Ecology of the Lappet-faced Vulture *Torgos tracheliotus* in Saudi Arabia

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Presented for candidature for Doctor of Philosophy to the Faculty of Science,
University of Glasgow, January 1996.

Contents

Dedication

This thesis is dedicated to my wife, my parents, and HRH prince Saud Al-Faisal for their support and encouragement throughout my academic career.

Acknowledgements

I am thankful to HRH prince Sultan ben Adulaziz, Second Deputy Premier, Minister of Defence and the head of the National Commission for Wildlife Conservation and Development (NCWCD) board of governors in the Kingdom of Saudi Arabia for his support and co-operation. My deep gratitude to HRH prince Saud Al Faisal the Saudi foreign Minister and Managing director of NCWCD for his support and encouragement, without whose interest this study would not have been possible. My sincere thanks to Professor Abdulaziz Abuzinada, Secretary General of NCWCD for his support and encouragement at every stage of the study. I am grateful to the British Council for giving me the opportunity to make this study through their scholarship.

I am grateful to Dr. David Houston for all his advice and encouragment over the last few years. Many thanks must go to Dr. Stephen Newton for his supervion in the field and encouragment during the period of the study. I am also grateful to Dr. Anna Newton for her useful discussions and suggestions.

At the NCWCD I wish to thank the following people for help and their support: Yusuf Al Wetaid, Borhan Qarri, Hamed Melebari and Mohammed Al-Harbi. I am grateful to Milton Hinshaw, aviation consultant of the NCWCD, for organizing the aerial survey. Special thanks to the pilots captain Hans, captain Erick, captain Clarck. Special thanks to Mr. Hieko for his help and advice on the GIS.

At the NWRC I am grateