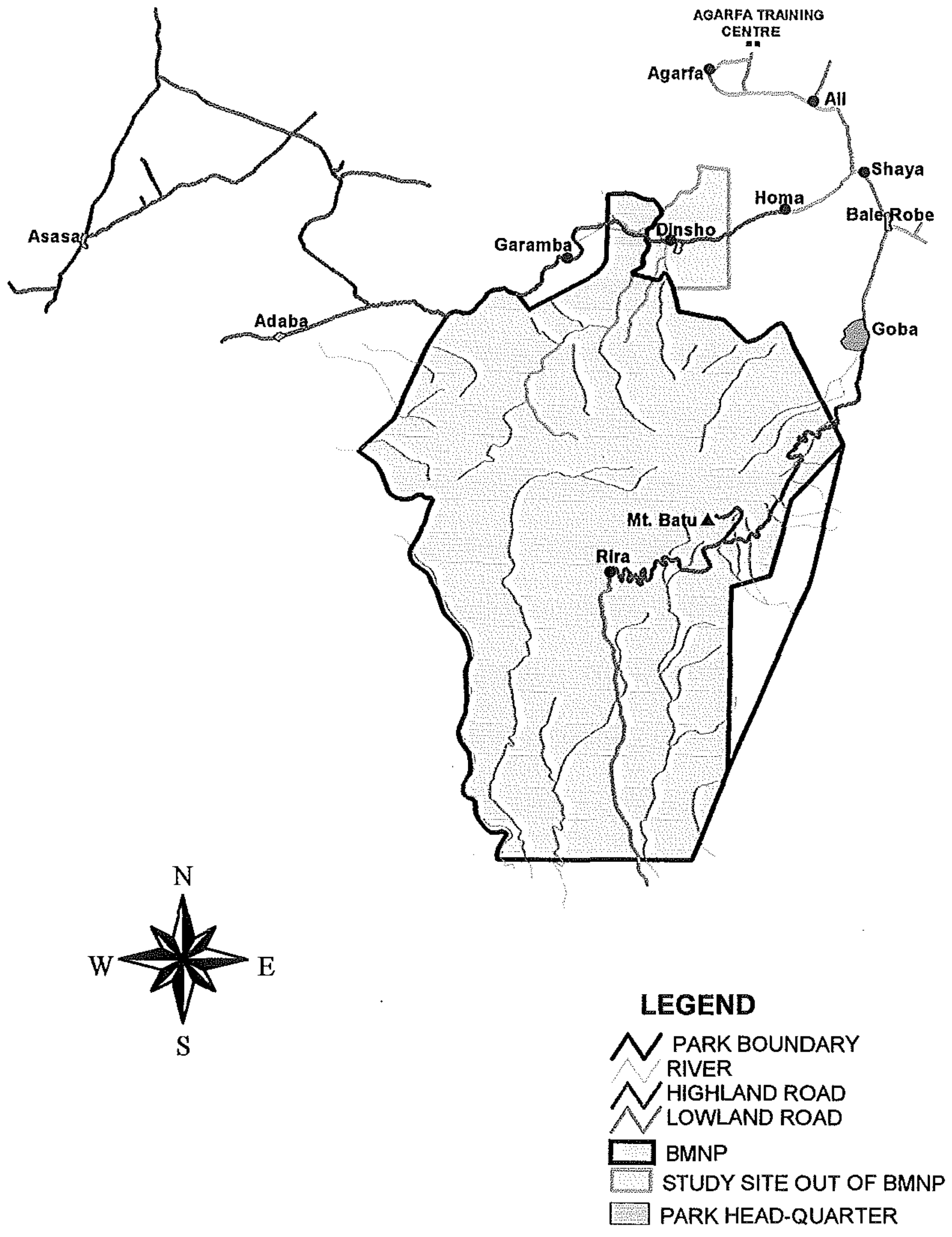

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Figure 4. Map of the spotlight transect in the study area

The following five assumptions must be fulfilled prior to the analysis of distance sampling data using distance methods:

1) Animals directly on the transect line are never missed (i.e. their detection probability is equal to one).
2) The spatial distribution of animals is random with respect to the transect line.
3) Animals are fixed at the initial sighting position; they do not move before being detected, and none are counted twice.
4) Distances are measured accurately, with no measurement error and no rounding errors.
5) Animals are correctly identified.

If all the above assumptions hold true, then one can estimate the proportion of animals missed during the counting and reach on an estimate of total abundance which can be combined with information on transect length and sampling width to generate density estimates.

Before attempting to fit a model, the data for each species was examined by plotting a histogram of perpendicular sighting distances for each transect. Following recommendations of Buckland *et al* (1993), sighting distances were truncated and grouped into distance categories to smooth the detection curve and facilitate model fitting. The data for each species on each transect was then analysed using the computer program Distance version 3.5. A mathematical model was used to describe the probability of detecting any organism. Various mathematical models have been developed that utilise distance sampling data to estimate the abundance of species (Buckland *et al.*, 1993). The mathematical models that have been shown to be useful in modelling Distance data are given below.

Key function	Series Expansion
Uniform	Cosine
Uniform	Simple polynomial
Half-normal	Cosine
Half-normal	Hermite polynomial
Hazard-rate	Cosine

The final choice of model, and associated density estimate, was based on Akaike's Information Criterion (AIC) and a chi-square goodness of fit test. In particular the Chi-square test was used to assess the fit of the model for the first two distance categories and shoulder where model fit is most critical. As judged by lowest AIC, the uniform, hazard-rate and half-normal key functions, with cosine or hermite polynomial expansion were selected for the analysis.

To obtain integrated estimates for the highland and lowland areas, transect were pooled. Contiguous transects were pooled by assigning transects undertaken in the same time period to a sampling period. The current version of Distance does not support unbalanced surveys; therefore, it was necessary to discard some transects from the analysis. For the Agarfa-Homa-Goba transect the Shaya leg of the Agarfa-Homa was also discarded, as otherwise this leg of the route would have been represented twice.

2.9. Epidemiology

2.9.1. Sampling and serology

Up to 9 ml of blood was taken from jackals and 5 ml from civets from the cephalic vein. These blood samples were allowed to clot before serum was extracted and frozen for storage. Sera from the smaller species were obtained by collecting 0.08 ml of blood in a heparinised capillary tube and then immediately diluting this 1/10 in 0.85 % saline containing 0.5 %

bovine albumin. Blood cells were sedimented before the supernatant was collected and frozen until tested.

Neutralisation tests on serum for antibody to CDV were carried out using the method of Appel and Robson (1973). The main difference was that 24 hours monolayers of Vero cells rather than suspension of these cells were used to detect the presence of the unneutralised virus. A serum neutralisation test was also used to detect antibodies to canine adenovirus 1 (CAV-1). The presence of antibodies to canine parvovirus 2 (CPV-2) was assayed by a haemagglutination inhibition test (Thompson *et al.*, 1988). Reciprocal titres of >/= 32 for CDV, >/= 64 for CPV-2 and >/= 32 for CAV-1 were considered to be sero positive.

2.10. Statistical tests

Wilcoxon-signed rank test was used to test significant difference between the different methods of home range estimation. Mann-Whitney test was used to test significant difference between home range estimates. Chi-square test at 0.05 level of significance was used to test significant difference on use between the different habitat types and among different individuals of the same species. Pearson correlation at 0.01 level of significance was used to test the relationship between number of locations and number of resting sites.

3.0. RESULTS

3.1. CAPTURE AND RADIOTAGGING

During the preliminary study, three carnivores (1 *Ichneumia albicauda*, 1 *Civitictis civetta*, 1 *Felis caracal*) were captured and radio-collared. Trapping was conducted in two sessions during the actual trapping. During the first trapping period, fifteen animals (8 *Canis aureus*, 2 *Ichneumia albicauda*, 1 *Atilax plaudinosus*, 1 *Mellivora capensis*, 1 *Ictonyx striatus*, 1

Genetta genetta and 1 *Civitictis civetta*) were trapped and equipped with radio-transmitters, and four individuals (CA9, CA12, CC3 and GG5) were recaptured, with CA9 being recaptured twice. During the second trapping session, only 2 *Ichneumia albicauda* were captured and packed with radio-transmitters, and one of them (IA13) was recaptured.

Table 1. Small carnivores trapped and equipped with radio-transmitters in and adjacent to the Bale Mountains National Park (BMNP).

Cap. code[1]	Sex	Weight (Kg)	Tooth wear	Age at capture	Capture site[2]	Notes
CA6	M	8.25	Clean	Subadult	MR	
CA7	M	7.9	Sl. tartar	Subadult	MR	
CA8	M	8.8	Sl. tartar	Adult	MR	
CA9	F	7.0	Clean	Subadult	MR	
CA10	F	7.35	Front I worn	Adult	HQ	lots of fleas
CA11	F	8.2	Upper C Sl. wear	Subadult	HQ	
CA12	F	6.5	Upper C Sl. wear	Young	HQ	
CA13	M	9.55	Sl. tartar on molars	Adult	HQ	
IA8	M	4.0	Sl. wear	Adult	HQ	
IA10	F	3.9	Sl.wear & tartar	Adult	MR	
IA11	M	3.0	Sl.tartar	Adult	MR	
IA13	M	3.95	some tartar and wear	Adult	HQ	
IA14	M	?	Clean	Subadult	HQ	
AP1	M	2.3	Clean	Adult	MR	
CC1	F	?	Sl. wear	Adult	HQ	
CC3	M	8.75	Clean	Subadult	HQ	
FC1	M	8.7	Sl. wear	Adult	HQ	
MC1	M	14.5	wear on C	Adult	G	
IS1	M	1.15	I worn & C sl. wear	Adult	MR	
GG5	F	1.95	Clean	Adult	HQ	

[1]Capture code: CA = *Canis aureus*; IA = *Ichneumia albicauda*; AP = *Atilax plaudinosus*; CC = *Civitictis civetta*; FC = *Felis caracal*; MC = *Mellivora capensis*; IS = *Ictonyx striatus*; GG = *Genetta (Felina) genetta*.

[2]Capture site: HQ = Park Head-Quarter; MR = Mongoose Rock; G = Gaysay Area

Of the radio-collared carnivores, CC1 and FC1 had disappeared; IS1 had been killed and the collar for MC1 came off the animal's neck before getting any fixes from them. The number of small carnivores trapped and equipped with radio-collars is summarised in Table 1.

3.2. HOME RANGE ANALYSIS

3.2.1. Home range size and stability

A total of 950 fixes (297 in the wet and 653 in the dry seasons) were obtained from sixteen carnivores during monitoring from November 1998 to March 2000. The number of samples collected in the wet and dry seasons and their distribution from dusk to dawn is given in appendices 2 & 3.

C. aureus

The pattern of change in range size with increasing number of fixes or increasing period of monitoring varied among various age/sex groups of *C. aureus*. The home range sizes for CA6 and CA7 (subadult males) grew continuously throughout the entire period of tracking. However, CA8 and CA13 (adult males) reached a stable home range size after six months and one year of monitoring respectively (Fig. 5).

Females also attained a stable home range size, but the time period over which they reached varied depending upon age of the animal. The two subadult females (CA9 & CA11) reached an asymptote within the first six months and the only adult female did so in December 1999 (Fig. 5). However, overall consideration of change in range size with increasing number of locations showed that ranges used by the radio-tracked *C. aureus* grew rapidly in the first four to six months of tracking and then increased slowly until it reached an asymptote for several individuals.

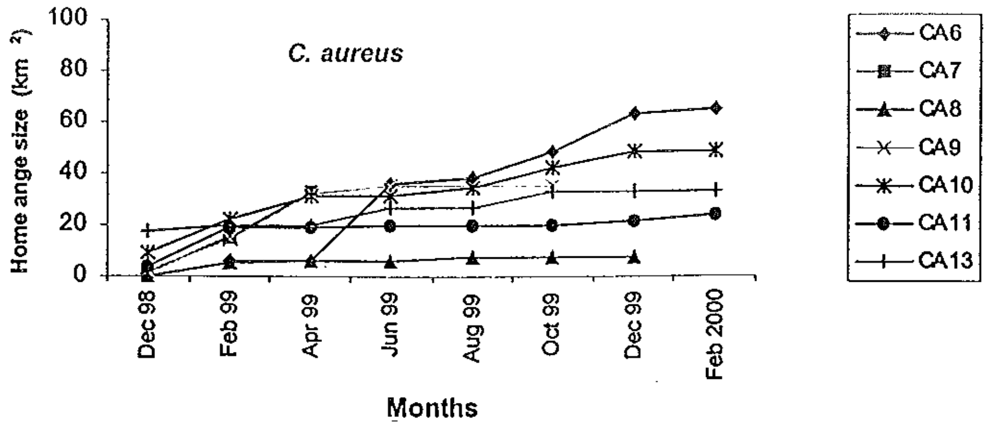
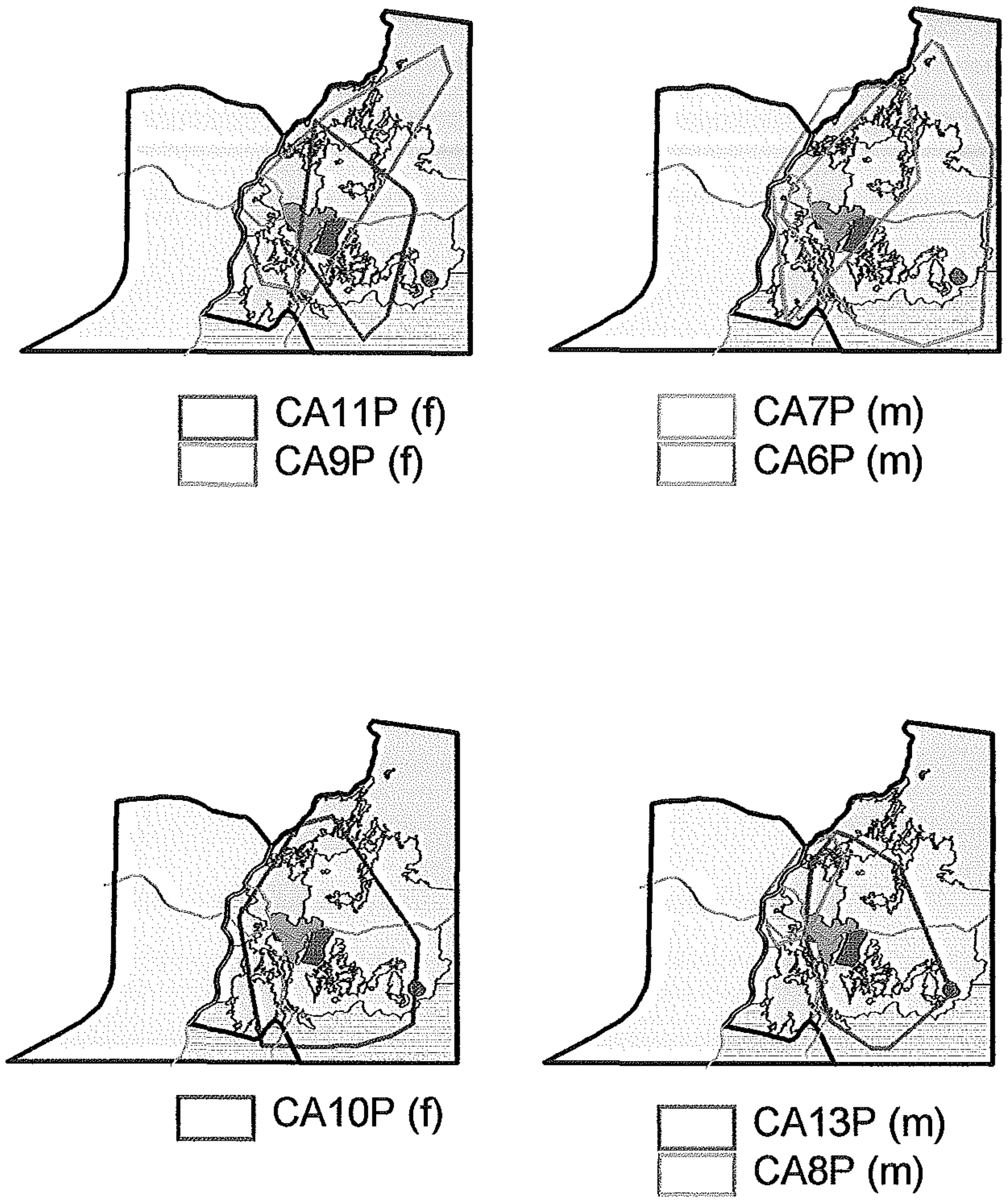


Figure 5. Cumulative areas (Minimum Convex Polygon with 100 % locations) utilized by radio-tracked *C. aureus* in and around the BMNP in 1998-2000.

Life-time home ranges calculated using the Minimum Convex Polygon (MCP) with 100 % of locations were relatively smaller than those estimated using Harmonic Mean (HM) with 95 % of locations for the individuals except for CA6 and CA8 (Table 2), but they were not statistically significant (Wilcoxon signed rank test, p = 0.31). Life-time home range size for CA8 computed using both methods was very small, and home ranges were shifted during the study period for 95 % HM (Table 2). There were no enough data to calculate the home range size for CA12 because it disappeared soon after it had been followed for one night only.

The average MCP for females is 36 km^2 (s.d = 12) and the average for males is 35 km^2 (s.d = 23). The 100 % MCP figure for CA6 was remarkably larger because of high dispersion of locations (Fig. 18). The core of activity for the jackals showed that CA9 and CA13 had stable core of activity and that the remaining five individuals shifted their centres of home ranges, ranged from 2 to 3, during the period of tracking (Table 2). The spatial distribution of home ranges of the various age and sex groups of radio-tracked *C. aureus* is shown in Figure 6.



Scale 1:250000

Figure 6. Spatial distribution of home ranges of radio-tracked golden jackals

Table 2. Life-time home ranges in km^2 of radio-collared *C. aureus* in and adjacent to the BMNP using Minimum Convex Polygon (MCP) with 100 % locations and Harmonic Mean (HM) with 95 % of locations. Harmonic mean with 50 % of locations was used to determine core of activity.

ID	Sex/age class[1]	Total no. of fixes	Life-time home ranges 100 % MCP	95 % HM	50 % HM
CA10	Ad. F	82	48.15	56.53	4.90 7.48 0.18
CA9	Subad. F	82	24.17	35.32	4.36
CA11	Subad. F	42	35.52	45.86	4.53 0.82
CA6	Subad. M	62	64.76	43.10	6.99 0.41
CA7	Subad. M	45	32.76	41.94	2.40 0.49
CA8	Ad. M	60	7.87	4.02 3.21	0.10 1.26
CA13	Ad. M	79	33.22	41.67	7.65

[1] Ad. F = Adult female; Ad. M = Adult male; Subad. F = Subadult female; Subad. M = Subadult male

I. albicauda and A. plaudinosus

Like golden jackals, radio-tracked *Ichneumia* range sizes in general enlarged with increasing number of fixes. Adults of both sexes attained an asymptotic range size, with the exceptions of IA8 and IA13 because they were not monitored for the whole period of the study (Fig. 7). However, the female reached an asymptote earlier than males.

Life-time home ranges for *Ichneumia* adult males ranged from 1.11 km^2 to 4.27 km^2, and the only adult female used an area of 2.63 km^2. The home range size for the only radio-tracked *Atilax* was 3.93 km^2. Home range size of *Ichneumia* males except for IA8 was larger than that of female.

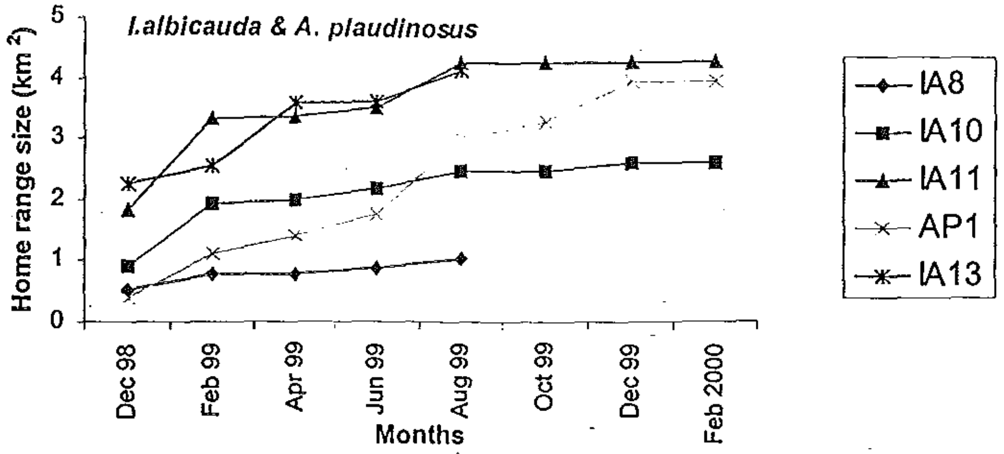
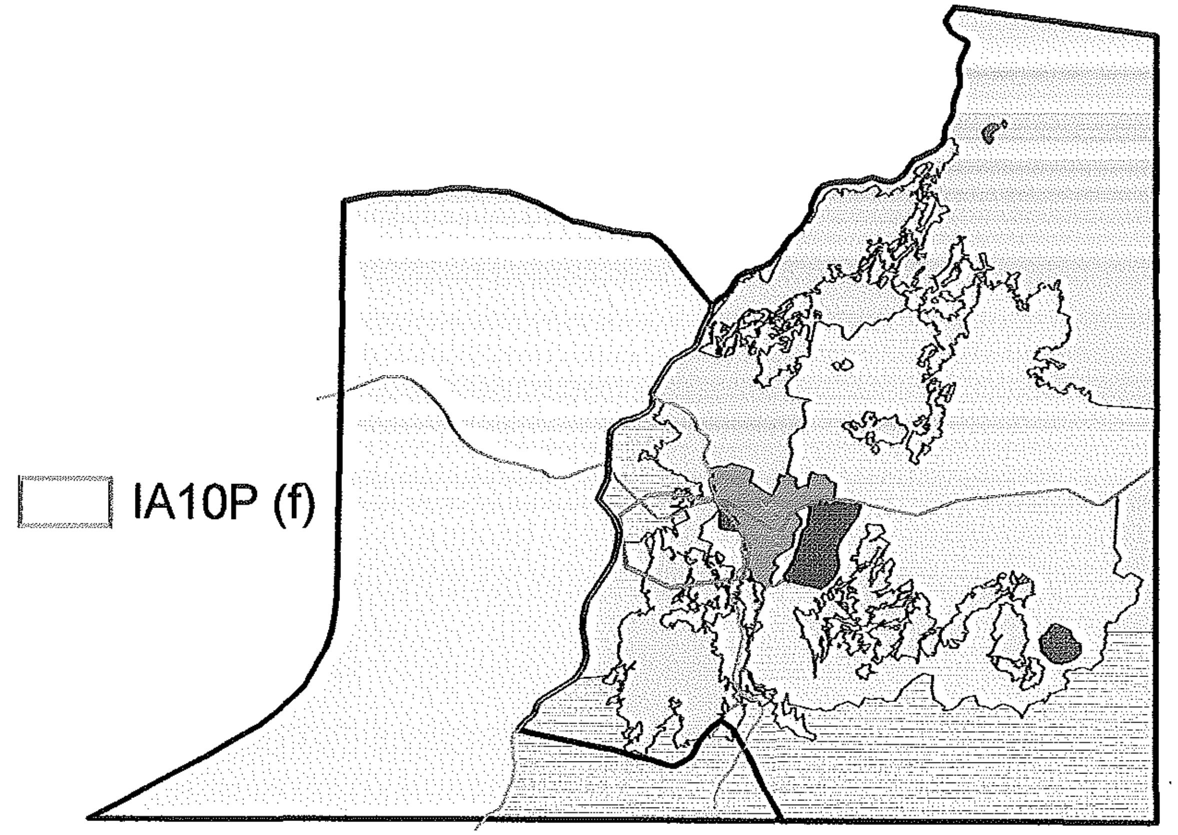


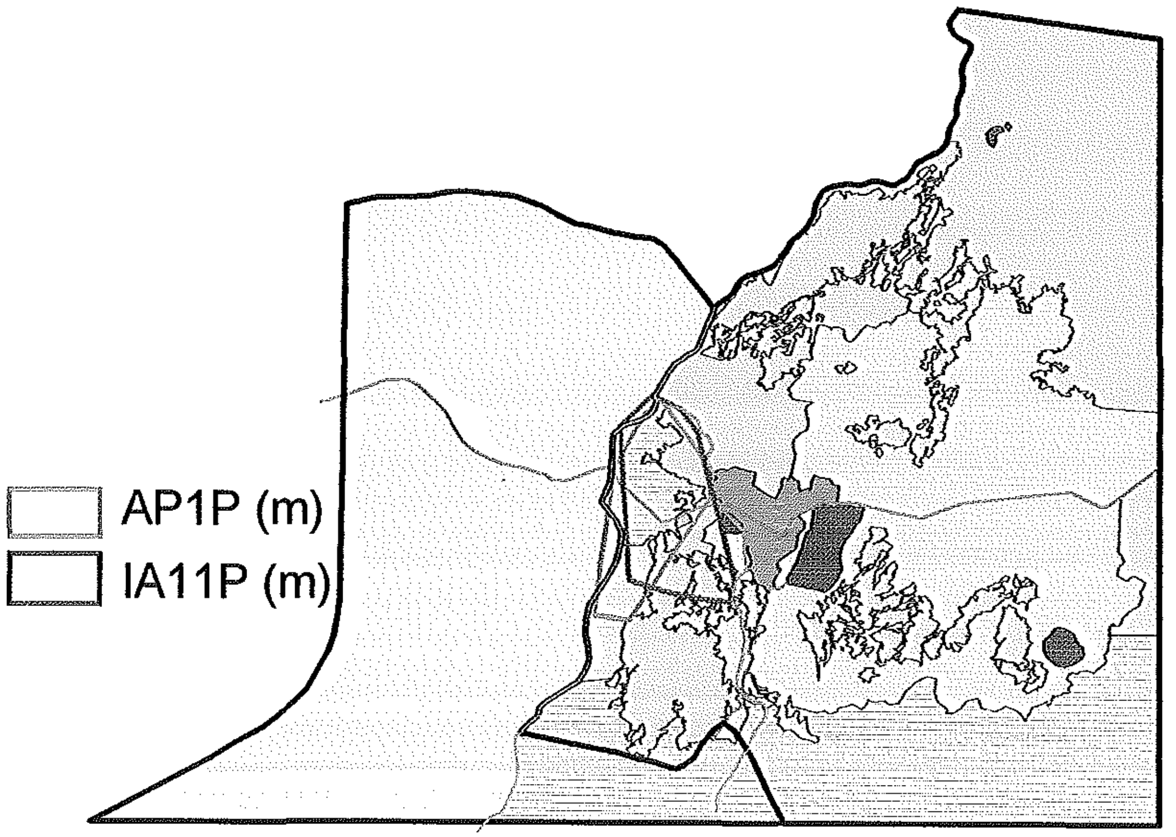
Figure 7. Cumulative areas (Minimum Convex Polygon with 100 % locations) utilized by radio-tracked *I. albicauda* and *A. plaudinosus* in and around BMNP in 1998-2000.

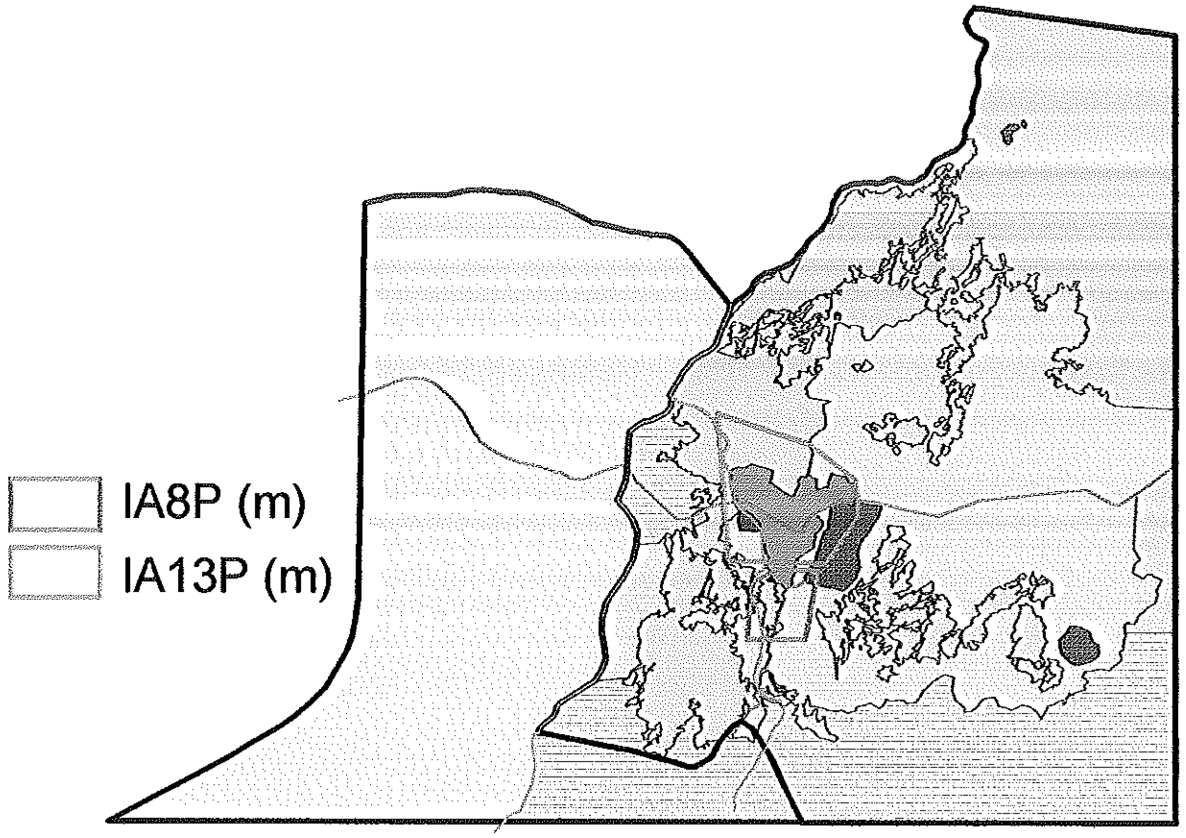
Table 3. Life-time home ranges in km^2 of radiocollared *I. albicauda* and *A. plaudinosus* in and adjacent to the BMNP using Minimum Convex Polygon (MCP) with 100 % locations, and Harmonic Mean (HM) with 95 % of locations. Harmonic mean with 50 % of locations was used to determine core of activity.

ID	Sex/age class[1]	Total no. of fixes	Life-time home ranges 100 % MCP	95 % HM	50 % HM
IA10	Ad. F	76	2.63	2.61	0.06
					1.30
IA8	Ad. M	47	1.11	1.38	0.26
					0.01
IA11	Ad. M	67	4.27	4.52	0.44
					0.26
IA13	Ad. M	58	4.15	5.41	1.11
					0.03
AP1	Ad. M	76	3.93	2.57	0.90
					0.01
					0.05

[1] Ad. F = Adult female; Ad. M = Adult male


IA10P (f)


AP1P (m)
IA11P (m)



Scale 1: 125000

Figure 8. Spatial distribution of home ranges of radio-tracked mongooses

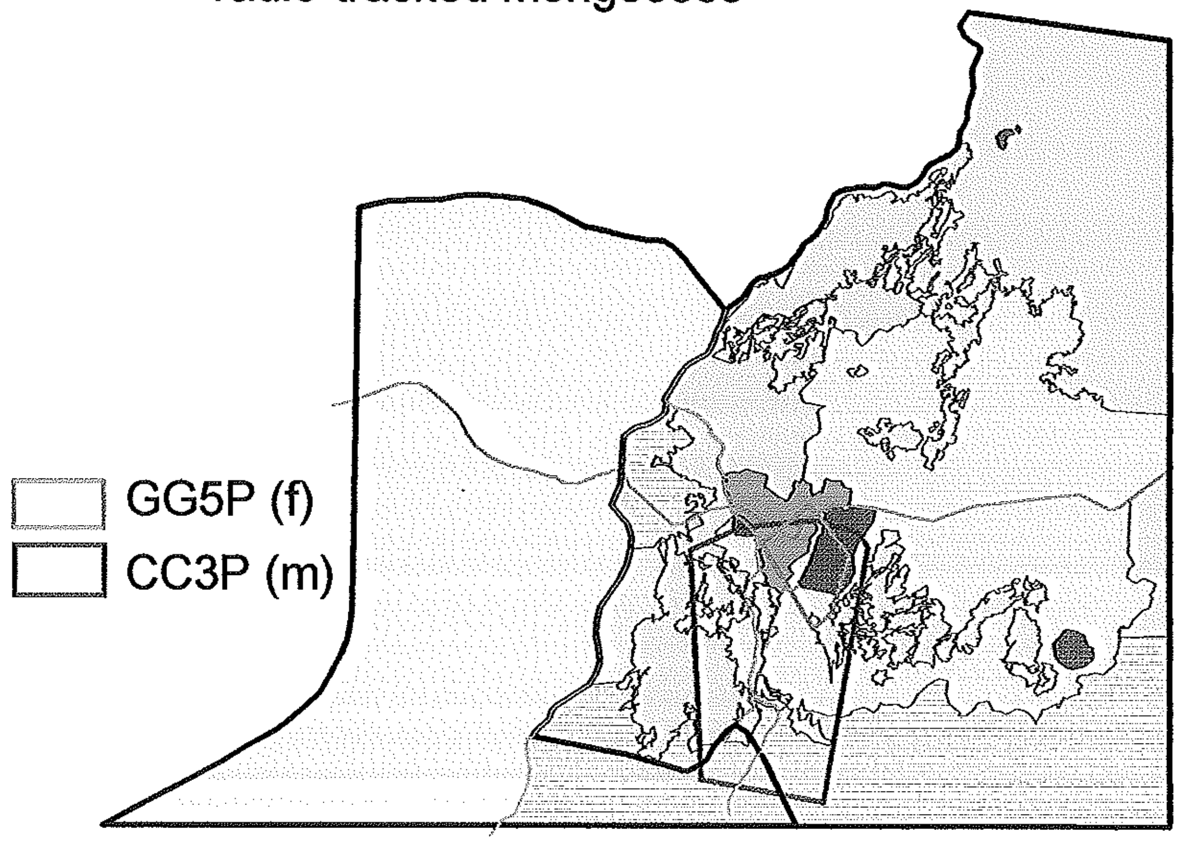


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Figure 10. Spatial distribution of home ranges of radio-tracked African civet & common genet

The spatial distribution of home ranges of *Ichneumia* and *Atilax* is shown in Figure 8. Despite IA8's smaller range size (Table 3) in comparison with the other adult males, and even with that of the female, they were not statistically different (Mann-Whitney test, all p's = 0.32). Life-time home ranges computed using 100 % MCP and 95 % HM methods showed no significant difference for each individual male and female mongooses (Wilcoxon- test, p = 0.18). Like golden jackals, shifts in the centres of home ranges, ranging from 2 to 3, were seen in the radiocollared *Ichneumia* and *Atilax* (Table 3).

C. civetta and G. genetta

Areas used by CC3 and GG5 also grew with increasing number of fixes. Range size for CC3 reached an asymptote after one year of monitoring but that of GG5 grew continuously, but slowly, throughout the entire period of tracking (Fig. 9).

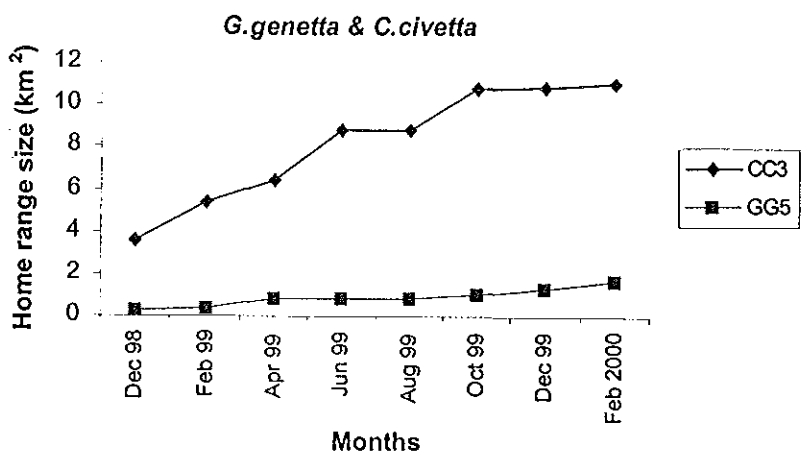


Figure 9. Cumulative areas (Minimum Convex Polygon with 100 % locations) utilized by radiotracked *C. civetta* and *G. genetta* in and around the Bale Mountains National Park (BMNP) in 1998- 2000.

Life-time home range size for CC3 and GG5 were 11.06 km^2 and 1.71 km^2 for 100 % MCP and 18.61 km^2 and 2.04 km^2 for 95 % HM respectively (Table 4). The spatial distribution of home ranges of radiotracked African civet and Common genet is shown in Figure 10. The range size estimated by the two methods was almost identical for GG5, but there is slight variation for that of CC3 (100 %MCP < 95 % HM). Both animals had a stable home range during the entire period of monitoring (Table 4).

Table 4. Life-time home ranges in km^2 of radiocollared *C. civetta* and *G. genetta* in and adjacent to the BMNP using Minimum Convex Polygon (MCP) with 100 % locations and Harmonic Mean (HM) with 95 % of locations. Harmonic mean with 50 % of locations was used to determine core of activity.

ID	Sex/age class[1]	Total no. of fixes	Life-time home ranges		
			100 % MCP	95 % HM	50 % HM
CC3	Subad. M	68	11.06	18.61	0.40
GG5	Ad. F	87	1.71	2.04	0.19

[1] Subad. M = Subadult male; Ad. F = Adult female

3.2.2. Spatial distribution

Canis aureus

The average value of range overlap was 46 % for all males and 57 % for all females. The home ranges of the radio-tracked jackals overlapped to a great extent between various age/sex groups (Table 5). The spatial distribution of the home ranges of all the golden jackals (Fig. 11) showed that two groups were discovered: adult component and subadult component.

The adult component comprised CA10 (F) and CA13 (M), and the subadult component was composed of CA6 (M), CA7 (M), CA9 (F) and CA11 (F). The range of CA6 overlapped greatly to all members, but CA7 due to small number of fixes, of the two groups. The range of CA11 was almost similar to CA13 and was included in CA10's large range (Fig. 11). The ranges of subadults overlapped greatly to that of the adult pair (CA10 and CA13), ranging from 37 % - 100 % (Table 5). The unusually strange adult male (CA8) overlapped to a lesser extent with members of both groups, ranging from 2 % - 17 %.

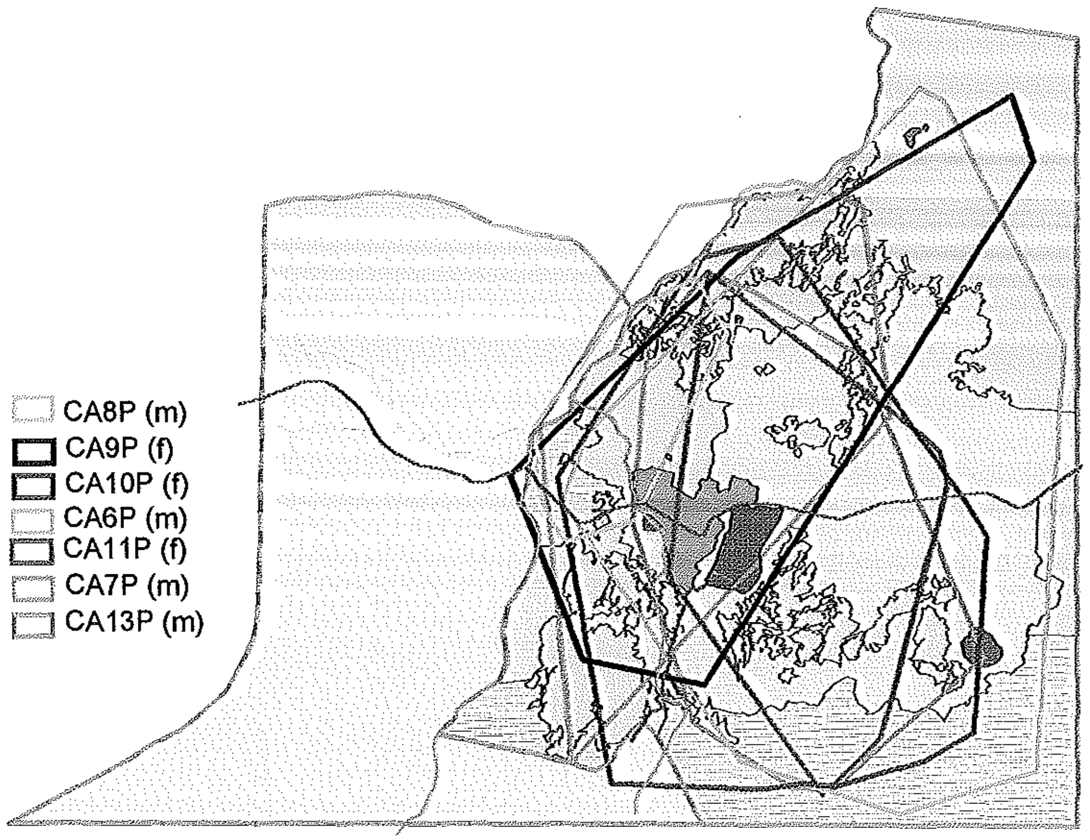
Ichneumia albicauda

The home ranges of neighboring *Ichneumia* overlapped to a varying degree. The range overlap for all the individuals of mongooses averaged 29 %. The extent of overlap was strongly marked between opposite sexes rather than among individuals of the same sex (Table 6; Fig. 12). Home range overlap between the adult female (IA10) and neighboring males ranged from 12.58 % to 81.25 %. IA10 used a larger part of IA11's range (81.25 %) than that of IA13's (24.62 %) (Table 6; Fig 12).

The home range overlap between two adjacent male individuals (IA11 and IA13) was 0.08 km^2 (1.93 % to 2.97 %; Table 6). Unfortunately, home range overlap between neighboring IA8 and IA13 was not calculated due to small sample of locations but the spatial distribution of home ranges of mongooses demonstrated no range overlap between them (Fig. 12). A great overlap between ranges used by IA11 and AP1 was identified, ranging from 67.97 % to 73.26 % (Table 6; Fig 12). However, this could be due to the limitation of the computation model in that the MCP (100 % locations) incorporated areas that had never been visited by AP1.

Between C. aureus, I. albicauda and A. plaudinosus

Home ranges of mongooses and golden jackals overlapped to a varying extent, ranged from 0.09 % to 100 % (Table 7). Two extremes of overlaps could be identified from the spatial distribution of home ranges of all mongooses and golden jackals (Fig. 13).



Scale 1:125000

Figure 11. Spatial distribution of home ranges of radio-tracked golden jackals together

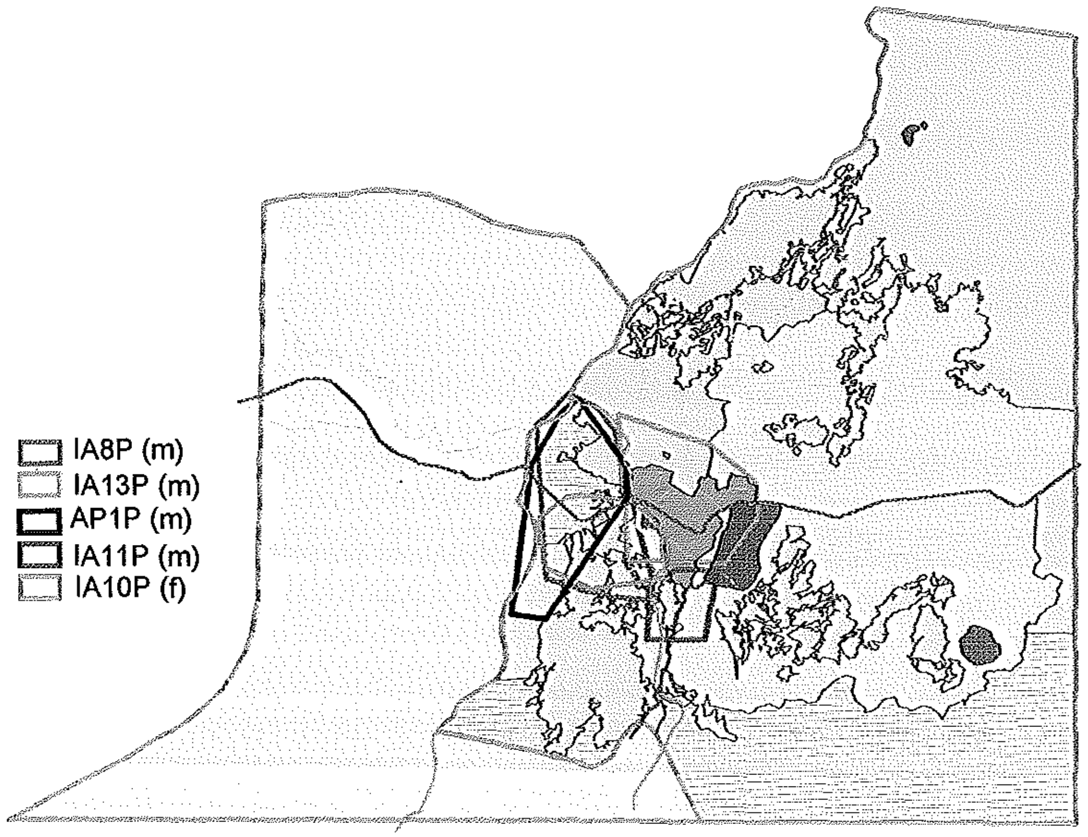


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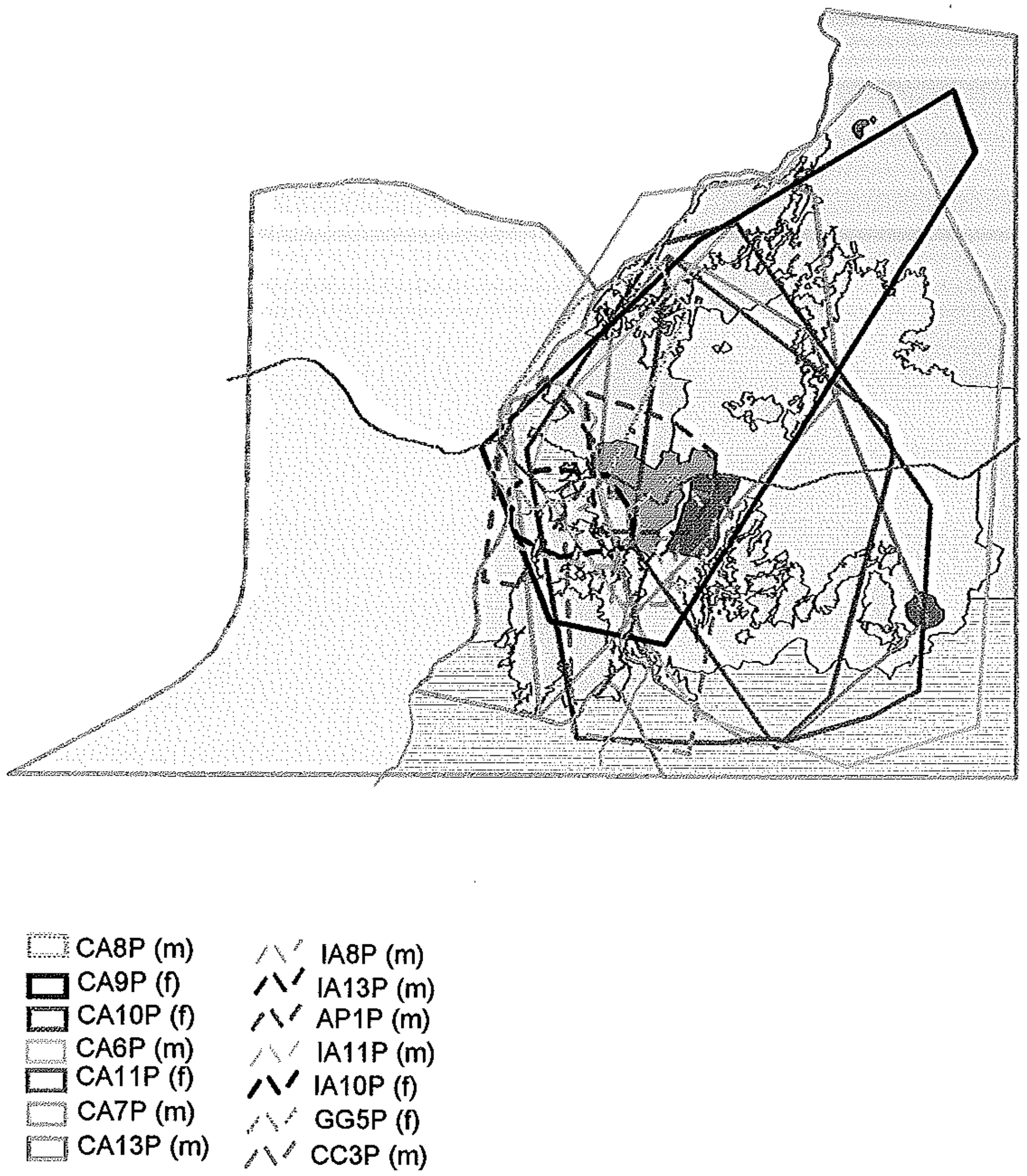
Figure 12. Spatial distribution of home ranges of radio-tracked mongooses together



Scale 1:125000

Figure 13. Spatial distribution of home ranges of radio-tracked carnivores

Table 5. **Home range overlap (percentage of the range of animal in the rows shared with animal in the columns) within *C. aureus* calculated using 100 % MCP. The actual overlap area (in km^2) is given in parentheses. * indicates fixes are between 25 and 30, and ? indicates fixes are < 25.**

	CA6	CA7	CA8	CA9	CA10	CA11	CA13
CA6	_	?	6.56 (4.25)	56.87 (28.20)	62.15 (40.25)	37.15 (24.06)	49.69 (32.18)
CA7	?	_	16.0 (5.24)	73.09 (23.95)*	?	29.23 (9.58)	36.95 (12.10)
CA8	54.02 (4.25)	98.37 (5.24)	_	76.47 (6.02)	70.85 (5.58)	5.24 (0.41)	34.26 (2.70)
CA9	79.39 (28.20)	74.02 (23.95)*	16.94 (6.02)	_	55.76 (19.81)	32.08 (11.39)	48.53 (17.24)
CA10	83.59 (40.25)	?	11.58 (5.58)	46.07 (19.81)	_	50.06 (24.10)	68.86 (33.16)
CA11	99.54 (24.06)	49.85 (9.57)	1.91 (0.41)	57.23 (11.39)	99.72 (24.10)	_	96.34 (23.29)
CA13	96.86 (32.18)	60.07 (12.10)	8.12 (2.70)	51.89 (17.24)	99.80 (33.16)	70.10 (23.29)	_

Table 6. Home range overlap (percentage of the range of animal in the rows shared with animal in the columns) within *Ichneumia*, and between *Ichneumia* and *Atilax* calculated using 100 % MCP. The actual overlap area (in km^2) is given in parentheses. ? denotes number of fixes are < 25.

	IA10	IA8	IA11	AP1	IA13
IA10	_	0	81.25 (2.1)	40.84 (1.1)	24.62 (0.5)
IA8	0	_	0	0	?
IA11	50.05 (2.1)	0	_	67.97 (2.9)	2.79(0.1)
IA13	12.58 (0.5)	?	1.93 (0.1)	1.3 (0.1)	_
AP1	27.12 (1.1)	0	73.26 (2.9)	_	1.65(0.1)

Table 7. Home range overlap (percentage of the range of jackals in the rows shared with two species of mongooses in the columns) calculated using 100 % MCP. The percentage of overlap of the mongooses with the jackals is given in parentheses. * Indicates 25-30 fixes were used to calculate the range overlap, and ? - not estimated due to small sample size (< 25 no of locations).

	IA10	IA8	IA11	AP1	IA13
CA6	2.51 (61.8)	?	3.34 (50.6)	2.04 (33.3)	2.52 (31.6)
CA7	5.96 (61.5)	2.41 (100)	9.53 (92.7)	2.58 (60.4)	?
CA8	8.87 (26.5)	0	34.41 (63.4)	29.67 (59.0)	27.5 (21.9)*
CA9	6.95 (100)	3.13 (100)	11.36 (94.5)	7.79 (83.6)	?
CA10	4.59 (84.0)	0.90 (28.4)	6.07 (68.5)	3.71 (45.2)	9.97 (87.9)
CA11	0.09 (0.8)	2.50 (44.9)	0	0	?
CA13	1.60 (20.2)	3.38 (81.8)	0.29 (2.2)	0	0.48 (2.0)

The first extreme comprised IA8, IA10 and IA11 from mongooses and CA7 and CA9 from jackals and that ranges of mongooses overlapped to a very large extent (90 % to 100 %) with the jackals. The second one characterized by the ranges of mongooses overlapped to a fewer extent with those of jackals and that comprised IA11, AP1 from the mongooses and CA6, CA8, CA10, CA11and CA13 from the jackals. The only exceptions were IA8-CA11 and IA8-CA13, which overlapped greatly (44. 94 % and 81.83 % respectively; Table 7).

3.3. SOCIAL INTERACTION

3.3.1. Intra-specific interaction

C. aureus

Jackals were observed most of the time alone than with one or more of their conspecifics. Of 452 sample of locations, sightings of jackals alone were 394 (87 %) and those in group were 58 (13 %) (Table 8; Fig. 14). However, the strength of association in group-sighted jackals in general seemed to be strong. Of the 58 sightings for the group, 25 (43 %) were within 20 m distance to each other, and 28 (48 %) were between 20 and 100 m apart (Table 8; Fig. 15). Only 5 (9 %) were greater than 100 m apart.

Table 8. The pattern of grouping in radio-tracked golden jackals (*C.aureus*) in the study area.

ID	Total fixes	sightings alone	sightings in group	Proximity in group (m) 0-20	20-100	> 100
CA10	82	70	12	5	7	0
CA11	82	75	7	2	4	1
CA13	79	66	13	6	6	1
CA6	62	57	5	4	0	1
CA7	45	36	9	4	5	0
CA8	60	53	7	4	3	0
CA9	42	37	5	0	3	2
Total	452	394	58	25	28	5

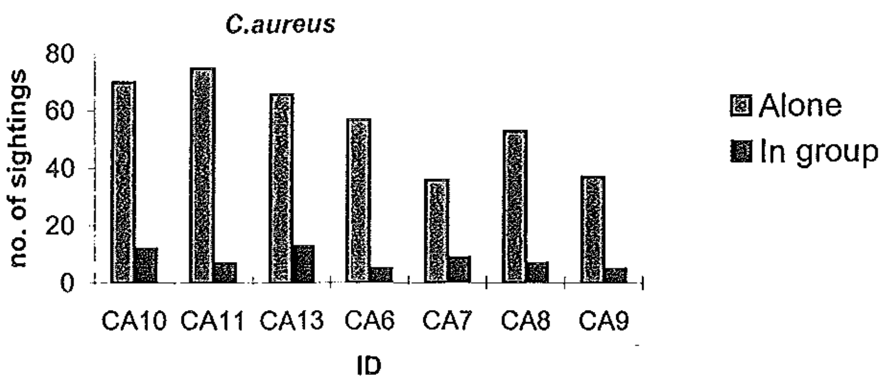


Figure 14. Frequency distribution of the number of sightings alone and in group for the radiotracked *C. aureus*.

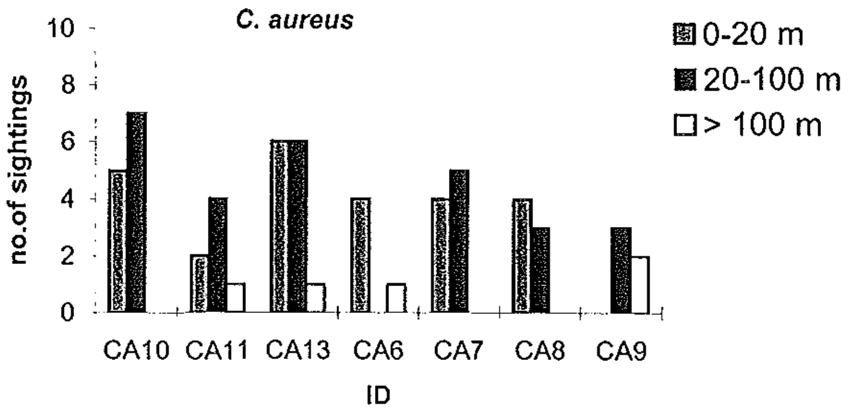


Figure 15. Frequency distribution of proximity in group-sighted *C. aureus*.

Table 9. Frequency distribution of proximity of pair of *C. aureus* seen or determined by radiotracking. Any association among males of the same age group was not observed and hence are not listed here.

Jackal pair	n	Distance between interacting individuals (m)			
		0	< 20	20-100	> 100
		Adult male x subadult male			
CA13 x CA7	2		1		1
		Subadult females			
CA11 x CA9	1				1
		Adult female x subadult female			
CA10 x CA9	1			1	
		Male x female			
CA10 x CA13	4	2	1	1	
CA10 x CA7	3	1		2	
CA10 x CA8	3			3	
CA13 x CA11	4	2		2	

Jackal sociality within each sex/age group seemed to have become very weak. The strongest affiliation to interact with each other was between males and females. Most (14 of the 18 or 77.8 %) of observations on social behaviour was between males and females (Table 9). In six of the fourteen observations, pair was located together or very near to each other while the remaining eight records were at medium distance from each other.

Jackals were observed at various levels of grouping in this study. Pair formation was relatively more important in comparison with other levels of grouping. 24 of 28 observations (86 %) were pair, and 11 % were groups of three. Only 3 % were group of four. Four jackals (CA7, CA9, CA11and CA13) were located during daylight resting in thick bushes within 20 to 100 m apart from each other, and CA9 was located approximately less than 30 m from CA11.

Contacts of radio-collared jackals with non-collared ones were also observed during tracking the animals. On one occasion, the old adult female (CA10) was observed sharing a horse carcass with two other non-collared jackals. On January 28, 1999, CA6 was located twice on the same night standing together with a non-collared jackal. On February 2, 1999, CA13 was seen together with another non-collared jackal. On May 4, 1999 at 19:27 CA8 was seen pairing with one dark tailed adult female jackal and after 15 minutes the same female jackal was observed moving less than 10 m apart from CA8, and at 19:58, both were located standing side by side.

I. albicauda and A. plaudinosus

Individuals of *Ichneumia* were observed mostly alone (n =224; 91 %), and sightings in group were few (n = 23; 9 %; Table 10 & Fig 16). In group-sighted white-tailed mongooses, 17 sightings were within 20 m proximity, and 5 were between 20 and 100 m apart (Table 10; Fig 17). Only one was greater than 100 m apart. *Atilax* was usually observed alone (n=70; 92 %), and sightings in group were few (n=6; 8 %; Table 10 & Fig. 16). In group-sightings of Atilax, 5 were within 20 m proximity, and one was greater than 100 m apart.

Table 10. The pattern of grouping in radio-tracked *I. albicauda* and *A. plaudinosus* in the study area.

ID	Total fixes	sightings alone	sightings in group	Proximity in group (m)		
				0-20	20-100	> 100
IA8	47	47	0	0	0	0
IA10	76	67	9	8	1	0
IA11	67	57	10	8	1	1
IA13	57	53	4	1	3	0
Overall	247	224	23	17	5	1
AP1	76	70	6	5	0	1

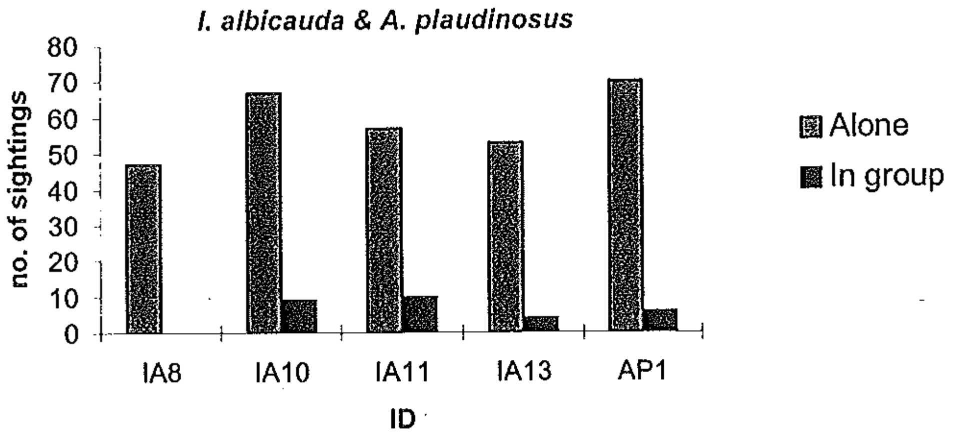


Figure 16. Frequency distribution of the number of sightings alone and in group for radiotracked *I. albicauda* and *A. plaudinosus*.

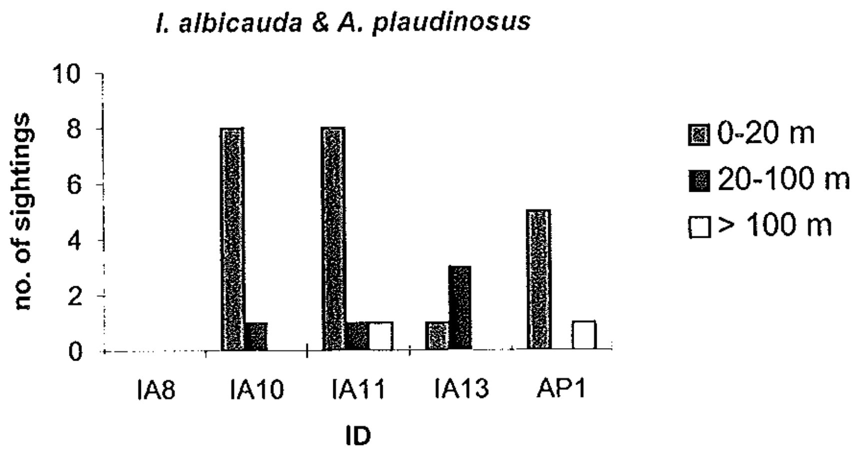


Figure 17. Frequency distribution of proximity in group-sighted *I. albicauda* and *A. plaudinosus*.

Male *Ichneumia* usually avoid associating with each other. No male was observed staying together or in the various lengths of proximity with another male (Table 11). All records on *Ichneumia* sociality were between male and female. 10 of the 14 observations were male-female pair bonds while the remaining four were distributed among the various lengths of proximity (Table 11). AP1 was observed coming out of its den around dusk with another non–collared mongoose and after seven minutes both were observed running together along the Web riverbank. These two mongooses were again observed fishing side by side in Denka riverbank.

Table 11. Frequency distribution of proximity of pair of white-tailed mongooses seen or determined by radiotracking (* denotes resting site fixes).

Mongoose pair	Distance between interacting individuals (m)			
	0	< 20	20-100	> 100
		Male x female		
IA10 x IA11	7(3*)	1		1
IA10 x IA13			2	

3.3.2. Inter-specific interaction

Inter-specific interaction among guild of carnivores was observed in this study. Of the 16 observations on inter-specific associations, 8 (50 %) were between radio-tracked *C. aureus* and *C. crocuta*, and 4 (25 %) were between *C. aureus* and *Ichneumia* (Table 12). The remaining four were distributed among different species of carnivores (Table 12).

On March 1, 1999 at 23:00 CA6 stood within 5 m from five hyenas, of which two were pups and one adult hyena observed chasing the jackal but the jackal hang around. After 45 minutes, CA6 was observed whining on an adult hyena standing behind it. *C. aureus* were also observed associating with *Ichneumia*, but the frequency of social interaction was small (n = 4) compared with that of jackal-hyena (n = 8; Table 12).

Despite such observed levels of inter-specific interactions between the guild of wild carnivores found around the BMNP HQ, especially jackal with spotted hyena, only one instance of association between CC3 and other radio-tracked carnivores was recorded. Fortunately, on May 18, 1999 at 03:30 CC3 was already rested less than 20 m from the position where IA13 was located.

Table 12. Frequency distribution of proximity between interacting wild carnivores (both collared and non-collared) in and adjacent to the BMNP (n shows the number of observations recorded from radio-tracking).

Interacting species	n	Distance between interacting individuals (m)				group size
		0	< 20	20-100	> 100	
CA X CrCr	8	1	3	4	0	2-6
CA X IA	4	0	1	2	1	2-3
CA10 X IA X CrCr	1	0	0	1	0	5
AP1 X CrCr	1	0	1	0	0	2
IA X CC3	1	0	1	0	1	2
IA13 X GG	1	0	0	1	0	2

Key words: CA – *Canis aureus*; CrCr – *Crocuta crocuta*; IA – *Ichneumia albicauda*; CC – *Civitictis civetta*; GG – *Genetta genetta*.

Throughout the tracking period, GG5 and IA8 were not observed or located even for once associating with members of the same or different species. A single non-collared adult genet was observed climbing up a tree less than 50 m from IA13 at 03:27 on September 6, 1999.

There were no enough data to see the pattern of sociality of IA14 because it disappeared soon after it had captured and collared.

The various species of carnivores were also observed interacting with domestic dogs (*Canis familiaris*) in different periods of the tracking time (Table 13). During the daylight, CA6 was found killing adult female sheep and one dog was located at a distance greater than 100 m from the jackal. After a couple of days at 21:30, CA7 was observed at medium distance (20-100m) from two dogs near by a horse carcass.

On December 15, 1998 at 00:57 CA10, six hyaenas and three domestic dogs were observed at a carcass of horse, and one dog was eating the carcass. At 01:55 one adult white-tailed mongoose was observed moving greater than 100 m beyond the carcass, and at 02:14 CA10 and CA13 were observed trying to steal offal from four hyaenas eating the carcass. At 02:32 two domestic dogs were seen within 20-100 m from CA13.

Table 13. Frequency distribution of proximity between interacting domestic dogs and other wild carnivores (both collared and non-collared) in and adjacent to the BMNP (n shows the number of observations).

Interacting species	n	Distance between interacting individuals (m)				group size
		0	< 20	20-100	> 100	
CFxCA	3			2	1	2-3
CFxCAxCrCrxIA	2		1		1	5-10

Key words: CA – *Canis aureus*; CrCr – *Crocuta crocuta*; IA – *Ichneumia albicauda*; CF – *Canis familiaris*.

Because of the difficulty of data collection conditions, intra- and inter- species behaviour with regard to the transmission modes of canid pathogens were not observed.

3.4. HABITAT USE AND SELECTION

3.4.1. Habitat use during resting

3.4.1.1. Micro-habitats

3.4.1.1.1. Habitat type

A total of 71 microhabitat fixes was obtained from seven *C. aureus*, one *C. civetta* and one *G. genetta*. Individuals of *C. aureus* were generally located in three different types of habitat, by decreasing order: bush, forest and farmland. The difference on use between bush and forest was not significant (x^2 = 1.723, d.f = 1, p = 0.189; Table 14). One jackal, CA9, was located resting in crop field during day light on two occasions. CC3 was entirely located in bushes where as GG5 was detected only in the forest (Table 14).

Table 14. Frequency on use of each habitat type during resting in radio-tracked carnivores (the number of individuals detected is given in parentheses).

Species	n	Farm	Grass	Bush	Forest
C. aureus	49 (7)	2	0	28	19
C. civetta	10 (1)	0	0	10	0
G. genetta	12 (1)	0	0	0	12

On the other hand, *Ichneumia* used empty house in the town and/or holes of big boulders for denning. The old adult male (IA8) was located only in holes of big boulders. The remaining white-tailed mongooses, i.e., IA10, IA11 and IA13, used both types of resting sites equally (x^2 = 0.36, d.f = 2, P = 0.84; Table 15). Underground dens were significantly more often used than empty houses (x^2 = 24.09, d.f = 4, p < 0.001). The only radio-tracked *Atilax* used only holes of big boulders for resting (Table 15).

Table 15. Frequency on use of each resting habitat type in radio-tracked *I. albicauda* and *A. paludinosus* (the percentages on use are given in parentheses).

ID	Empty house	Holes
IA10	13 (46.4)	8 (17.0)
IA11	10 (35.7)	9 (20.0)
IA13	5 (17.9)	4 (8.5)
IA8	0	12 (25.5)
AP1	0	14 (29.8)

3.4.1.1.2. Habitat quality

3.4.1.1.2.1. Height of the habitat

Out of the 28 bush resting sites for the jackals, twenty-five (89.3 %) were greater than one meter high. Only three (10.7 %) were between 50 and 100 cm high. The jackals used forests greater than one meter in height (Table 16). The height of the farmland used by CA9 was 20-50 cm.

Nine of the ten bush resting sites for CC3 were greater than one meter in height. Forest resting sites for GG5 were all greater than one meter in height (Table 16).

3.4.1.1.2.2. Density of the habitat

The density of the different resting site microhabitats used by all the radiotracked carnivores was high for most locations, i.e., sixty-eight of the total seventy-one fixes (Table 17). Golden jackals were located in a moderately dense bush on three occasions.

Table 16. Frequency on use of height of each resting habitat type used by radiotracked carnivores (the number of individuals detected is given in parentheses).

Habitat type	Species	n	Height of the habitat type (cm)			
			0-20	20-50	50-100	> 100
Farm	*C. aureus*	2 (1)	0	2	0	0
Bush	*C. aureus*	28 (5)	0	0	3	25
	C. civetta	10 (1)	0	0	1	9
Forest	*C. aureus*	19 (6)	0	0	0	19
	G. genetta	12 (1)	0	0	0	12

Table 17. Frequency on use of density of each resting habitat type used by radiotracked carnivores (the number of individuals detected is given in parentheses).

Habitat type	Species	n	Density of the habitat type			
			Open	Low	Medium	High
Farm	*C. aureus*	2 (1)	0	0	0	2
Bush	*C. aureus*	28 (5)	0	0	3	25
	C. civetta	10 (1)	0	0	0	10
Forest	*C. aureus*	19 (6)	0	0	0	19
	G. genetta	12 (1)	0	0	0	12

3.4.1.2. Area habitats

3.4.1.2.1. Habitat type

A total of 182 area habitat fixes for the resting sites of the animals were obtained. Table 18 shows the frequency of use of each habitat type encompassing the microhabitat used by the radiotracked carnivores. The proportions of use of farmland and forest for the jackals were almost the same but they were relatively more used than bush. In white-tailed mongooses, bushes were used in a great proportion in comparison to other types of habitats (Table 18). Bushes were significantly more often used than forests ($x^2 = 4.091$, d.f = 1, $p = 0.043$). White-tailed mongooses used a resting site in a farmland on two occasions (Table 18). The only tracked *Atilax*, marsh mongoose, used only bush and forest area habitats at equal proportion (Table 18).

Forests comprised 91 % (10 of 11) and 94 % (17 of 18) of the resting area habitats for the civet (CC3) and the genet (GG5) respectively (Table 18). Both were detected in resting site micro-habitat surrounded by bushes on one occasion each, but were never located within grass and farmland area habitats.

Table 18. Frequency on use of each habitat type (within 20 m from resting fix) in sixteen radio-tracked carnivores (the number of individuals detected is given in parentheses).

Species	n	Farm	Grass	Bush	Forest
C. aureus	61 (8)	26	0	7	28
I. albicauda	78 (5)	2	7	35	20
A. plaudinosus	14 (1)	0	0	7	7
C. civetta	11 (1)	0	0	1	10
G. genetta	18 (1)	0	0	1	17

3.4.1.2.2. Habitat quality

3.4.1.2.2.1. Height of the habitat

Most (22 of 26) arable fixes for jackals were less than 20 cm high. Only four were between 20 and 50 cm high. Of the two arable fixes for the white-tailed mongooses, one was less than 20 cm and the other was between 50 and 100 cm in height. The relative importance of height of bush area habitats for the jackals and the two species of mongooses was the same (Table 19). The two fixes of bush habitats for the civet and the genet were greater than one meter in height. Otherwise, all the forest area habitats for the radiotracked individuals were very tall plants (Table 19).

Table 19. Frequency on use of height of each habitat type for the radiotracked carnivores during resting (the number of individuals detected is given in parentheses).

Habitat type	Species	n	Height of the habitat type (cm)			
			0-20	20-50	50-100	> 100
Farm	*C. aureus*	26 (6)	22	4	0	0
	I. albicauda	2 (2)	1	0	1	0
Grass	*I. albicauda*	5 (4)	4	1	0	0
Bush	*C. aureus*	7 (3)	0	0	2	5
	I. albicauda	35 (4)	0	1	3	31
	A. plaudinosus	7 (1)	0	0	2	5
	C. civetta	1 (1)	0	0	0	1
	G. genetta	1 (1)	0	0	0	1
Forest	*C. aureus*	28 (8)	0	0	0	28
	I. albicauda	20 (3)	0	0	0	20
	A. plaudinosus	7 (1)	0	0	0	7
	C. civetta	10 (1)	0	0	0	10
	G. genetta	17 (1)	0	0	0	17

3.4.1.2.2.2. Density of the habitat

With respect to density of area habitat type for the jackals, most (22 of 26) of the arable fixes were open and three were moderately dense (Table 20). Only one was low in density. The frequency of the moderately dense area bushes (n=3) was almost the same as that of highly dense bushes (n=4). However, moderately dense forests were significantly more often used than very dense forests (x^2 = 8.33, d.f = 1, $p < 0.01$). Jackals were detected in resting site surrounded by low dense forests on one occasion (Table 20).

Table 20. Frequency on use of density of each area habitat type for the radiotracked carnivores during resting (the number of individuals detected is given in parentheses).

Habitat type	Species	n	Density of the habitat type			
			Open	Low	Medium	High
Farm	*C. aureus*	26 (6)	22	1	3	0
	I. albicauda	2 (2)	1	0	0	1
Grass	*I. albicauda*	5 (4)	5	0	0	0
	C. aureus	7 (3)	0	0	3	4
Bush	*I. albicauda*	35 (4)	0	24	7	4
	A. plaudinosus	7 (1)	3	1	3	0
	C. civetta	1 (1)	0	0	0	1
	G. genetta	1 (1)	0	0	0	1
	C. aureus	28 (8)	0	1	21	6
Forest	*I. albicauda*	20 (3)	9	3	8	0
	A. plaudinosus	7 (1)	0	1	6	0
	C. civetta	10 (1)	10	0	0	0
	G. genetta	17 (1)	1	1	0	15

White-tailed mongooses were detected in open grass area habitats (Table 20). The relative importance on use of density of bush habitats by decreasing order was: low, medium and high for the various age groups of white-tailed mongooses (Table 20). Low dense bushes were significantly more used than moderately dense bushes (x^2 = 9.323, d.f = 1, $p < 0.01$). Of the seven bush habitat fixes for the marsh mongoose, three were open, three medium and one low. Of the 20 fixes in forest for white-tailed mongooses, 8 were in moderately dense forest and 9 in open woodland and the remaining 3 were in low dense forest. The marsh mongoose was almost completely detected in moderately dense forest. The two fixes in bush area habitats obtained for CC3 and GG5 were high in density. Forest area habitats for the CC3 were entirely open whereas those for GG5 were almost completely densely wooded (Table 20). GG5 was detected on one occasion in open woodland and in another instance in low dense forest.

3.4.1.3. Number of resting sites per individual, re-use rates, and spatial location.

C. aureus

Seven individuals used 41 different resting sites on 60 occasions (Table 21). The number of different resting sites used per individual averaged 5.9 (s.d = 2.34, n = 7, range = 3-9). There was a significant correlation between number of locations and number of used resting sites (r = 0.857, p = 0.01), showing that no stabilization in the number of resting sites used by the radiotracked jackals. The average re-use rate was 1.44 (s.d = 0.43, n = 7, range = 1.0-2.2). When examining the pattern of use of resting sites by the more frequently located individuals (n > 10), the same resting site was used more than once (mode = 7).

Table 21. Number of locations, number of different resting sites used and re-use rates (total number of resting fixes divided by the number of different resting sites) for various age/sex classes of radiotracked *C. aureus*.

ID	No. of locations	Resting sites	Re-use rates
CA10	12	9	1.33
CA11	11	5	2.20
CA13	7	4	1.75
CA6	3	3	1.00
CA7	8	7	1.14
CA8	14	8	1.75
CA9	5	5	1.00

Occasionally, the same resting site was used simultaneously by more than one individual. Three individuals were located on one occasion using the same resting site during day light in thick bushes. The spatial distribution of the different resting sites within home ranges of radiotracked golden jackals is shown in Figure 18.

I. albicauda and A. plaudinosus

Five individuals used 24 different resting sites on 64 occasions (Table 22). The mean number of different resting sites used per individual was 4.8 (s.d = 2.49, n = 5, range = 1-7). There was no significant positive correlation between number of sampled nights and number of used resting sites (r = 0.677, $p > 0.01$), indicating that stabilization in the number of resting sites used by white-tailed mongooses. The mean re-use rate was 2.67 (s.d = 1.29, n = 5, range = 1.7- 4.75). The only radio-collared marsh mongoose (AP1) used 4 different resting sites on 14 occasions (Table 22). The re-use rate was 3.5. The marsh mongoose used the same resting site at most 7 times (Fig. 19)

Table 22. Number of locations, number of different resting sites used and re-use rates (total number of resting fixes divided by the number of different resting sites) for various age/sex classes of radiotracked *I. albicauda*, *C. civetta*, *A. plaudinosus* and *G. genetta*.

ID	No. of locations	Resting sites	Re-use rates
IA10	22	7	3.14
IA11	19	4	4.75
IA13	9	5	1.8
IA8	12	7	1.7
IA14	2	1	2.0
AP1	14	4	3.5
GG5	18	12	1.5
CC3	11	3	3.67

Different individuals of white-tailed mongoose frequently used the same resting site. For instance, one resting site, a horse camp, was used by IA10 (adult female) and IA11 (adult male) more than ten times (Fig. 19). IA13 (adult male) and IA14 (subadult male) shared empty house in Dinsho town during day-time resting.

Two individuals of white-tailed mongoose also occurred simultaneously in the same resting site several times. IA11 and IA10 were detected resting together during day light on five occasions, and IA13 and IA14 on one occasion. The spatial distribution of resting site locations within home ranges of radiotracked mongooses is shown in Figure 19.

C. civetta and G. genetta

The only African civet (CC3) in this study used 3 different resting sites on 11 occasions (Table 22). The re-use rate was 3.67. The civet used the same resting site at most 9 times (Fig. 20). The civet was never detected using the resting sites of other animals. On the other hand, GG5 used 12 different resting sites on 18 occasions (Table 22). The re-use rate was 1.5. The genet used the same resting site at most 3 times, and others were used either once or twice (Fig 20).

3.4.2. Habitat use during active periods

3.4.2.1. Microhabitats

3.4.2.1.1. Habitat type

During activity, a total of 356 fixes on use of microhabitat type were obtained from the radio-tracked carnivores. All the animals, except for marsh mongoose, were detected in four different types of habitats, i.e. farmland, grass, bush and forest. The relative percentage on use of the different habitat types between the radiotracked carnivores varied depending upon the species.

Of the 180 fixes obtained for golden jackals, 86 were in bushes and 46 were in farmland and 41 were in grass (Table 23). Only seven were in forest. Bushes were significantly more often used in comparison with both farmland and grass (all $x^2 > 12.12$, d.f = 1, all p's < 0.001). There was no significant difference on the use of farmland and grassland ($x^2 = 0.287$, d.f = 1, $p = 0.592$), but both were used significantly more than forest (all $x^2 > 24.08$, d.f = 1, all p's < 0.001).

Table 23. Frequency on use of each habitat type (within 3 m from location fix during visual contact) during activity in sixteen radio-tracked carnivores (the percentages of use are given in parentheses). n shows total number of fixes obtained from the radiotracked individuals of each species; and the number of individuals detected is given in parentheses.

Species	n	Farm	Grass	Bush	Forest
C. aureus	180 (8)	46 (25.6)	41 (22.7)	86 (47.8)	7 (3.9)
I albicauda	105 (5)	11 (10.5)	62 (59.0)	26 (24.8)	6 (5.7)
A. plaudinosus	26 (1)	0 (0)	18 (69.2)	7 (26.9)	1 (3.9)
C. civetta	20 (1)	1 (5)	3 (15)	5 (25)	11 (55)
G.genetta	25 (1)	1 (4)	5 (20)	4 (16)	15 (60)

There was a significant difference on use between the different habitat types for white-tailed mongooses ($x^2 = 73.171$, d.f = 3, $p < 0.001$). The frequency of use of the different habitat types by the white-tailed mongooses is given in Table 23. Grassland was used significantly more often than bush ($x^2 = 19.55$, d.f =1 $P < 0.001$), and bush was significantly more often used than both farmland and forest (all $x^2 > 6.081$, d.f = 1, all p's < 0.05). However, there was no significant difference on use between farmland and forest ($x^2 = 1.471$, d.f = 1, $p = 0.225$).

Of the 26 fixes obtained for the marsh mongoose (*A. plaudinosus*), 18 were in grassland, 7 were in bush and only one was in forest. Grassland was used significantly more often than bushland ($x^2 = 4.84$, d.f = 1, $p < 0.05$).

The relative importance on use between the different habitat types during activity for CC3 and GG5 was the same (Table 23). Forests were used relatively more than the remaining habitat types. Both civet and genet were detected in the farmland on one occasion (Table 23).

3.4.2.1.2. Habitat quality

3.4.2.1.2.1. Height of the habitat

Farmland

Golden jackals and white-tailed mongooses used more often crop fields that were less than 20 cm high (Table 24). Most (41 of 46 or 89 %) fixes were in fields that were < 20 cm in height, and three were between 20-50 cm in height for golden jackals. Only two fixes were in > 50 cm high field. For five individuals of white-tailed mongooses, 9 of the 10 fixes (90 %) were in < 20 cm high crop fields. CC3 and GG5 were located in very short fields (< 20 cm in height) each on one occasion.

Grassland

Golden jackals were located mostly in very short grasses (Table 24). Of the 41 fixes, 35 (85.4 %) were in grasses that were < 20 cm, and 3 were between 20-50 cm and the remaining 3 were 50-100 cm high grasses.

White-tailed mongooses used significantly more often grasses that were not greater than 20 cm in height than the other habitat height categories (all $x^2 > 38.4$, d.f = 1, $p < 0.001$). They were detected in grasses that were between 20-50 cm high on 6 occasions and 50-100 cm high grasses on two occasions. The marsh mongoose used relatively more often grasses that were between 50-100 cm in height (10 of the 18) than the other categories of habitat height (Table 24). CC3 was located on grasses that were not greater than 50 cm high on three occasions while GG5 was located on grasses that were not greater than 100 cm on five occasions (Table 24).

Table 24. Frequency on use of height of each habitat type by active radiotracked carnivores (the number of individuals detected is given in parentheses).

Habitat type	Species	n	Height of the habitat type (cm)			
			0-20	20-50	50-100	> 100
Farm	*C. aureus*	4 6 (7)	41	3	1	1
	I. albicauda	11 (5)	9	1	1	0
	C. civetta	1 (1)	1	0	0	0
	G. genetta	1 (1)	1	0	0	0
Grass	*C. aureus*	41 (8)	35	3	3	0
	I. albicauda	62 (5)	54	6	2	0
	A. plaudinosus	18 (1)	3	4	10	1
	C. civetta	3 (1)	1	2	0	0
	G. genetta	5 (1)	3	1	1	0
Bush	*C. aureus*	86 (8)	1	37	32	16
	I. albicauda	26 (5)	0	13	7	6
	A. plaudinosus	7 (1)	0	0	0	7
	C. civetta	5 (1)	0	2	3	0
	G. genetta	4 (1)	1	0	1	2
Forest	*C. aureus*	7 (3)	0	0	0	7
	I. albicauda	7 (4)	0	0	0	7
	A. plaudinosus	1 (1)	0	0	0	1
	C. civetta	11 (1)	0	0	0	11
	G. genetta	15 (1)	0	0	0	15

Bush

Almost none of the radiotracked carnivores were detected in very short bushes (Table 24). For golden jackals, difference on use between 20-50 cm and 50-100 cm high bushes was not significant (x^2 = 0.362, d.f = 1, p = 0.547), but both were used significantly more than bushes that were greater than 100 cm high (all x^2 > 5.33, d.f = 1, all p's < 0.05). However, difference on use between classes of bush > 20 cm high were not significant for white-tailed mongooses (x^2 = 3.308, d.f = 2, p = 0.191). The marsh mongoose was detected only in bushes > 100 cm in height. CC3 was located in classes of bush height ranging 20-100 cm on five occasions whereas GG5 was located in all categories except 20-50 cm class on four occasions (Table 24).

Forest

All the radiotracked carnivores used exclusively forests that were > 100 cm in height (Table 24).

3.4.2.1.2.2. Density of the habitat

Farmland

Golden jackals used almost entirely open farmland than the other classes of habitat density. Of the 46 fixes in farmland, 42 were open, 2 were high, 1 was low and 1 was medium (Table 25). White-tailed mongooses also used almost entirely open farmland. Of the 11 fixes, 10 were in open farmland and only one was in moderately dense field (Table 25). CC3 and GG5 were detected in open farmland each on one occasion.

Grassland

The distribution of radio-locations for grass (Table 25) showed that all the radiotracked individuals of both golden jackals and white-tailed mongooses used open grassland more frequently in comparison with the other classes of habitat density. On the other hand, the marsh mongoose used densely covered grasses more frequently. CC3 was also located completely in open grassland on three occasions and GG5 on two instances possibly resulted from low use of this habitat.

Table 25. Frequency on use of density of each habitat type by active radiotracked carnivores (the number of individuals detected is given in parentheses).

Habitat type	Species	n	Density of the habitat type			
			Open	Low	Medium	High
	C. aureus	46 (7)	42	1	1	2
Farm	*I. albicauda*	11 (5)	10	0	1	0
	C. civetta	1 (1)	1	0	0	0
	G. genetta	1 (1)	1	0	0	0
	C. aureus	41 (8)	38	1	0	2
Grass	*I. albicauda*	62 (5)	59	1	1	1
	A. plaudinosus	18 (1)	3	3	2	10
	C. civetta	3 (1)	3	0	0	0
	G. genetta	5 (1)	2	1	2	0
	C. aureus	86 (8)	22	28	27	9
Bush	*I. albicauda*	26 (5)	12	7	4	3
	A. plaudinosus	7 (1)	0	0	1	6
	C. civetta	5 (1)	1	2	2	0
	G. genetta	4 (1)	1	1	0	2
	C. aureus	7 (3)	0	0	3	4
Forest	*I. albicauda*	6 (4)	3	0	1	2
	A. plaudinosus	1 (1)	1	0	0	0
	C. civetta	11 (1)	2	1	1	7
	G. genetta	15 (1)	1	2	1	11

Bush

Differences on use between the first three classes of habitat density were not significant (x^2 = 0.805, d.f = 1, p = 0.669), but these were significantly more often used than highly dense bushes (all $x^2 > 5.45$, d.f = 1, all p's < 0.05) for golden jackals. For white-tailed mongooses, differences on use between the different classes of habitat density were not significant (x^2 = 7.538, d.f = 3, p = 0.57). For the marsh mongoose, six of the seven fixes were in highly dense bushes and only one in moderately dense bush (Table 25). CC3 was not located in bushes that were highly dense whereas GG5 was not located in moderately dense bushes (Table 25).

Forest

Golden jackals used moderately or highly dense forests whereas white-tailed mongooses were detected in open woodland three times and in moderately or highly dense forests on three occasions (Table 25). CC3 (7 of 11 the fixes) and GG5 (11 of the 15 fixes) used highly wooded forest more often than the others (Table 25).

3.4.2.2. Area habitats

3.4.2.2.1. Habitat type

A total of 525 area habitat fixes were obtained from eight golden jackals, five white-tailed mongooses, one marsh mongoose, one African civet and one common genet. Bushes were significantly more often used than the other classes of habitat types (all $x^2 > 7.12$, d.f = 1, all p's < 0.01), and difference on use between farmland and forest was not significant (x^2 = 2.843, d.f = 1, p = 0.092) for golden jackals. But, both farmland and forest were significantly more used than grass (all x^2's > 13.47, all p's < 0.001).

Despite differences on the relative frequency of use among grass, bush and forest habitats for the white-tailed mongooses (Table 26), forests were used significantly more often than farmland and grassland (all $x^2 > 7.024$, d.f = 1, all p's < 0.01). But there was no significant difference on use between forest and bushland ($x^2 = 3.682$, d.f = 1, $p = 0.055$). There was no significant difference on use between farmland and grassland ($x^2 = 1.143$, d.f = 1, $p = 0.565$). The marsh mongoose used grassland and bushland equally ($x^2 = 0.111$, d.f = 1, $p = 0.739$) but both habitats were used significantly more than forest (all $x^2 > 5.261$, d.f = 1, all p's < 0.05).

The civet and the genet used more frequently micro-habitats surrounded by forests (62.2 % and 84 % respectively, Table 26) than the other habitat types.

Table 26. Frequency on use of each area habitat type (within 20 m from location fixes) for eight golden jackals, five white-tailed mongooses, one marsh mongoose, one African civet and one common genet (the percentages are given in parentheses).

Species	n	Farm	Grass	Bush	Forest
C. aureus	258	73 (28.3)	22 (8.5)	109 (42.2)	54 (20.9)
I albicauda	144	29 (20.1)	27 (18.8)	35 (24.3)	53 (36.8)
A. plaudinosus	42	0 (0.0)	19 (45.2)	17 (40.5)	6 (14.3)
C. civetta	37	3 (8.1)	4 (10.8)	7 (18.9)	23 (62.2)
G.genetta	44	2 (4.5)	1 (2.3)	4 (9.1)	37 (84.1)

3.4.2.2.2. Habitat quality

3.4.2.2.2.1. Height of the habitat

Farmland

Golden jackals that were located in farmland used more frequently very short crops (Table 27). Of the 73 fixes of farmland, 57 were < 20 cm and 14 were between 20-50 cm high crops. Only two were 50-100 cm high. Crop fields that were less than 20 cm high were significantly more often used than those between 20-50 cm high ($x^2 = 26.042$, d.f = 1, $p < 0.0001$).

White-tailed mongooses that were detected in farmland also used very short crops. Of the 29 fixes on farmland, 21 were < 20 cm, 4 were between 20-50 cm and the remaining 4 were between 50-100 cm high (Table 27). CC3 fixes on farmland on three occasions were completely < 20 cm high; and the two fixes for GG5 were 0-20 cm and 50-100 cm high (Table 27). All the radiotracked animals were not located in crops that were > 100 cm high.

Table 27. Frequency on use of height of each habitat type by active radiotracked carnivores (the number of individuals detected is given in parentheses).

Habitat type	Species	n	Height of the habitat type (cm)			
			0-20	20-50	50-100	> 100
Farm	*C. aureus*	73 (7)	57	14	2	0
	I. albicauda	29 (4)	21	4	4	0
	C. civetta	3 (1)	3	0	0	0
	G. genetta	2 (1)	1	0	1	0
Grass	*C. aureus*	22 (7)	15	6	1	0
	I. albicauda	27 (5)	15	11	1	0
	A. plaudinosus	19 (1)	3	3	13	0
	C. civetta	4 (1)	2	2	0	0
	G. genetta	1 (1)	0	0	1	0
Bush	*C. aureus*	109 (8)	1	37	44	27
	I. albicauda	35 (5)	0	22	6	7
	A. plaudinosus	17 (1)	0	12	5	0
	C. civetta	7 (1)	0	2	5	0
	G. genetta	4 (1)	0	1	1	2
Forest	*C. aureus*	54 (8)	0	1	0	53
	I. albicauda	53 (5)	0	1	0	52
	A. plaudinosus	6 (1)	0	0	2	4
	C. civetta	23 (1)	0	0	0	23
	G. genetta	37 (1)	0	0	0	37

Grassland

Like farmland, golden jackals that were detected on grassland used more frequently very short grasses. Of the 22 fixes, 15 were < 20 cm and 6 were 20-50 cm high grasses (Table 27). Only 1 was between 50-100 cm high grasses.

White-tailed mongooses used almost entirely the first two categories of habitat height, and differences on use between the two categories of habitat height were not significant (x^2 = 0.615, d.f = 1, p = 0.433; Table 27). Of the 19 fixes for the marsh mongoose, 13 were 50-100 cm, 3 were 20-50 cm and the remaining 3 were < 20 cm in height. Of the 4 fixes for CC3, 2 were < 20 cm and the remaining 2 were 20-50 cm high. GG5 was located on 50-100 cm tall grasses on one occasion (Table27). All the radiotracked animals were not located in grasses that were > 100 cm in height.

Bush

Golden jackals showed no difference on use between bushes that were between 20-50 cm in height and the last two categories of habitat height (all x^2 < 1.56, d.f = 2, all p's > 0.21; Table 27). But bushes that were 50-100 cm in height were significantly more often used than bushes that were > 100 cm in height (x^2 = 4.07, d.f = 1, p = 0.04). Golden jackals were located in bushes that were < 20 cm high on one occasion. All the remaining radiocollared carnivores were never detected in bushes that were < 20 cm high (Table 27).

Unlike golden jackals, white-tailed mongooses used 20-50 cm bushes significantly more often than bushes > 50 cm high (x^2 = 8.33, d.f = 1, p < 0.01). The marsh mongoose used relatively grasses that were between 20-50 cm in height (12 of the 17; Table 27) more often than the remaining ones.

Despite small number of fixes for the civet and the genet (n = 7 and n = 4 for CC3 and GG5 respectively), CC3 used more frequently 50-100 cm tall bushes and GG5 was detected completely in bushes that were > 20 cm in height (Table 27).

Forest

All the radiotracked individuals used almost entirely forests that were greater than 100 cm in height (Table 27). Golden jackals and white-tailed mongooses each were located in 20-50 cm tall underbrush on one occasion, and marsh mongoose in 50-100 cm tall undergrowth on two occasions.

3.4.2.2.2.2. Density of the habitat

Farmland

Golden jackals used mostly open farmland in comparison with the other categories of habitat density (Table 28). Of the 73 fixes for the jackals, 58 were open, 9 were low and 4 were medium. Only 2 were high. Four individuals of white-tailed mongooses used relatively open farmland more compared to the others (Table 28). Of 29 fixes for white-tailed mongooses, 21 were open, 4 were high, 2 were low and the remaining 2 were medium. CC3 was located completely in open farmland on three occasions, and GG5 was detected in open farmland on one occasion and in moderately dense one on another instance (Table28).

Grassland

Golden jackals and white-tailed mongooses used mostly open grassland than the other habitat densities (Table 28). Of the 4 fixes for CC3, three were in open grasses and only one was in low dense grasses. Marsh mongoose was detected nearly equally in the four categories of habitat density where as GG5 was located in highly dense grassland only on one occasion (Table 28).

Table 28. Frequency on use of density of each habitat type by active radiotracked carnivores (the number of individuals detected is given in parentheses).

Habitat type	Species	n	Density of the habitat type			
			Open	Low	Medium	High
Farm	*C. aureus*	73 (7)	58	9	4	2
	I. albicauda	29 (4)	21	2	2	4
	C. civetta	3 (1)	3	0	0	0
	G. genetta	2 (1)	1	0	1	0
Grass	*C. aureus*	22 (7)	14	5	1	2
	I. albicauda	27 (5)	24	2	1	0
	A. plaudinosus	19 (1)	4	5	3	7
	C. civetta	4 (1)	3	1	0	0
	G. genetta	1 (1)	0	0	0	1
Bush	*C. aureus*	109 (8)	21	38	36	14
	I. albicauda	35 (5)	13	16	3	3
	A. plaudinosus	17 (1)	10	4	3	0
	C. civetta	7 (1)	0	1	6	0
	G. genetta	4 (1)	0	0	1	3
Forest	*C. aureus*	54 (8)	2	6	35	11
	I. albicauda	53 (5)	19	17	16	1
	A. plaudinosus	6 (1)	0	0	6	0
	C. civetta	23 (1)	1	2	18	2
	G. genetta	37 (1)	5	6	22	4

Bush

For golden jackals, there was no significant difference on use between low and moderate dense bushes (x^2 = 0.054, d.f = 1, p = 0.816). Similarly, difference on use between open and high dense bushes for the golden jackals were not significant (x^2 = 1.4, d.f = 1, p = 0.24). Differences on use between open and low dense bushes for white-tailed mongooses were not significant (x^2 = 0.143, d.f = 1, p = 0.705), but both were used more significantly used than medium or highly dense ones (all x^2 > 6.25, d.f = 1, all p*'s* < 0.05). Marsh mongoose used mostly open bushland (10 of the 17) of all the categories of habitat density. CC3 used medium dense bushes 6 times out of the 7 fixes and low dense bushes on one occasion. Of the 4 fixes for GG5, 3 were high dense bushes and one was medium dense bush (Table 28).

Forest

Golden jackals used significantly more often moderate dense forests than densely wooded forests ($x^2 = 12.52$, d.f = 1, $p < 0.0001$), but the difference on use between densely wooded forests and low wooded forests was not significant ($x^2 = 1.471$, d.f = 1, $p = 0.225$). They were located in open woodland on two occasions (Table 28).

White-tailed mongooses were detected more often in the first three categories of habitat density and there was no significant difference on use between them (all $x^2 < 0.269$, d.f = 2, all p's > 0.612). White-tailed mongooses were detected in densely wooded areas on one occasion (Table 28). Marsh mongoose was detected only in medium dense forests. Both CC3 and GG5 used mainly medium dense forests than the others (Table 28). Of the 23 fixes for CC3, 18 were medium, 2 were low, 2 were high and only 1 was open woodland. Of the 37 fixes for GG5, 22 were medium, 6 were low, 5 were open and 4 were high.

3.4.3. Habitat selection

3.4.3.1. Index of selection

C. aureus

Habitat selection was determined for seven radiotracked golden jackals. All individuals of *C. aureus*, except for CA8 (adult male), avoided grassland and open woodland. But, they showed preference for farmland and bushland except for CA11 (subadult female), which avoided both habitats. Furthermore, the golden jackals showed avoidance for the town. Nevertheless, selection for closed woodlands varied with respect to their spatial organisation among the individuals of golden jackals. The adult pair [(CA10 (female) and CA13 (male)] and subadult and subadult female (CA11) preferred the closed woodland whereas the dispersing subadults of both sexes, except for CA6, avoided that habitat. The results of analysis of selectivity for the individuals of golden jackals are given in Table 29.

Table 29. Indices of habitat selection (S) computed using Jacob's formula for the radiotracked *C. aureus*. The values of S between - 1 and 0 indicate avoidance of that habitat, and those between 0 and + 1 indicate preference for that habitat.

Id	Farm	Bush	Grass	Open woodland	Closed woodland	Town
CA10	0.07	0.62	- 0.29	- 0.64	0.81	- 1
CA13	0.31	0.48	- 0.22	- 0.53	0.71	- 1
CA8	0.32	0.57	0.70	0.95	- 1	- 1
CA11	- 0.04	- 0.30	- 0.76	- 0.07	0.66	- 0.68
CA6	0.28	0. 76	- 1	- 0.58	0.43	- 1
CA7	0.38	0.70	- 0.39	- 0.46	- 1	- 0.25
CA9	0.17	0.78	- 0.03	- 0.46	- 1	- 1

The spatial distribution of movement fixes in the home ranges the radiotracked golden jackals that was superimposed in the vegetation map of the study area is shown in Figure 18.

I. albicauda

Habitat selection was determined for four individuals of radiotracked *I. albicauda*. All the individuals of radiotracked white-tailed mongooses preferred open woodland, and avoided open grassland, when available within the home range. However, there were variations on selectivity among the individuals for the farmland, bushland, closed woodland and even for town. The results of analysis of selectivity for the individuals of white-tailed mongooses are given in Table 30.

Table 30. Indices of habitat selection (S) computed using Jacob's formula for the radiotracked *I. albicauda* and *A. plaudinosus*. The values of S between - 1 and 0 indicate avoidance of that habitat, and those between 0 and + 1 indicate preference for that habitat. Blank spaces indicate habitat not available in the animal's home range.

Id	Farm	Bush	Grass	Open woodland	Closed woodland	Town
IA10	- 0.22	0	- 0.57	0.27	- 1	0.80
IA11	0.31	0.04	- 0.44	0.03		
IA13	0.76		- 0.15	0.19	0.33	- 0.24
IA8	- 0.28			0.22	- 1	0.13
AP1	- 1	- 0.16	0.16	0.16		

The spatial distribution of movement fixes in the home ranges the radiotracked white-tailed mongooses that was superimposed in the vegetation map of the study area is shown in Figure 19.

A. plaudinosus

The only tracked marsh mongoose (AP1) preferred grassland and open woodland, and avoided farmland and bushland when available (Table 30). Unfortunately, closed woodland habitats and town were not available in its home range and thus selectivity was not computed for them. The spatial distribution of movement fixes in the home range of the radiotracked marsh mongoose that was superimposed in the vegetation map of the study area is shown in Figure 19.

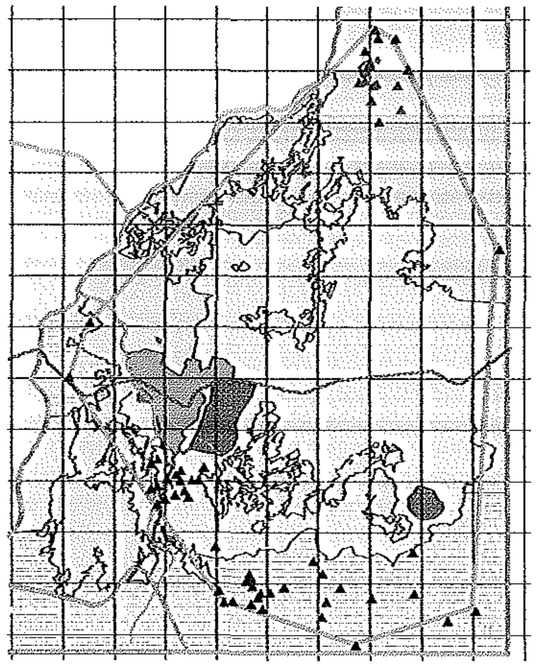
C. civetta and *G. genetta*

The S value for the only tracked African civet showed that this civet avoided farmland, bushland and open woodland, and preferred grassland and closed woodland (Table 31). On the other hand, the indices of selection for the common genet showed that it avoided farmland, and preferred both open woodland and closed woodland (Table 31).

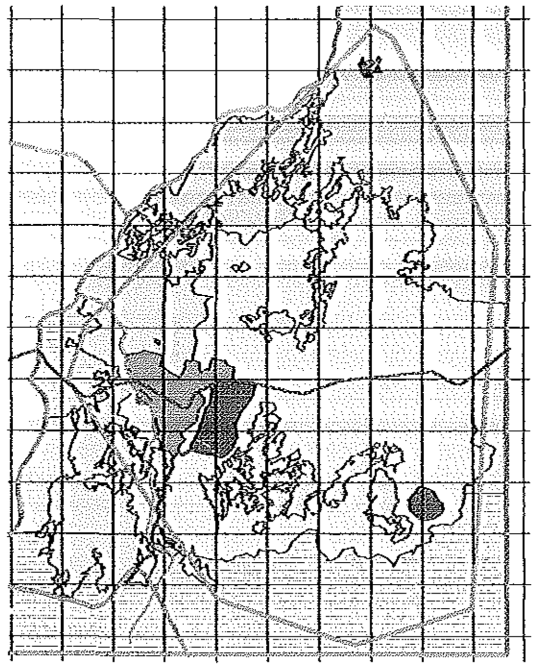
Table 31. Indices of habitat selection (S) computed using Jacob's formula for the radiotracked *C. civetta* and *G. genetta*. The values of S between - 1 and 0 indicate avoidance of that habitat, and those between 0 and + 1 indicate preference for that habitat. Blank spaces indicate habitat not available in the animal's home range.

Id	Farm	Bush	Grass	Open woodland	Closed woodland	Town
CC3	- 0.67	- 0.66	0.34	- 0.26	0.84	0.40
GG5	- 1			0.20	0.27	- 0.54

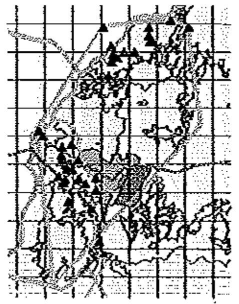
With respect to selection for the town, the African civet showed preference for the town whereas the common genet showed avoidance of this habitat. The spatial distribution of movement fixes in the home ranges of the radiotracked African civet and common genet that was superimposed in the vegetation map of the study area is shown in Figure 20.



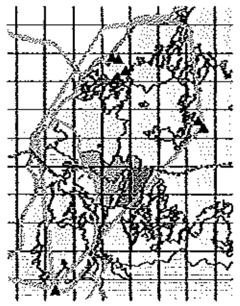
CA6A (m)



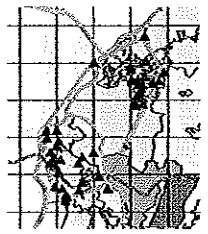
CA6R (m)



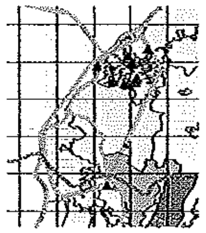
CA7A (m)



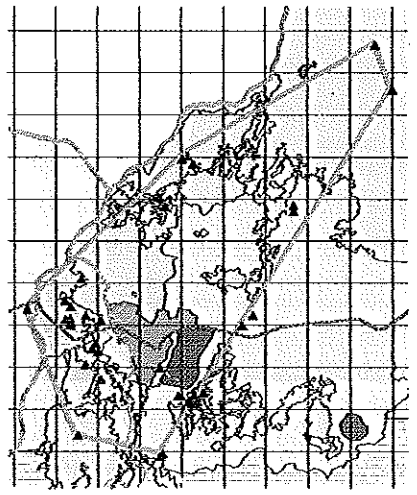
CA7R (m)



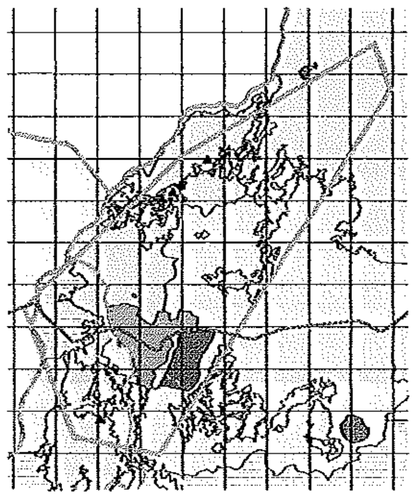
CA8A (m)



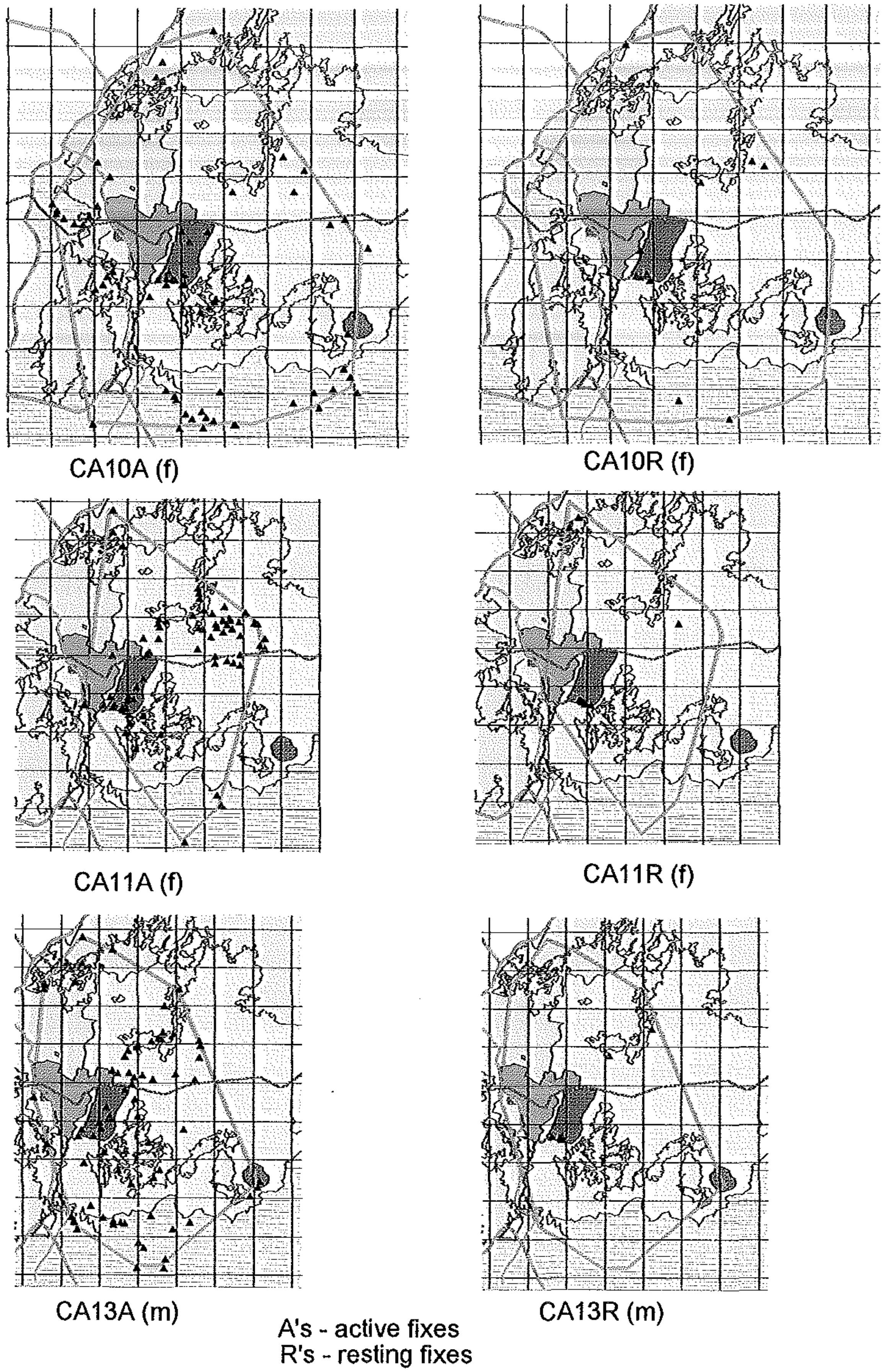
CA8R (m)



CA9A (f)

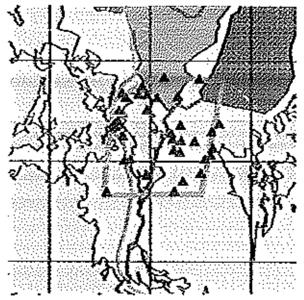


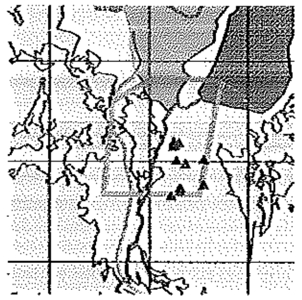
CA9R (f)

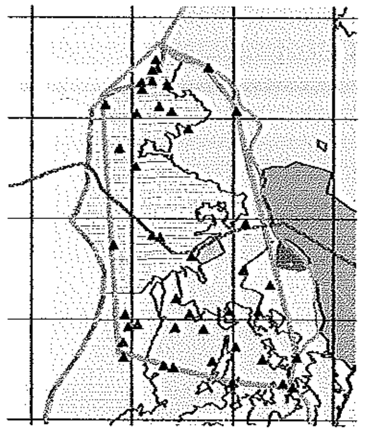


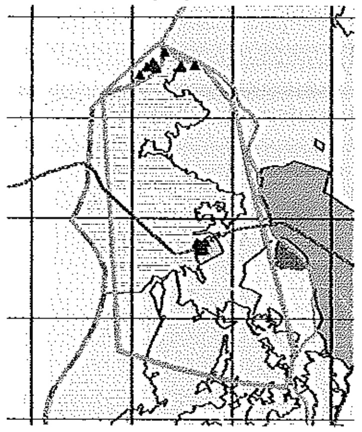
Scale 1:150000

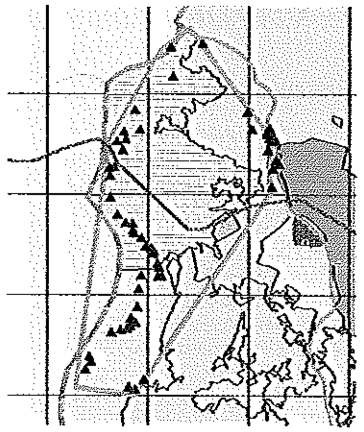
Figure 18. A cartesian grid overlaying the vegetation map and fixes distribution in home ranges of radio-tracked golden jackals

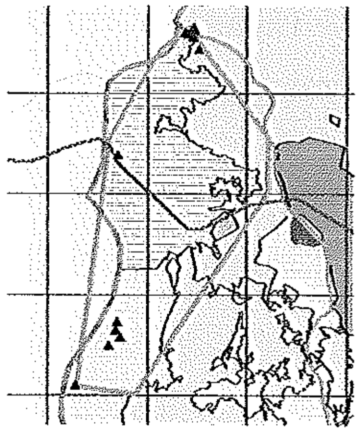

IA8A (m)

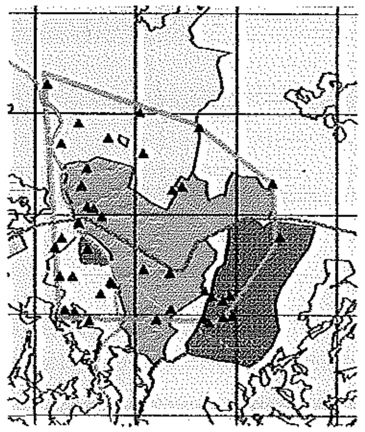

IA8R (m)

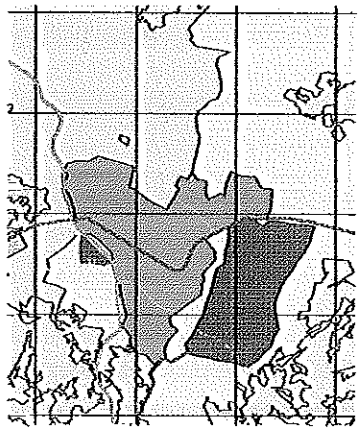

IA11A (m)

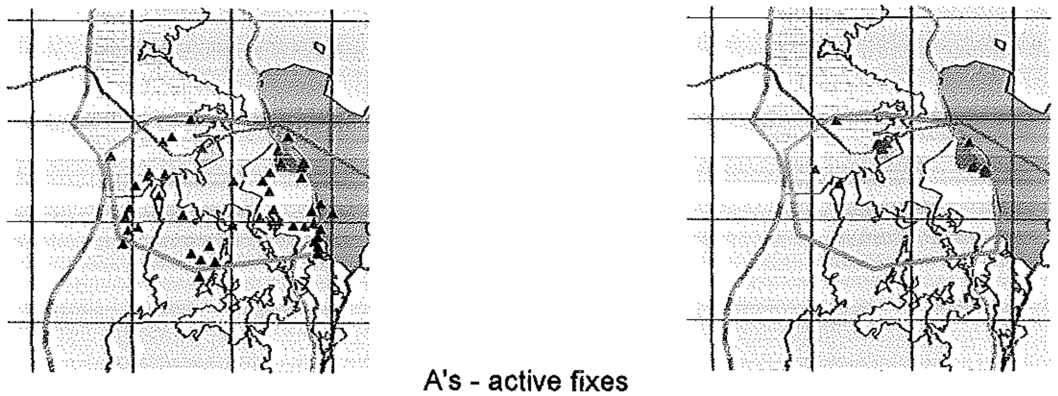

IA11R (m)


AP1A (m)


AP1R (m)


IA13A (m)

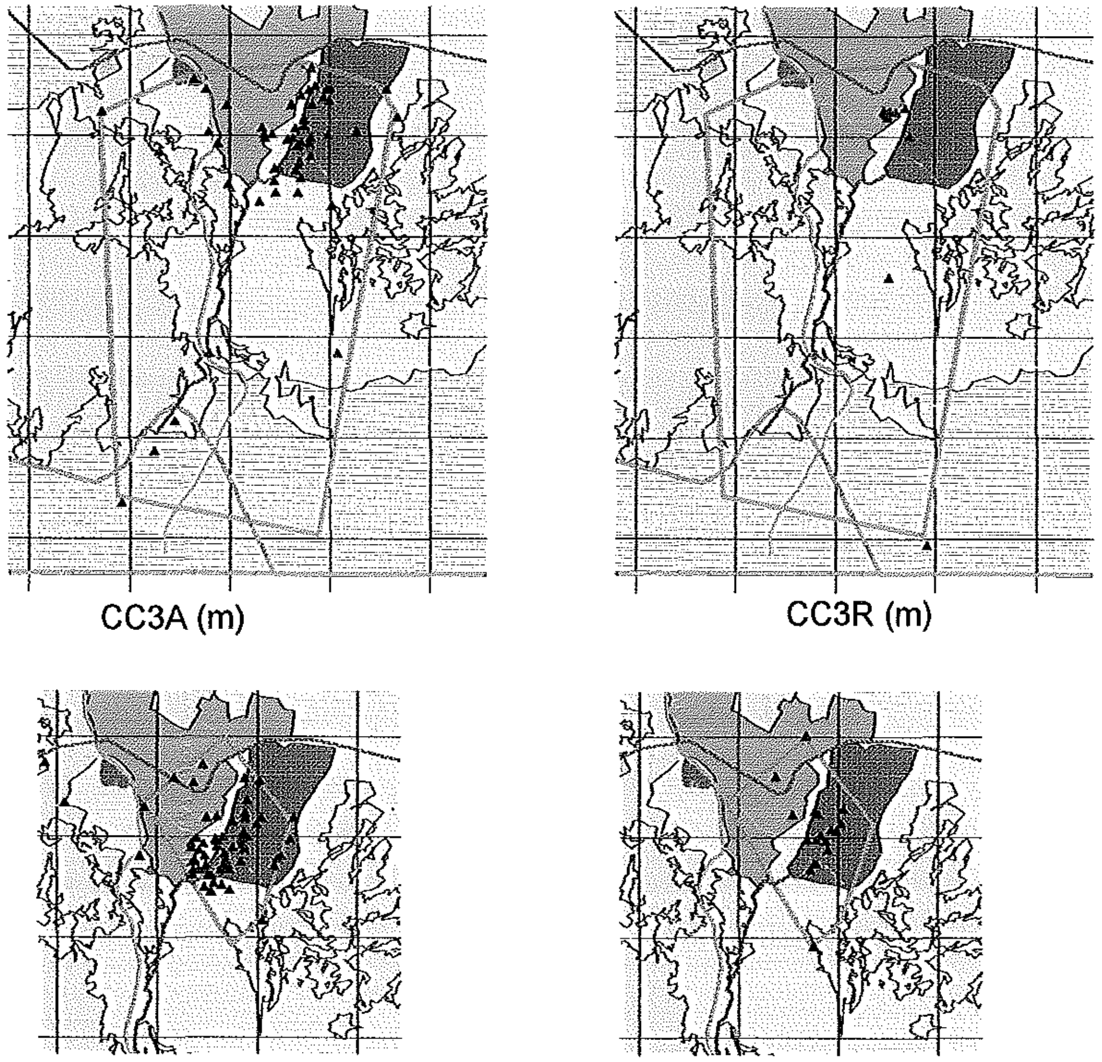

IA13R (m)



IA10A (f) A's - active fixes R's - resting fixes IA10R (f)

Scale 1:75000

Figure 19. A cartesian grid overlaying the vegetation map and fixes distribution in home ranges of radio-tracked mongooses



CC3A (m) CC3R (m)

GG5A (f) A's - active fixes Rs - resting fixes GG5R (f)

Scale 1:75000

Figure 20. A cartesian grid overlaying the vegetation map and fixes distribution in home ranges of radio-tracked African civet & common genet

3.5. DENSITY ESTIMATION

3.5.1. Trapping Index

Of the total 155 trap nights for cage trapping, 17 traps were occupied with animals including 4 recaptures. Similarly, of 97 trap nights for leg-hold trapping, 27 traps were occupied with animals including 5 recaptures. Traps sprung without catching accounted to 15 and 28 for the cage and leg-hold traps respectively. The results were summarised in Table 32.

Table 32. The number of individuals of each species captured and recaptured in the cage and leg-hold traps from October 1998 - March 1999 in and around the BMNP. R (1) indicates animals captured for the second time and R (2) those captured for the third time.

Trap type	species caught[1]	Capture	Recaptures		Grand total
			R(1)	R(2)	
	CC	2	1		3
	CF	3	1		4
	CS	2			2
Cage	GG		1		1
	HG	1			1
	IA	3	1		4
	IS	1			1
	UN	1			1
Total		13	4		17
	CA	9	2	1	12
	CF	5	2	0	7
	CS	2			2
Leg-hold	GG	1			1
	MC	1			1
	IA	2			2
	AP	1			1
	FC	1			1
Total		22	4	1	27

[1] CC= *Civitictis civetta*; CF = *Canis familiaris*; CS = *Canis simensis*; GG = *Genetta genetta*; HG = *Hystrix galeata*; IA = *Ichneumia albicauda*; IS = *Ictonyx striatus*; UN = unknown; CA = *Canis aureus*; AP = *Atilax plaudinosus*; MC = *Mellivora capensis;* FC = *Felis caracal.*

Individuals of *C. aureus* and *I. albicauda* were not captured at all in Gaysay, but in Head-Quarter and Mongoose rock, for leg-hold trapping (Appendix 4). We caught 1.5 times as many jackals and mongooses per catch effort in Head-Quarter than in Mongoose rock for leg-hold trapping (Table 33).

Table 33. Index of density per catch effort of the different species captured in the different trap units for leg-hold traps.

Species caught	Gaysay	Head-Quarter	Mongoose rock
Canis aureus	0	0.13	0.09
Ichneumia albicauda	0	0.03	0.02
Atilax plaudinosus	0	0	0.02
Canis familiaris	0	0.08	0.05
Canis simensis	0	0	0.05
Genetta genetta	0	0.03	0
Mellivora capensis	0.07	0	0

For cage trapping, white-tailed mongooses were not captured in Gaysay but in Head-Quarter and Mongoose rock (Appendix 4). We caught the same number of mongooses per catch effort in Mongoose rock as in Head-Quarter (Table 34). Golden jackals avoided entering in the cage traps probably due to the small trap size and/or they were trap shy animals.

Table 34. Index of density per catch effort of the different species captured in the different trap units for cage traps.

Species caught	Gaysay	Head-Quarter	Mongoose rock
Civitictis civetta	0	0.03	0
Canis familiaris	0	0.03	0.03
Canis simensis	0.04	0	0
Genetta genetta	0	0	0
Ichneumia albicauda	0	0.03	0.03
Ictonyx striatus	0	0	0.03

3.5.2. Extrapolation from radiotracking data

The population density of nocturnal carnivores determined from collared individuals' home range sizes and overlaps were all less than one individual km^{-2} (Table 35). The densities of white-tailed mongooses, marsh mongooses and common genets in and around Dinsho were appreciable; the golden jackals and African civets occurred in small (~ 0.1 individual km^{-2}) but non-negligible numbers (Table 35).

Table 35. Carnivore population densities (individual km^{-2}) that were determined from radio-collared individuals' home ranges and overlaps including any observations of uncollared ones.

Species	Density	Total numbers
C. aureus	0.1	9
I. albicauda	0.46	5
A. plaudinosus	0.51	2
C. civetta	~ 0.1	1
G. genetta	0.58	2

3.5.3. Opportunistic sightings

3.5.3.1. Periodic and seasonal patterns

A total of 450 hours of tracking, of which 333.23 hours during the dry season and 116.77 hours during the wet season, and 6576 hours of non-tracking periods were measured. We opportunistically sighted 33.3 times as many carnivores per hour monitoring effort when tracking than during non-tracking periods.

During the tracking period, we saw 4.3 as many carnivores per hour monitoring effort in the dry season than in the wet season. The relative proportion of more frequently sighted carnivores in the dry season by decreasing order was: Spotted hyaenas, white-tailed mongooses and golden jackals (Table 36).

Table 36. Periodic and seasonal distribution of opportunistic sightings of carnivores in the study area. Effort is measured in terms of the length of hours of tracking and non-tracking periods.

Species sighted[1]	Tracking		Non-tracking	
	Dry	Wet	Dry	Wet
CC	0	0	1	0
CA	8	0	0	0
FD	1	0	0	0
CF	2	0	4	6
HI	0	0	1	1
CS	0	0	1	1
GG	1	0	0	0
CrCr	16	2	1	0
FS	3	0	0	1
IA	12	1	2	2
Grand total	43	3	10	11

[1] CC= *Civitictis civetta*; CA= *Canis aureus*; FC= *Felis domesticus*; CF = *Canis familiaris*; IH= *Herpestes Ichneumon*; CS = *Canis simensis*; GG = *Genetta genetta*; CrCr= *Crocuta crocuta*; IA = *Ichneumia albicauda*; FS= *Felis serval.*

During the non-tracking period, the number of all the different animals seen per hour observation effort was the same between the wet and dry seasons (Table 36).

3.5.3.2. Monthly patterns

The distribution of the number of sightings of the different carnivores for each month showed that the numbers were relatively higher in December, January and March. Few sightings were obtained in the remaining months of the year (Fig. 21). No animals were sighted in April.

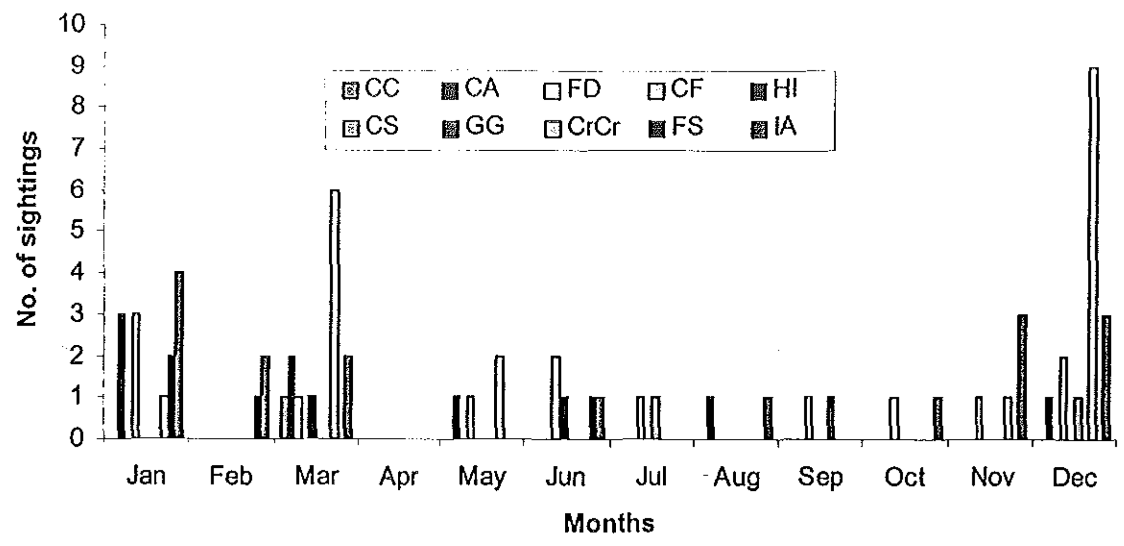


Figure 21. Monthly distribution of sightings of small carnivores that were opportunistically located over the time period from November 1998- October 1999.

3.5.3.3. Daily patterns

During the night-time, three carnivores – spotted hyaena, golden jackal and White-tailed mongoose – were more frequently sighted while domestic dogs did so during daylight (Fig. 22 & Table 37). Ethiopian wolf and Egyptian mongoose, *Herpestes ichneumon*, were seen exclusively during day light. A subadult civet was located in a hole dug for toilet during day light on one occasion, and of four sightings for serval cat, one was during the day light.

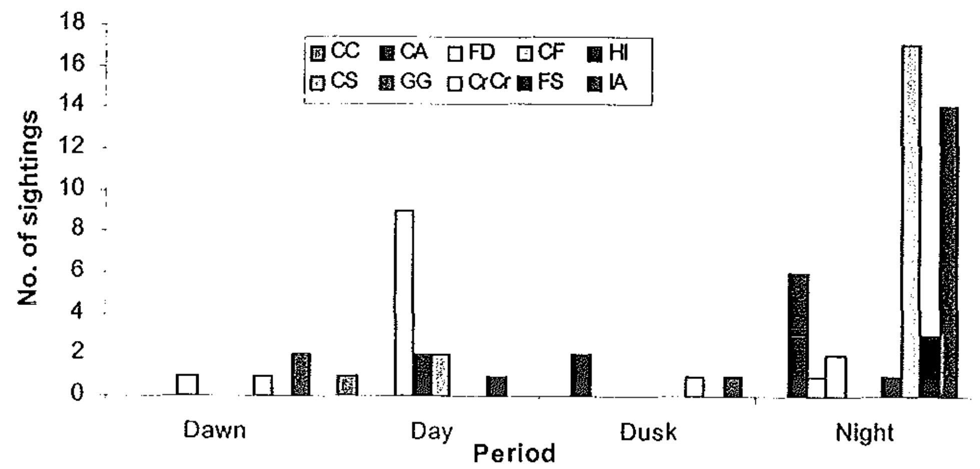


Figure 22. Distribution of fixes throughout the time from dusk to dawn of small carnivores that were sighted opportunistically.

Table 37. Information on the distribution of opportunistic sightings of carnivores throughout the time from dusk to dawn.

Species sighted	Duration			
	Dawn	Day	Dusk	Night
Civitictis civetta	0	1	0	0
Canis aureus	0	0	2	6
Crocuta crocuta	1	0	1	17
Ichneumia albicauda	2	0	1	14
Herpestes ichneumon	0	2	0	0
Felis domesticus	0	0	0	1
Canis familiaris	1	9	0	2
Canis simensis	0	2	0	0
Genetta genetta	0	0	0	1
Felis serval	0	1	0	3

3.5.4. Density estimation by Distance sampling

304 sightings in the highlands and 183 sightings in the lowlands were obtained on 885.4 km and 536 km drives by car respectively (Table 38 & 39). The number of sightings and individuals of the most frequently encountered carnivores was substantially higher in the wet season than in the dry season both for highlands and lowlands except spotted hyaena, whose sightings in the dry season were greater than those in the wet season for the highlands. The number of sightings in the dry and wet seasons for the highlands and lowlands of transect routes for each species of carnivore is given in Table 39.

Table 38. Distance driven (km) in the highlands and lowlands of the Bale region from December 1998-2000.

Season	Highlands	Lowlands	Total
Dry	339.4	108	447.4
Wet	546.0	428	974.0
Total	885.4	536	1421.4

Of total 885.4 km driven in the highlands, 339.4 were during the dry season and 546 were during the wet season; and of 536 km driven in the lowlands, 108 were during the dry season and 428 were during the wet season (Table 38).

In the highlands of the transect route, density estimates were obtained for domestic dog, golden jackal and spotted hyaena whereas in the lowlands of the transect route, estimates were obtained for domestic dog and golden jackal (Table 40). Estimates of domestic dog densities were 6 times greater than those of golden jackal in the highlands (Garamba-Homa) whereas they were 2 times greater than the jackals in the lowlands (Agarfa-Goba). However, the density of golden jackal was almost the same both in the highlands and lowlands (Table 40).

Mean estimated density of jackals in the highlands was 2 times greater than that of the spotted hyaena, which was 0.64 individual/km^2. Sightings of hyaena were too low in the lowlands to give an estimate (Table 40). Data were few to estimate the density of other carnivores that were sighted (Table 39). The results of Distance analysis for the highlands and lowlands of the study area are summarised in Table 40.

Table 39. **The number of sightings both in the dry and wet season for the highlands and lowlands of the transect route.**

Species	Highlands					Lowlands				
	Dry		Wet			Dry		Wet		
	Sightings	Number	Sightings	Number	Comment	Sightings	Number	Sightings	Number	Comment
CF	11	18	69	82		7	12	42	72	
CrCr	26	44	14	38	4 CrCr (?) Dry	1	1	8	10	
IA	7	7	31	34	1 (MC/IA)	4	4	15	17	1 IA (?) Wet
FS	10	10	11	12		1	1	10	10	
CA	30	33	30	32		4	6	48	57	
FD	13	16	23	23	1 FD (?) Wet	7	7	22	22	
CS	1	1	2	2		0	0	0	0	
CC	2	2	12	13	1 CC (?) Wet	1	1	5	6	
MC	0	0	1	2		0	0	2	2	
C	0	0	2	2		0	0	1	1	
IS	2	2	1	1		0	0	0	0	
GG	1	1	1	1		0	0	1	1	
OA	0	0	0	0		0	0	2	2	
FL	1	1	1	1		0	0	1	1	
AP	2	2	0	0		1	1	0	0	
Total	106	137	198	243		26	33	157	201	

[1]species = CF = *Canis familiaris*; CrCr = *Crocuta crocuta*; IA = *Ichneumia albicauda*; FS = *Felis serval*; CA = *Canis aureus*; FD = *Felis domesticus*; CS = *Canis simensis*; CC = *Civitictis civetta*; MC = *Mellivora capensis*; C = carnivore; IS = *Ictonyx striatus*; GG = *Genetta genetta*; OA = *Orycteropus afer*; FL = *Felis lybica* ; AP = *Atilax plaudinosus*

Table 40. **Density of small carnivores in the highlands and lowlands of Bale region estimated using distance methods.**

Species	Transect[1]	Sightings	L	R	T	f/km	n/L	D	LCL	UCL	Key Function	Exp.	Group	AIC	Sum chi sq.	d.f
							Distance estimates									
Highlands																
CF	G-H	66	29	14	406	0.16	0.16	6.39	3.58	11.3	Uniform	Cosine	6	153	na	na
CA	G-H	39	29	14	406	0.10	0.10	1.42	0.38	5.26	Hazard-rate	Cosine	4	60.4	2.21	1
CrCr	G-H	37	29	14	406	0.09	0.09	0.64	0.34	1.21	Half-normal	Hermite	4	?	2.59	2
Lowlands																
CF	A-G	19	45	5	225	0.08	0.08	2.151	1.01	4.33	Half-normal	Hermite	4	45.1	2.68	2
CA	A-G	52	45	5	225	0.23	0.23	1.431	0.06	3.11	Hazard -rate	Cosine	5	156	3.87	2
CrCr	A-G	9	45	5	225	0.04	0.04	Too Few Data								
IA	A-G	15	45	5	225	0.07	0.07	Too Few Data								

Key words: L = length (in km) of each transect route; R = number of repeated drives in each transect; T = Total distance driven (i.e. replicate x transect length); f/km = frequency of sighting per km stripe; n/L = encounter rate; D = mean estimated density /km^2; LCL = 95 % Lower Confidence Limit; UCL = 95 % Upper Confidence Limit; Exp = Series Expansion; AIC = Akaike's Information Criterion.

[1]G-H = Garamba-Homa; A-G = Agarfa-Homa-Goba.

3.6. EPIDEMIOLOGY

3.6.1. Wild carnivores serology

Blood samples were obtained from 10 *C. aureus*, 5 *I. albicauda*, 1 *M. capensis*, 1 *C. civetta*, 1 *G. genetta*, 1 *A. plaudinosus*, 1 *I. striatus* and 2 *C. simensis* during the trapping period. All golden jackals, with the exception of CA15, were seronegative for Canine distemper virus (CDV). However, 60 % (n = 4) of the golden jackals were seropositive for Canine adenovirus (CAV) and Canine parvovirus (CPV). All the white-tailed mongooses were seronegative for each type of canine virus, and the same is true for ratel, African civet, common genet, marsh mongoose and zorilla. Of the two Ethiopian wolves sampled, one was seropositive for all canine viruses whereas the other was seropositive for CPV only. The results of diagnosis of sera taken from the carnivores, which were captured during the trapping period, for canine viruses are summarised in Table 41.

Overall, 15 *C. aureus*, 15 *I. albicauda*, 5 *C. simensis* and 11 (*G. genetta/C.civetta/F.caracal*) were sampled around the Bale Mountains National Park from 1998 to 1999 (Table 42). All the white-tailed mongooses were seronegative for both CDV and CAV, and only 7 % were seropositive for CPV. Similarly, the common genets, the African civets and the caracals were seronegative for both CDV and CAV, and 18 % were seropositive for CPV. Nevertheless, 40 % and 50 % of golden jackals and Ethiopian wolves sampled during this period were seropositive for CDV, 52 % and 50 % to CAV, and 67 % and 33 % to CPV respectively (Table 42).

Table 41. Serology of carnivore species captured during the trapping period. Titre value greater than or equal to 32 is positive for CDV and CAV, and value greater than or equal to 64 is positive for CPV.

Notes	Field code	Date	Place	Species	Sex	Age	CDV titre	CAV titre	CPV titre
Serum	CA6	03/11/98	Mong. rock	*Canis aureus*	M	SA	<8	<8	<4
Serum	CA7	04/11/98	Mong. rock	*Canis aureus*	M	SA	<8	**>512**	**2048**
Serum	CA8	04/11/98	Mong. rock	*Canis aureus*	M	A	<8	<8	8
Serum	CA9	04/11/98	Mong. rock	*Canis aureus*	F	SA	<8	**>512**	**2048**
Serum	CA10	11/11/98	Head-Quarter	*Canis aureus*	F	O	<8	**>512**	**1024**
Serum	CA11	18/11/98	Head-Quarter	*Canis aureus*	F	SA	<8	<8	**128**
Serum	CA12	19/11/98	Head-Quarter	*Canis aureus*	F	J	<8	<8	32
Serum	CA13	20/11/98	Head-Quarter	*Canis aureus*	M	A	<8	**>512**	**128**
Serum	CA14	21/11/98	Head-Quarter	*Canis aureus*	F	O	<8	**32**	32
Serum	CA15	23/11/98	Flats	*Canis aureus*	M	A	**181**	**>512**	**1024**
10% dilu.	MC1	17/10/98	Gaysay	*Melivora capensis*	M	A	<8	<8	<4
10% dilu.	CC3	13/11/98	House	*Civitictis civetta*	M	YA	<8	<8	16
10% dilu.	GG5	10/11/98	House	*Genetta genetta*	F	A	<8	<8	4
10% dilu.	IA10	29/10/98	Horse camp	*Ichneumia albicauda*	F	A	<8	<8	8
10% dilu.	IA11	30/10/98	Horse camp	*Ichneumia albicauda*	M	A	<8	<8	8
10% dilu.	AP1	03/11/98	Mong. rock	*Atilax plaudinosus*	M	SA	<8	<8	4
10% dilu.	IA12	04/12/98	Gaysay	*Ichneumia albicauda*	F	SA	<8	<8	32
10% dilu.	IS1	29/10/98	Horse camp	*Ictonyx striatus*	M	A	<8	<8	<4
Serum	CS4	04/12/98	Gaysay	*Canis simensis*	F	J	<8	<8	64
Serum	CS1	06/12/98	Gaysay	*Canis simensis*	M	O	**128**	**181**	64
10% dilu.	IA 13	Feb-99	Head-Quarter	*Ichneumia albicauda*	M	A	<8	<8	32
10% dilu.	IA 14	Mar-99	Head-Quarter	*Ichneumia albicauda*	M	SA	<8	<8	32

Table 42. Percent of each species seropositive for canine viruses (n indicates the number of individuals sampled).

Species	n	CDV	CAV	CPV
I. albicauda	15	0	0	7
G. genetta/C. civetta/F. caracal	11	0	0	18
C. aureus	15	40	52	67
C. simensis	5	50	50	33

CDV = Canine distemper virus; CAV = Canine adenovirus; CPV = Canine parvovirus. Data obtained from Karen Laurenson's epidemiological project.

In addition to canine viruses, rabies cases were confirmed for 1 Ethiopian wolf, 1 golden jackal and 1 serval cat in 1998.

4.0. DISCUSSION

4.1. HOME RANGE ANALYSIS

4.1.1. Home range size and stability

Canis aureus

In the current study, the average MCP (100 %) for males was 35 km^2 and 36 km^2 for females. Although there was no difference on the average MCP figure between males and females home range size between individual *C. aureus* vary considerably. Most of the variability in range size between individual *C. aureus* could be explained by the unusual behaviour of CA6 and CA8. CA8 individual was an adult male, whose skin colour was different from the other radio-collared jackals. Despite the fact that CA8 was an adult male, it had by far the smallest range size of all the radio-tracked jackals. The possible explanation could be the metabolic rate of the individual (Ferguson *et al.*, 1983). On the other hand, CA6 (subadult male) had the largest home range among the individuals. This is because of the high dispersion of locations in the animal's home ranges. This suggests that the subadult male CA6 possibly moved to exploit new food resources that could influence the large home range size of this individual. Alternatively, the largest home range size of this individual could be as a result of young dispersal.

In the current study, CA10 (adult female) has a larger home range than CA8 and CA13 (adult males). This is probably because CA10 had three pups during March, 2000 and thus she would be expected to utilize larger areas than males, which are not contributing to pup raising (Estes, 1991), as the case in female lynx (Okarma *et al.*, 1997). Alternative explanation for the old female jackal larger home range size than the adult male jackals could be exploitation of new food resources. Other studies show that males carnivores usually have a larger home range than females because males are usually heavier and this is correlated with the more extensive movement of the male suggesting that a larger foraging space may be required for its maintenance (Tomich, 1969).

Differences in the size of home range are likely in widely divergent ecological conditions and could contribute to differences in the results of various studies of golden jackals. Different data have been reported in different areas such as Bangladesh (1.1 km^2 for males and 0.6 km^2 for females; Pouche *et al.*, 1987), Rift Valley of Kenya (2.4-21.7 km^2, Fuller *et al.*, 1989), Ngorongro Crater, Tanzania (2.56-5.11 km^2; Van Lawick and Van Lawick-Godall, 1970), Serengeti, Tanzania (10.24 - 23 km^2; Van Lawick and Van Lawick-Goodall, 1970), Serengeti, Tanzania (0.5-5 km^2; Van Lawick and Van Lawick-Godall, 1971, Moehlman, 1983, 1986), Israel (0.1 km^2; Macdonald, 1979a).

The measured home ranges for the golden jackals, in the present study, were larger than those measured elsewhere. These could be attributed to the extensive farming practices occurring in the study area (i.e. at present, 33 % of the study area is converted into farmland) compared to the natural habitats of others. The farmland presumably provided less food for the jackals and thus led to bigger ranges. Nonetheless, the difference in range size from one area to another suggests that the species, as the case in *C. mesomelas* Ferguson *et al* (1983), can adapt to diverse ecological settings.

Variation in home range size, under different ecological conditions, has also been reported in closely related species. For example, the home ranges of black-backed jackals, *C. mesomelas* vary from 0.7-842 km^2 (Wyman, 1967; Rowe-Rowe, 1982; Ferguson *et al.*, 1983; Moehlman, 1986; Fuller *et al.*, 1989). A study conducted in the Rift Valley of Kenya showed that side-striped jackals, *C. adustus*, had a home range of 1.1 km^2 (Fuller et al., 1989). If all these three species of jackals live sympatrically in East Africa (Fuller *et al.*, 1989) and they converge on a similar size (Valkenburgh and Wayne, 1994), one might suspect that they have a similar range size. But, the comparative studies of black backed jackals and golden jackals in the Serengeti revealed that they show considerable variation in range size (Moehlman, 1986). Macdonald (1983) attributes the variation in home range size among the three jackal species to the availability and dispersion of food.

Several of the radio-tracked golden jackals had two or three centres of activity of their home ranges during the period of tracking. This may be because of the uneven distribution of resources in the area. *C. aureus* used specific areas as their centres of foraging activity and denning sites. All the radio-collared individuals were mainly nocturnal although some diurnal activity was observed, particularly by CA6, in areas far from human disturbance. Since all of the individuals spent most of the time resting, selection of sites that provide safety from human interference was important. However, a large portion of the area that could serve as shelter is modified by agriculture and thus, the few patches of cover that are available are widely distributed in different parts of the study area. Therefore, the uneven distribution of key habitat elements such as shelters and foraging sites made it possible for the individual to focus on the denning activity in certain areas where cover and escape routes were secured while foraging activities in areas where prey abundance was good.

Ichneumia albicauda

In the present study, *I. albicauda* MCP (100 %) home ranges for males averaged 3.18 km^2, and that of the only female tracked was 2.63 km^2. There were few data to compare the finding of this study, with only two previous estimates of home range for this mongoose has been made. Taylor (1972) reported a home range of 8 km^2 in Kenya. Waser and Waser (1985) showed that in the Serengeti, males had average home ranges of 0.97 km^2 (range= 0.8-1.23) and females with 0.64 km^2 (range= 0.39-1.18). The reason for bigger home ranges of white-tailed mongooses in the present study compared to the Serengeti mongooses could be the difference on the type of habitat, availability and dispersion of food between the two areas. The short grassy plains of Serengeti, unlike the small relicts of the montane grassland seen in the study area, support large herds of ungulates. The ungulates left large quantities of dung, which attract abundant dung beetles that were main food items for white-tailed mongoose (Waser, 1980). The relatively higher density of food in a small area allows the Serengeti mongooses to range in a smaller area. These studies serve to demonstrate the variability of home rage size within the same species in different areas.

Most of the variability in home range size between individual *I. albicauda* (Table 6) could be explained by the unusual behaviour of IA8. It was the largest adult male captured and radio-collared (Table 1), but it had by far the smallest home range estimated. It is possible that the availability and dispersion of food (i.e. lower dispersion and higher density of food in his range) might have contributed to the smallest home range of IA8.

The ranges of male white-tailed mongooses were all substantially larger than females. This supports data from studies of other mongoose species which demonstrate that male ranges are consistently larger than females [*Herpestes auropunctatus*: Pimental (1955), Tomich (1969), Gorman (1979); *Cynictis pencillata* and *Galerella pulverulenta*: Cavallini and Nel (1995); *Herpestes ichneumon*: Stuart (1981)]. According to Sandell (1989), the home range size of males and females in solitary predators are determined by different factors: First, body mass of animal plays an important role in determining the individual's home range size (Gittleman and Harvey, 1982). If there is significant difference in body mass between sexes, one suspects that a more extensive movement is experienced by the heavier sex and that a large foraging space may be required for its maintenance (Tomich, 1969). However, in the present study, there was no significant difference in body mass between the males and the female. Therefore, body mass can not be considered as a possible explanation for the variation in range size between the males and the female. Second, social needs can also be considered as a cause for the intersexual variation in range size (Tomich, 1969). In the present study, social needs, particularly in males can explain the variation in home range size between sexes.

The radio-collared *I. albicauda* did not have stable centres of home ranges. Since white-tailed mongooses were strictly nocturnal in the study area and ranging in and around human habitation, daytime beds that provide good cover and protection from any danger were essential. However, the denning sites that contained these particular features were not abundant and regularly spaced in the range. Thus, they should concentrate on foraging activity in areas where food availability is high and denning activity in those sites where good cover characteristics are available.

Atilax plaudinosus

When the minimum convex polygon method of calculating home range was utilised, the range area of *Atilax* covered areas that have never been visited by this mongoose. The range of this individual was stretched linearly along the Web and Denka rivers. Thus, a modified estimate of range size obtained by multiplying home range length by the width of the rivers (measured at evenly distributed points along the river) could be a more accurate reflection of the specialised nature of *Atilax* in this study. In the current study, the MCP (100 %) figure for the only tracked adult male was 3.93 km^2. In South Africa, the adjusted home range size of two radio-tracked marsh mongooses averaged about 0.7 km^2 (Maddock, 1988). In southwestern Central African Republic, the MCP (100 %) for this mongoose was 2.2 km^2 and 0.54 km^2 for the adjusted home range size (Ray, 1997). It was impossible to compare the Maddock's and Ray's findings with this study because of differences in the method of home range estimation used between this study and theirs.

This mongoose did not have a stable centre of its home ranges. The difficulty of access to foraging area or resting site from anywhere in the range, given the uneven distribution of foraging sites and denning sites in the range, made it possible to have unstable centres of home ranges.

Genetta genetta (*G. felina*)

In the current study, the only captured and radio-collared adult female had a home range of 1.17 km^2. The minimum convex polygon figure for *G. felina* previously radio-tracked in the Omo National Park, Ethiopia was 0.03 km^2 (Ikeda *et al.*, 1982). Waser (1980) reported, based on visual sightings, a much smaller home range size than that reported here. The possible explanation for the variation in the results of the different studies could be differences in the method used in each study. The feeding sites used by Ikeda and his colleagues and sightings by Waser could underestimate the actual home ranges.

The only comparable solitary and nocturnal genet that has been studied in the Donana National Park, southwestern Spain, European genet, *Genetta genetta*, has a much larger home range (mean = 7.81 km^2 +/- 3.94 for maximum range size; range = 0.73-14.71) than observed in the current study (Palomares and Delibes, 1994). The resource abundance and dispersion theory (Macdonald, 1979) could explain the variation in use of space by *G. felina* in the different ecological settings. This theory proposed that territory size is constrained by the dispersion of patches of key habitat elements. If these key habitat elements are widely dispersed, the territory occupied by the animal will enlarge so as to encompass these key habitats. Accordingly, the smaller home range size of the common genet, reported here, could be related to the specialised feeding habits of this genet in this study. The common genet scavenged primarily in the park Head-Quarter and thus, this could attribute to the smaller home range size of this genet compared with that measured in the Donana National Park, southwestern Spain.

GG5 had a stable centre of home range during the entire period of tracking. It was frequently observed scavenging in the garbage around the park Head-Quarter kitchen, and climbing in the nearby tree when it realised the presence of the observer. The park people have also seen this genet stealing poultry from the kitchen several times during the night. This genet was often found resting during the daytime in the dense forest of the park Head-Quarter. Thus, the availability of a resting site and feeding site in a short distance might preclude shifts in the centres of activity by GG5 and also led to a small range size.

Civitictis civetta

In the current study, the only captured and radio-collared subadult male civet had a home range of 11.06 km^2. The MCP figure for this civet was substantially smaller than the proposed 25.27 km^2 for a carnivore with a body mass of 8 kg (Harested and Burnell's (1997) equation for carnivores; home range = 0.011 x $weight^{1.36}$). Unfortunately, there is no opportunity to compare the finding of the current study with others because data on the spatial patterns of this civet was absent. However, further study on the ranging ecology of this species in widely divergent ecological conditions as well as with similar habitats in different areas might reveal differences in home range size as evident from studies in other mammals.

The animal showed a stable core of activity. Scavenging activity by CC3 has been witnessed in the park Head- Quarter. The animal rested most of the time (10 of 11 resting locations) in the same place, which is less than 100 m from the Head-Quarter. Thus, the stable core of activity exhibited by CC3, in the present study, could be attributed to the availability of the denning site in close proximity to the specialised feeding sites.

4.1.2. Spatial Distribution

Canis aureus

In the present study, the female jackals' ranges overlapped by average 50 % and the male jackals' by 46 %. Schmidt *et al* (1997) recorded larger home range overlap for females' lynx (*Lynx lynx*). This supports the finding of the present study, where the average value of range overlap for all females was greater than that of males. Adult males have exclusive or nearly exclusive home ranges but home ranges of subadult males overlapped extensively with those of adult males. The opportunity to investigate adult females range overlap was not practised because of the capture of only one adult female. However, the home ranges of subadult females overlapped extensively with the adult female.

In the present study, CA10 (adult female) and CA13 (adult male) have established home ranges while the home ranges of subadults overlap extensively with those of the adult pair. *C. aureus* are territorial and yearling offspring remain in the natal territory and serve as helpers (Moehlman, 1986; Estes, 1991). Fuller *et al.*, (1989) reported that *C. mesomelas* pairs were territorial and juveniles range within those of adults and ranges for subadults are larger but included ranges of adults. Ferguson *et al* (1983) showed that *C. mesomelas* pairs have mutually exclusive home ranges, and the home ranges of immature overlap extensively with those of adult pairs. It has been argued that food resource acts as a limiting factor when pairs are strictly territorial and that young are not allowed to use natal range (Ferguson *et al.*, 1983). In the present study, the young are allowed to use the range and thus it is possible to argue that food supply was not a limiting factor for the spatial organisation of *C. aureus*.

The subadult individuals seem to fall into two groups: those that remain with their parents (female CA11) and those that disperse (males CA6, CA7 and female CA9). The home range of CA11 was fitted into the existing adult home range structure. It is arguable that CA11 could have been a helper from previous litter. This corresponds to the data of *C. mesomelas* (Ferguson *et al.*, 1983). What are the advantages obtained from staying in the mother's range and not breeding regularly by some immature jackals? First, the inclusive fitness of the immature jackal is increased if the immature keeps to the home ranges of its parents to help with the rearing of their pups (Hamilton, 1971; Moehlman, 1979). Second, when an immature keeps within the home range of its parents, it has the opportunity to perfect its hunting techniques in a familiar environment, because without this expertise, it would be unable to meet extra food requirements when caring for the young (Ferguson *et al.*, 1983). Third, helpers might also stay in the natal territory because dispersal is dangerous and there are few opportunities to find a new territory (Pers. comm. with Thirgood, S.).

Ichneumia albicauda

In the present study, *I. albicauda* exhibited exclusive or nearly exclusive males' home ranges, by overlapping over a range of female, IA10. The possible explanation for this could be males move outside their 'normal' ranges during the short mating season to get a mate. A good illustration of this kind of spatial organisation was IA10, whose range overlapped greatly with IA11 (81.25 %) but also partly with that of IA13 (24.62 %). Sandell (1989) proposed that use of space by solitary carnivores, and their associated mating systems, are related to the distribution of food resources in females, and to both food resources (outside the mating season) and receptive females (during the mating season) in males. Sandell's prediction for females was ruled out because we tracked only one female, and his prediction for males was not supported as well. Data on the pattern of spacing exhibited by *I. albicauda*, though scarce, suggest that they have a flexible social system. Along the eastern edge of the Kirawira, Serengeti, Tanzania, adult males *I. albicauda* have exclusive or nearly exclusive ranges but male-female ranges overlap widely while in the central and western sides of Kirawira, where high density populations occurred, multiple adult females share ranges (Waser and Waser, 1985).

4.2. SOCIAL INTERACTION

4.2.1. Intra-specific interaction

C. aureus

In the current study, *C. aureus* were commonly observed foraging alone (87 % of observations). Male-female pair formation was the most frequently observed social groups. The limitation of the method to simultaneously track two or more individuals might underestimate the frequency of locating animals together or in proximity. The complete or nearly complete overlap of home range exhibited by adult female CA10 and adult male CA13 supports this argument. Therefore, it is possible to argue that *C. aureus* in this study live in small family groups. Most data on this jackal social system regard them as living in pairs (Schaller, 1967; Wyman, 1967; Eaton, 1969; Van Lawick and Van Lawick-Goodall, 1970; Golani and Keller, 1975; Fuller *et al.*, 1989).

Previous studies have demonstrated that golden jackals are capable of forming large social groups under special conditions in which an abundant, localised source of food is available (Macdonald, 1983). For example, Macdonald (1979a) reported groups of 10-20 individuals, with several breeding males and females in Israel where food was provisioned for the jackals. Moehlman (1986) described the Serengeti's *C. aureus* as monogamous, with non-breeding adults up to four in the family group that care for their young siblings. The capacity for maintaining large groups might have evolved as an adaptation for the exploitation of patchy food resources through co-operative defence (Macdonald, 1979a). In East Africa, Van Lawick and Van Lawick-Goodall (1970) reported 14 individuals at a carcass. Such large groups of jackals have never been seen in the BMNP, but three radio-collared jackals were observed at a carcass on one occasion.

Advantages obtained from group formation in jackals are various. In the first place, it always assures one to have a mate that can participate in hunting activities. Hunting by more than one jackal is more successful in *C. mesomelas* in the Kalahari Gemsbok National Park (Ferguson, 1980), and *C. aureus* in the Serengeti National Park (Lamprecht, 1978a). In the second place, it allows for defence of territory and kills. Thirdly, it also allows for scavenging. The few social groups of jackals reported here might indicate that foods for the golden jackals were not patchy in their distribution in the study area, as were for jackals of Israel.

I. albicauda

I. albicauda were commonly observed foraging alone (91 % of observations) in contrast to Kingdon's (1977) claim that pairs or families are the typical grouping in this species. The relatively solitary nature of white-tailed mongooses in the current study is comparable to the percentage of sightings of individuals in other asocial mongooses (e.g. *H. auropunctatus*, 95 %; Gorman, 1979; *H. sanguineus*, 72 %; Rood, 1989; *H. pulverulentus*, 89, 95 and 93 %; Crawford *et al.*, 1983; Cavallini and Nel *et al.*, 1990; Stuart, 1991 respectively).

Even if we detected a male and female together several times (10 of 14 observations), the social unit of this mongoose is considered as solitary (Rood, 1986). White-tailed mongooses are not gregarious. Predation is a widely accepted phenomenon as one of the principal causes why animals live in groups (Krebs and Davies, 1993). Individuals of *I. albicauda* can be up to twice as large as group-living herpestids (Rood, 1986), and it was nocturnal as other authors concur (Kingdon, 1977; Rood, 1986; Waser and Waser, 1985; Estes, 1991). The potential nocturnal predators for white-tailed mongooses in the study area are spotted hyaenas. However, it has never been recorded any hyaena attack or interference on white-tailed mongooses during the whole period of monitoring the animals. On the other hand, individuals of *I. albicauda* were frequently observed feeding on dung beetles and to a lesser extent on ants. So, the renewal rate of the prey is high and would favour the formation of group life (Waser, 1981). When prey renewal is higher, several white-tailed mongooses may forage simultaneously and displaying more complex societies including female gregariuosness (Waser and Waser, 1985). Because of the sampling bias and difficulty of the data collection conditions, the data would have been strengthened by more data with regard to tolerance of home range overlap between female white-tailed mongooses. Therefore, it was impossible to demonstrate, with the data collected and presented here, female gregariousness in the white-tailed mongooses as has been reported in the Serengeti white-tailed mongooses (Waser and Waser, 1985). As in other species (Macdonald, 1983), food resources may be the primary ecological factor affecting the social system of the *I. albicauda* in different areas.

On the other hand, two species of mongooses, dwarf mongoose (*Helogale parvula*) and banded mongoose (*Mungos mungo*), live in cohesive social groups in which several breeding males and females forage and den together, and are intolerant of neighbouring packs (Rood, 1986). Waser and Waser (1985) suggested that the root difference between the social system of these mongooses and that of *I. albicauda* is the degree of spatial association between members of a social network. According to him, the real social differences were the secondary result of female gregarousness in the latter species.

According to Waser and Waser (1985), ecological factors that favour the formation of groups in viverrids can be grouped into two stages: (1) Group-living has been argued allowing the more efficient exploitation of patchy food resources. However, the distribution of food resources is not uniform in habitats where many carnivores used for foraging (Macdonald, 1983). In the Serengeti National Park, Tanzania, Waser (1981) reported no evidence of clumping in the distribution of the important prey of small nocturnal African carnivores but a high renewal rate. Therefore, hunting of rapidly renewable prey by viverrids can act as a necessary precondition for the tolerance of home range overlap and favour non-dispersal of at least some young. (2) Even if it has been argued that insectivory is a necessary condition for the tolerance of range overlap in viverrids, other factors must act on the Ichneumia-like social structure to favour gregariuosness and complex social systems as in *Helogale* and *Mungos*. Rood (1986) argued that predation has been the main selective force promoting cohesive social groups in the mongooses. Small, diurnal and insectivorous mongooses can detect and deal with predators more effectively if they are in a group than alone. This is because more eyes are better than one to spot the predator from far and then escape (Krebs and Davies, 1993), and there exists a potential for frightening predators by their group defiance (Rood, 1986).

4.2.2. Inter-specific Interaction

The radio-tracked carnivores in the current study were largely nocturnal although there was a small amount of diurnal activity observed in *C. aureus* where human interference was low. There was also clear home range overlap between the individual carnivore species. Accordingly, it was plausible to suspect direct interactions between the different species. In the present study, there were observed interactions between the different species of carnivores, and the frequency of contact was higher among four species - *C. familiaris*, *C. aureus*, *I. albicauda* and *C. crocuta* - with the number interacting individuals ranging from 2-6. However, the radio-collared *C. civetta* and *G. genetta* were notably solitary and showed no sign of interaction with other species.

What ecological factors allow these potentially competing carnivores to coexist in the study area? It has been argued that if two or more species live in a stable environment, they do so because of niche differentiation, i.e. differentiation of their realised niches (Begon *et al.*, 1997). If, however, there is no such differentiation, or if it is made impossible by the habitat, then one competing species will eliminate or exclude the other. In the present study, this is easily demonstrated. Golden jackals depended primarily on rodents; white-tailed mongooses fed on dung beetles and ants by digging the ground, and that African civet and common genet primarily scavenged in the Head-Quarter (pers. obser.). Many authors (Kingdon, 1977; Waser, 1980; Estes, 1991) also reported feeding niche differentiation between these species. It is, therefore, arguable that differentiation on food resources avoids competition between the different species.

The carnivore species, particularly golden jackals and spotted hyaena were also observed interacting directly with domestic dogs. For instance, groups of carnivores comprising hyaena, golden jackals and domestic dogs were observed at a carcass, with the number interacting individuals eleven. This suggests that there is a potential for disease transmission between wild carnivores and domestic dogs.

4.3. HABITAT USE AND SELECTION

4.3.1. Diurnal resting sites

C. aureus

The pattern of habitat use changed as the denning activity approached and individual jackals moved to areas where cover and protection were available. Bush and forest microhabitats were particularly important as denning activities. Positive relationship was observed between the availability of quality denning site and *C. aureus* habitat utilisation. *C. aureus* intensified its utilisation in densely wooded areas and made significant use of forests and bushlands.

As far as area habitat is concerned, farmlands and forests were particularly important for golden jackals. Nevertheless, the quality of area habitats was rather poor in comparison with that of the microhabitats. The farmlands were open where as the forests were moderately dense. This shows that the presence of suitable microhabitat as daytime beds determines the pattern of habitat utilisation by golden jackals, at least in this study, no matter what would be the quality of the area habitat.

In the present study, a positive relationship was observed between the number of sampled nights and the number of resting sites used by jackals indicating that there was little fidelity to the same resting site although the same resting site was used more than once by some individuals. The social organisation of *C. aureus* is characterised by frequent contact between related individuals (Moehlman, 1986). Thus, the use of the same resting site by related individuals could facilitate interchange of information and meeting of family groups. However, jackals were rarely detected together during diurnal resting. A more plausible explanation may be the cost of travelling from a foraging site to a denning site that was distantly spaced in the area, given the characteristic sightings of jackals as solitary in activity.

I. albicauda

Individuals of *I. albicauda* were strictly nocturnal in the study area; therefore, selection of sites that provide both cover and protection from danger is very important. Underground dens and empty houses in the town fulfilled both requirements. The reason for using empty houses as day-time beds by the mongooses could be the limitation of suitable dens such as underground dens in individual ranges. This is supported by the pattern of habitat use exhibited by adult male IA8, which was never found resting in houses due to the absence of either empty or abandoned house in its range.

As far as area habitat is concerned, bush habitats were particularly important for white-tailed mongooses. Nonetheless, no positive relationship was observed between habitat type and habitat quality. This suggests that the presence of suitable microhabitat as denning site determine the pattern of resting habitat utilisation by white-tailed mongooses no matter what would be the quality of the area habitat.

Few resting sites were regularly used. This is in consistent with observation on *Ichneumon* (Palomares and Delibes, 1993). It has been postulated that fidelity by mongooses to some resting sites could facilitate the meeting of males and females after foraging, thereby favouring mating (Palomares and Delibes, 1993). The present data suggest that social organisation of *I. albicauda* is characterised by male-female contacts. The present finding where adult female and adult male used the same resting site both at different dates and together supports this.

A. plaudinosus

Individual of *A. plaudinosus* exclusively used underground dens along the riverbank as denning sites. However, the data for area habitat showed that it rested in the underground dens surrounded by bushes or forests, but there were no distinct preferences for any habitat quality. Therefore, one can argue that it is the microhabitat, not the area habitat that determines the pattern of resting habitat use by this mongoose in the study area.

C. civetta and G. genetta

CC3 exclusively rested under bushes whereas GG5 almost exclusively rested in trees. Indeed, the genet was located on two occasions resting under roofs. Both species preferred densely wooded microhabitats.

No deviation was observed on use of area habitat type between the two species. They used a resting site surrounded by woodlands. However, they differed in the quality of the area habitats that they used. CC3 intensified its relative utilisation in the open woodlands whereas GG5 in closed woodlands. Given the diurnal denning activity of CC3 and this is correlated with the searching for good quality habitats, it is arguable again that it is the microhabitat that determines resting habitat use by this civet. On the other hand, GG5 showed no variation on the pattern of use between microhabitats and area habitats. This is mainly related to the denning habits of the genet in that it spent most of the daytime resting in the tree since it requires a closed surrounding that influence visibility of potential predator.

There was no opportunity of detecting use of the same resting site by different individuals of *C. civetta* and *G. genetta* since only one civet and genet each were radio-tracked. CC3 showed fidelity to some resting site more intensively than any of the others radio-collared carnivores.

On the other hand, GG5 showed positive relationship between the number of resting locations and number of used resting sites, indicating no fidelity to some resting site.

4.3.2. Nocturnal foraging sites

C. aureus

The present data suggest that *C.aureus* were seen foraging in all habitats though they intensified their habitat utilisation in bushlands both for microhabitats and area habitats. This shows that C. aureus obtains its food requirements from all habitats. Densely covered bush micro-habitats were avoided whereas no specificity to any category of density of bush area habitats was observed. This may be due to difficulties in stealthily hunting small vertebrates in dense bush micro-habitats.

I. albicauda

The present study suggests a different pattern of use between microhabitats and area habitats during activity. Open grasslands constitute a major portion of microhabitat use whereas forests, though closed areas were avoided, comprise that of area habitats. This shows that the natural habitat of this mongoose in the study area is indeed wood land, but that this is certainly not the habitat where the species intensified its foraging activity.

A. plaudinosus

The only tracked marsh mongoose used grass tussocks extending in the Web and Denka rivers with greater intensity as caching areas while grasses and bushes along the riverbank were utilised as foraging areas. In southwestern Central African Republic, Ray (1997) reported a restriction to streamside habitat. Microhabitat use was restricted to densely covered areas whereas no specificity was observed for area habitats. The use of closed areas as catching sites may be related to the successful hunting of small vertebrates and invertebrates from the water without interference from conspecifics and other competitors.

C. civetta and G. genetta

In the current study, both *C. civetta* and *C. genetta* exhibited a similar pattern of use of microhabitats and area habitats. Headquarter forests were largely utilised by both species. The most probable explanation for this could be the habit shown by both of scavenging on special feeding sites available in the park Head-Quarter.

4.3.3. Habitat selection from movement data

C. aureus

In the present study, golden jackals generally preferred farmland and bushland, and avoided grassland and open woodland. In the Rift Valley of Kenya, golden jackals are common in grasslands (Fuller *et al*., 1989). In central Kenya, they are found in well drained, open grass tussocks (Kingdon, 1977). In the Serengeti, Tanzania, they are found on the grassy plains (Wyman, 1967; Moehlman, 1983; 1986). Nevertheless, in Bangladesh, it is found in gallery forests, agricultural lands. The variations in habitat selection between different areas suggest that golden jackals can inhabit different habitats in different ecosystems although the natural habitat of them is indeed an open savanna.

The present data also suggest that golden jackals are avoiding villages, *contra* to their occurrence in and around human habitation in Bangladesh (Pouche *et al*., 1987). If villages were the sources of diseases in the Bale Mountains, one would expect that the jackals were not avoiding human habitations. Thus the present finding could have possible ramification if Karen Laurenson's work found that villages were the sources of diseases.

On the other hand, the individuals of golden jackals showed different values of selection for closed woodlands. The adult pair [(CA10 (female) and CA13 (male)] and subadult female (CA11) preferred the closed woodland whereas the dispersing subadults of both sexes, except for CA6, avoided that habitat. The variation in selectivity among the individuals could be related to their spatial organisation in the study area. The adult pair had established home ranges, encompassing the home range of the subadult female (CA11), and thus had the opportunity to explore and master the different habitats available within their ranges and ultimately show clear preference or avoidance for a given habitat. Conversely, the subadults that were dispersing had not yet established home ranges and thus had no ample time needed to explore and perfect the different habitats found in their ranges.

I. albicauda

In the present study, individuals of *I. albicauda* preferred open woodland and avoided grassland when available within the home range. The analyses of selectivity for farmland, bushland and closed woodland, when available, showed that the individuals showed no general preferences for these habitats (i.e. while some individuals preferred a habitat, others avoided it). Our data are different from those reported elsewhere in Africa. In the Nechisar National Park, Ethiopia, it was common in bush and some forests (Duckworth, 1995). Most of the existing literature quotes *I. albicauda* as a savanna or grassland species (Kingdon, 1977; Waser, 1980; Waser and Waser, 1985), but with a great potential of living in habitat ranging from desert to savanna (Estes, 1991). The possible explanation for the difference in habitat selection between this study and data from other studies could be the great modification of the original habitats of the study area due to human interference as compared to the natural habitats of the other ecosystems. Alternatively, different authors used different methods in the different areas and this could contribute to the observed variation in selectivity between the different areas.

Unlike golden jackals, several individuals of *I. albicauda* did not avoid using villages, when available in the home range. If villages were the sources of diseases in the Bale Mountains, one would expect that the white-tailed mongooses are more likely getting infection from domestic dogs. However, analysis of serological data from Karen Laurenson's work does not support this argument. Therefore, it is possible to argue that white-tailed mongooses are avoiding dogs.

A. plaudinosus

In the present study, the only tracked marsh mongoose (AP1) preferred riparian grassland and open woodland, and avoided farmland and bushland when available. Unfortunately, there were few data to compare the findings of this study with. In the southwestern Central African Republic, the marsh mongoose was restricted to the Riparian habitat (Ray, 1997). This is in consistent with the present data. However, further research on the habitat preference of this mongoose in widely divergent ecological conditions as well as with similar ecosystems in different areas make it possible to fully understand the habitat selection of the marsh mongoose and the biological reasons associated with this.

C. civetta* and *G. genetta

In the present study, the only tracked African civet showed avoidance for farmland, bushland and open woodland, and showed preference for grassland and closed woodland. The only comparable data was the study conducted in an Ethiopian Rift Valley National Park. In the Nechisar National Park, Ethiopia, it is common in the Riparian forest, but much rarer in adjacent bushland and Ground water forest (Duckworth, 1995). This is in agreement with the present data.

On the other hand, in the current study, the common genet showed avoidance for farmland, and showed preference for both open woodland and closed woodland when available in the home range. In the Nechisar National Park, Ethiopia, this genet was common in bushland, usually in more open areas, but never seen in forest (Duckworth, 1995). In the Serengeti, Tanzania, the common genet also showed attachment to bushes even on the plains (Waser, 1980). It is difficult to compare the findings of this study with Duckworth's Nechisar and Waser's Serengeti findings because bushes were not available, as were grasslands, in the home range of the common genet in this study.

With respect to selection for the town, the African civet showed preference for the town whereas the common genet showed avoidance of this habitat. Since only one individual of both species was radiotracked in this study, it was difficult to relate this to the epidemiology of disease and give some suggestions based on few samples. This could have been possible with more samples as the case in golden jackals and white-tailed mongooses.

4.4. DENSITY ESTIMATION

4.4.1. Trapping index

Trap results could not be used to estimate the population size using capture -mark-recapture technique because of the small size of captured individuals. However, an index of abundance for each carnivore species for the three trap units can be obtained by calculating numbers caught per catch effort. Even if trap nights for cage trapping (155) were substantially greater than those for leg-hold trapping (97), the number of animals captured in the cage traps were smaller in comparison with that of leg-hold traps. This is partly due to trap shyness and proneness observed in trapping animals. Traps that were sprung without catching were considerably significant. This may underestimate the number of captures and recaptures for each trap type.

For leg-hold trapping, the index of abundance for *C. aureus* was 0, 0.13 and 0.09 whereas the index of abundance for *I. albicauda* was 0, 0.03 and 0.02 for Gaysay, Head-Quarter and Mongoose rock respectively. For cage trapping, the index of abundance for *I. albicauda* was 0, 0.03 and 0.03 for Gaysay, Head-Quarter and Mongoose rock respectively. Golden jackals were not captured in the cage traps.

More individuals of *C. aureus* and *I. albicauda* were caught in the Head-Quarter than in the Mongoose rock. Both species were never captured in Gaysay area. What ecological factors explain such variation in the relative abundance of these two species between the two areas? Differing habitats and availability of food are the two most likely factors. Studies on the food habits of *I. albicauda* revealed the importance of beetles in its diet although other insects such as termites and millipedes also constitutes a major portion of the diet (Waser, 1980). When the large herds of antelopes in particular Mountain Nyala grazed in the park Head-Quarter, they left behind large quantities of dung. The abundant dung beetles attracted by this resource (Pers. obs.) can allow more mongooses to forage, consistent with observations on *Mungos mungo* and *Helogale parvula* (Rood, 1975 cited in Rood, 1986; 1983). On the other hand, the Head-Quarter contained the required resources for the jackals such as cover and protection, and may also contain abundant small mammals especially, forest dwelling rodents compared to the open areas of the mongoose rock where cover and protection were in short supply. Thus, the availability of good cover and protection that serve as day-time beds and may be appreciable food supply can allow more jackals to occur in the Head-Quarter than in the Mongoose rock.

4.4.2. Extrapolation from radiotracking data

In the present study, estimates of population densities of white-tailed mongooses, marsh mongooses and common genets were appreciable (0.52 +/- 0.06 km^{-2}); golden jackals and African civets were found in small numbers (~ 0.1 individual km^{-2}). It was difficult to compare the numbers found here, with the exception of white-tailed mongooses, with those reported in the Serengeti by Waser (1980) because of differences in the methods used in each study. The population density of white-tailed mongooses, in this study, was substantially smaller than the numbers attained in the Serengeti, Tanzania (3.7 mongooses km^{-2}, Waser 1980). Estimation of population density by extrapolating from radiotracking data has limitations. It is difficult to know other individuals of the study species that were not captured or seen. Despite such limitations, it is a useful method to come up with the idea of the species population density.

4.4.3. Opportunistic sightings

Difference in the number of opportunistic sightings is found between the tracking period and non-tracking period, as well as during the dry season and the wet season of the tracking period. When calculated against effort, the number of carnivores that were opportunistically seen during tracking periods was 33.3 times more than that of non-tracking periods. The more plausible explanation could be the difference on the intensity of observations made between the tracking period and the non-tracking period. With regard to seasonal changes of sightings for tracking period, 4.3 times as many carnivores were seen per hour monitoring effort in the dry season than in the wet season. The larger number of days of monitoring in the dry season

(145 days) partly due to the malfunctioning of the receiving equipment in heavy clouds could contribute to the larger number of carnivores seen in the dry season compared with that of the wet season (83 days). Even the monthly patterns of opportunistic sightings showed that more carnivores were encountered in the months of the dry season (i.e. from December to March). These months were the periods of intensive monitoring of the radio-collared carnivores. This provided a better chance of observing non-collared carnivores. In general, the unbalanced effort (i.e. difference in the intensity and number of days they monitored) is mainly attributed to the observed difference between the tracking period and non-tracking period, dry and wet season, and monthly opportunistic sightings. Interestingly, a relatively higher number of individuals of *C. crocuta*, *C. aureus* and *I. albicauda* were encountered during the night-time activity. This indicates that the potential for interaction between these three carnivores is relatively high compared to other carnivores.

4.4.4. Density estimation by Distance sampling

Distance methods were used for estimating the density of carnivores around the Bale Mountains National Park. However, the methods had some limitations. Animals lying on the centre line of the transect were not detected with certainty (i.e. the detection probability of the central line was not one). This could be due to the movement of the animals before being detected. Sighting distances for some animals were not always measured accurately. In addition to these, the different species of carnivores showed different reaction to the road. For instance, dog sightings showed distinct heaping on or very close to the road whereas spotted hyaenas were rarely seen on the road. The observed reaction to the road suggests that the animals were not randomly distributed relative to the transect lines. The limitation with animal distribution relative to the transect line was overcome by grouping of the sighting distances into distance categories. The grouping of sighting distances into categories is an acceptable practice. Buckland *et al* (1993) recommended grouping of distances into distance categories since grouping reduces the accuracy of results and can have a profound effect on density estimates.

In the highlands of the Bale Mountains, the mean density of *C. aureus*, *C. crocuta* and *C. familiaris* was 1.42, 0.64 and 6.39 individuals/km^2 respectively. In the lowlands, the mean density of *C. aureus* and *C. familiaris* was 2.15 and 1.43 individuals/km^2 respectively. This shows that golden jackals and domestic dogs were found at high density around the Bale Mountains National Park.

Due to unbalanced data in some transects, it was necessary to exclude some transects from the analysis. This resulted in the reduction of the data set to fewer sightings; for example, 19 sightings for domestic dogs in Agarfa-Goba transect route. Buckland *et al* (1993) assert that at least 70 sightings are needed for a distance analysis. However, a good model fit can often be obtained using as few as 30 sightings. While it is possible to fit models to fewer sightings, extreme caution must be attached to density estimates based on such few sightings. Accordingly, the test was still powerful enough to estimate densities of *C. aureus* and *C. crocuta* in the highlands and *C. familiaris* in the lowlands that were sighted less than the recommended value. There were not enough sightings to get distance estimates for most of the studied species (Table 39). The encounter rate was used as an index of abundance for these species. Therefore, the population abundance of *C. crocuta* and *C. civetta* was relatively substantially higher in the highlands than in the lowlands while the abundance of *I. albicauda* was relatively the same both in the highlands and the lowlands.

Distance methods did not give similar results to the other methods between the different areas. Density estimates for domestic dogs in the highlands were three times as large as those estimated in the lowlands where as the index of abundance (or encounter rate) in the highlands was twice as large as that found in the lowlands. Density estimates for golden jackals were the same between the highlands and the lowlands, but the index of abundance in the lowlands was more than twice as large as that found in the highlands.

4.5. EPIDEMIOLOGY

The ecological data collected and presented here demonstrating contacts between the sympatric carnivore species. However, these are the necessary conditions but not the sufficient conditions for the epidemiology of diseases between the sympatric carnivore species. For the likelhood of disease transmission, several of them had to be exposed to the generalist pathogens of carnivores. Diagnosis of sera obtained from carnivore species captured during the trapping period revealed the captured animals, except for golden jackals and Ethiopian wolves, had not been exposed to Canine distemper virus (CDV), Canine adenovirus (CAV) and Canine parvovirus (CPV). The golden jackals had been exposed to all the three canine viruses, with CAV and CPV highly seroprevalent. Of the two Ethiopian wolves tested for the three canine viruses, one was seropositive for all but the other one seropositive for CPV only.

On the other hand, serological survey on a wider scale of wild carnivores around BMNP demonstrated that a significant number of the sampled golden jackals and Ethiopian wolves were seropositive for CDV, CAV and CPV (Laurenson, K., unpublished data). However, all the other sampled carnivores tested for CDV and CAV antibodies were seronegative, but some individuals had been exposed to CPV. Unfortunately, so far, there has not been any information available on canid pathogens from the Bale Mountains wild carnivores. Thus, it is difficult, at present, to suggest whether the canine viruses are endemic in the wild carnivores. When the results of the epidemiological project are finished, it could be possible to establish which species acts as a reservoir host and transmit diseases to other carnivores including the Ethiopian wolf.

Rabies has also been reported from the wild carnivores during this study. In 1998, confirmed cases of rabies were reported from one Ethiopian wolf, one golden jackal and one serval cat (Laurenson, K., unpublished data). Rabies appears endemic in the area and rabid dogs have been reported in the park in 1997 (Laurenson *et al.*, 1997). An outbreak of rabies was reported in Ethiopian wolves in the BMNP which accounted for the dramatic decline by 75 % of the Web valley between October 1991and February 1992 and 50 % of the Sanetti plateau populations between April and June 1990 (Sillero-Zubiri *et al.*, 1996). In Bangladesh, golden jackals play an important role in the epidemiology of rabies, which is common to the region (Pouche *et al.*, 1987).

5.0. CONCLUSIONS

Serological survey of wild carnivores sampled around the Bale Mountains National Park from 1998-1999 suggests that some wild carnivore species are exposed to canine pathogens, in particular the viruses were highly seroprevalent among golden jackals. On the other hand, the study on the behaviour and ecology of a guild of sympatric carnivores suggested that there was contact between the sympatric carnivore species. First, the study species are strictly nocturnal although golden jackals were sometimes seen active during day light in areas where human activity was low. Second, there were clear home range overlaps between the study species. Third, contacts between the different wild carnivores, and between wild carnivores and domestic dogs were observed. Four, golden jackals and domestic dogs are found at high densities around the BMNP. If the density of a canid in an area is high, the likelihood of encounters between humans and domestic animals and sympatric wild carnivores is high. Accordingly, the observed encounter rates of golden jackals with domestic dogs as well as with the other sympatric wild carnivores was high in the present study. Finally, golden jackals utilised all the habitats to obtain food, indicating potential contacts with other carnivores during foraging activity. Therefore, given the encounters between sympatric carnivores in the BMNP, it is possible to conclude that it is likely that canid pathogens are transmitted between domestic dogs and wild carnivores in the study area.

Further more, the ecological and behavioural data from this study and serological data from the epidemiological project suggest that it is most likely that domestic dogs are the reservoir of the canid pathogens. However the canid diseases occasionally spill over into the wild carnivores particularly into wild canid species – the golden jackal and the Ethiopian wolf (Laurenson *et al.*, 1998).

Diagnosis of sera taken from wild carnivores revealed that golden jackals were seropositive to canine distemper, canine adenovirus and canine parvovirus for most of the individuals sampled in contrast to the other wild carnivores. There has also been confirmed case of rabies in golden jackals during the study period. Analysis of contacts between sympatric carnivores within the study area indicates that contacts between domestic dogs and golden jackals are relatively more frequent compared to domestic dog with other wild carnivores.

Local high densities and certain social systems may favour intra-specific transmission. In the present study, estimates of golden jackals' density around BMNP averaged 1.4 jackals/km^2.

When considering the social system of golden jackals in this study, they live in small family groups although large social groups were not observed as evident in other studies. Accordingly, the potential for intra-species transmission is high for golden jackals found around the BMNP.

There was not enough evidence to establish whether wild carnivores could act as a reservoir and transmit canid pathogens to Ethiopian wolves although golden jackals and Ethiopian wolves were seropositive to the canine viruses for most of the individuals sampled. Analysis of inter-specific contacts indicates little or no interaction between the wild carnivores studied and Ethiopian wolves. Moreover, none of the study animals crossed the Web river to Gaysay grasslands, where a small pack of Ethiopian wolf is found indicating no range overlap between the study species and the Ethiopian wolves. The great majority of the Bale Mountains wolf population lives in the Afro-alpine zone above 3500 m at altitudes where the other wild carnivores are less commonly found, thus further reducing the likelihood of contact between these species. The Afro-alpine zone is, however, becoming increasingly used by local people with their livestock and domestic dogs, increasing the risk of contact between canid diseases and wolves.

6.0. RECOMMENDATIONS

Management solutions

Domestic dogs are most likely reservoirs of canid pathogens in the Bale region. In the present study, it has been concluded that wild carnivores, particularly golden jackals, are most likely to get infection from domestic dogs. Therefore, important management solutions must be taken to minimise the spread of disease from domestic dogs to the wild carnivores found around the BMNP and possibly else where. Here are some of the management options available to control the spread of the disease:

1) The occurrence of contact between two species that would rarely or never encounter in the wild enhances the transmission of disease from the host to the susceptible species. The analysis of ecological and behavioural data indicates contacts between domestic dogs and wild carnivores. Thus the fundamental problem of contact between domestic dogs and wild carnivores must be resolved to safeguard the wildlife populations found in and around BMNP. This could be done by a number of strategies:

a) The dog population size must be reduced. This is made possible by either encouraging the local community to limit the number of dogs possessed by one dog owner (1-2 dogs/ownership) or sterilisation of one or both sexes by surgical means.

b) Educating the dog owners to prevent contacts between dogs and wild carnivores.

2) Domestic dogs found inside and around the BMNP have to be vaccinated to reduce pathogen transmission. If mortality of dogs due to disease is reduced as a result of vaccination, there is a potential for an increase in the dog population size if disease is regulating the population. Thus, dog vaccination program must be carried out simultaneously with action to control dog population size and reproduction.

Research priorities

In the present study, there were no evidences to establish which species of carnivores are either a reservoir host or an important source of disease transmission to Ethiopian wolves. Therefore, further research must be carried out in the following topics so as to assess which species acts as a reservoir and transmit diseases to Ethiopian wolves.

1) Further knowledge of the role of wildlife in the epidemiology of disease is essential.

2) Information must be gathered on the population dynamics and ecology of domestic dogs.

3) The likelihood of disease transmission between hosts is dependent on the transmission mechanism of the pathogen and thus on the type and frequency of contact between individuals. However, it was difficult to obtain data on the type and frequency of contacts between the sympatric carnivores in this study. Thus, further research with the present line of investigation must be carried out so as to obtain such data.

7.0. APPLICATION OF THE RESULT

The study on the ecology of a guild of small carnivores in the BMNP provides information on resource use, niche overlap, and the potential for inter- and intra-specific transmission of pathogens within sympatric carnivores. This information will be of immediate value in the planning and implementation of disease management programs for critically endangered Ethiopian wolf. The results of this study, in conjunction with the epidemiological project, provide information of wider relevance for rabies and other disease control programs where domestic dogs and wild carnivores interact. It also provides information on home range size, movement patterns, the density at which these small carnivores occur and social associations in the afroalpine habitat. This information will be of great importance to understand the ecology and behaviour of these less studied species of carnivores.

8.0. REFERENCES

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Appendix 1. Area of the different habitat types of the study area calculated from the vegetation map drawn using Global Information System (GIS), n shows the number of different plots.

Habitat type	n	Area (km^2)
Farmland	35	4.2
Cultivated woodland	70	30.1
Forest	6	1.5
Grass	14	12.3
Open woodland	4	57.1
Bush	49	23.9

Appendix 2. Distribution of fixes into time of day and seasons obtained from radio-collared carnivores tracked in and around the BMNP.

Cap. code	Total fixes	Frequency of visibility	Day fixes	Night fixes	Seasons Wet	Seasons Dry
CA10	82	43	16	66	26	56
CA11	82	43	22	60	10	72
CA12	7	2	2	5	0	7
CA13	79	42	16	63	22	57
CA6	62	37	6	56	26	36
CA7	45	28	13	32	0	45
CA8	60	40	12	48	20	40
CA9	42	28	9	33	18	24
IA8	47	21	7	40	14	33
IA10	76	29	18	58	26	50
IA11	67	33	16	51	27	40
IA13	57	27	8	49	37	20
IA14	13	9	2	11	6	7
AP1	76	17	13	63	22	54
CC3	68	30	7	61	21	47
GG5	87	28	18	69	22	65

Appendix 3. Distribution of position locations obtained from radio-tracked carnivores in the study area throughout the time from dusk until dawn. The number of hours in the night were splitted into four time periods.

Cap. code	Day fixes	Night fixes 1800-2115	2116-0030	0031-0345	0346-700
CA10	16	18	24	12	12
CA11	22	16	24	6	14
CA12	2	5	0	0	0
CA13	16	20	23	17	3
CA6	6	18	21	5	12
CA7	13	14	11	2	5
CA8	12	13	19	8	8
CA9	9	6	13	8	6
IA8	7	10	17	10	3
IA10	18	24	17	14	3
IA11	16	19	21	7	4
IA13	8	17	11	18	3
IA14	2	7	4	0	0
AP1	13	19	27	12	5
CC3	7	24	22	13	2
GG5	18	17	13	15	24

Appendix 4. The number of different species of carnivores trapped in cage and leg-hold traps in the three trap units of the study area from Oct, 1998-Mar, 1999.
* denotes radio-collared individual.

Trape type	Species caught[1]	Trap units[2] G	HQ	MR	Grand total
Cage	CC	0	2	0	2
	CF	0	2	1	3
	CS	2	0	0	2
	GG	0	1*	0	1
	HG	0	0	1	1
	IA	0	2	1	3
	IS	0	0	1	1
	UN	1	0	0	1
Total		3	7	4	14
Leg-hold traps	CA	0	5	4	9
	CF	0	3	2	5
	CS	0	0	2	2
	GG	0	1	0	1
	MC	1	0	0	1
	IA	0	1	1	2
	AP	0	0	1	1
	FC	0	1	0	1
Total		1	11	10	22

[1] CC= *Civitictis civetta*; CF = *Canis familiaris*; CS = *Canis simensis*; GG = *Genetta genetta*; HG = *Hystrix galeata*; IA = *Ichneumia albicauda*; IS = *Ictonyx striatus*; UN = unknown; CA = *Canis aureus*; AP = *Atilax plaudinosus*; MC = *Mellivora capensis*; FC = *Felis caracal.*
[2] G = Gaysay; HQ = Head-Quarter; MR = Mongoose rock.

Appendix 5. Habitat use and availability of *C. aureus* monitored by radiotelemetry in and around the BMNP from 1998-2001.

Cap. code	No. of locations		proportion of habitat					
			Farmland	Bushland	Grassland	Open woodland	Closed woodland	Town
CA10	67	U[a]	0.19	0.39	0.09	0.18	0.15	0
		A	0.17	0.13	0.15	0.50	0.02	0.03
CA11	71	U	0.14	0.04	0.01	0.62	0.17	0.01
		A	0.15	0.07	0.07	0.65	0.04	0.05
CA13	72	U	0.25	0.22	0.08	0.29	0.15	0
		A	0.15	0.09	0.12	0.57	0.03	0.05
CA6	62	U	0.31	0.44	0	0.21	0.05	0
		A	0.20	0.10	0.15	0.50	0.02	0.02
CA7	37	U	0.41	0.24	0.16	0.16	0	0.03
		A	0.24	0.05	0.30	0.34	0.03	0.05
CA8	46	U	0.24	0.48	0.24	0.04	0	0
		A	0.14	0.20	0.64	0.001	0.0002	0.02
CA9	36	U	0.33	0.25	0.19	0.22	0	0
		A	0.26	0.04	0.20	0.43	0.02	0.04

[a] U = use; A = availability.

Appendix 6. Habitat use and availability of *I. albicauda* monitored by radiotelemetry in and around the BMNP from 1998-2001.

Cap. code	No. of locations		proportion of habitat					
			Farmland	Bushland	Grassland	Open woodland	Closed woodland	Town
IA10	49	U[a]	0.16	0.16	0.06	0.53	0	0.08
		A	0.23	0.16	0.19	0.39	0.03	0.01
IA11	43	U	0.28	0.37	0.12	0.23		
		A	0.17	0.35	0.26	0.22		
IA13	40	U	0.03		0.23	0.27	0.20	0.28
		A	0.004		0.29	0.20	0.11	0.39
IA8	35	U	0.11			0.80	0	0.09
		A	0.18			0.72	0.03	0.07

[a] U = use; A = availability.

Appendix 7. Habitat use and availability of *A. plaudinosus*, *G. genetta* and *C.civetta* monitored by radiotelemetry in and around the BMNP from 1998-2001.

Cap. code	No. of locations		proportion of habitat: Farmland	Bushland	Grassland	Open woodland	Closed woodland	Town
AP1	61	U[a]	0	0.38	0.34	0.28		
		A	0.05	0.46	0.27	0.22		
GG5	61	U	0			0.39	0.48	0.13
		A	0.02			0.30	0.35	0.33
CC3	56	U	0.05	0.04	0.02	0.36	0.43	0.11
		A	0.21	0.17	0.01	0.49	0.06	0.05

[a] U = use; A = availability.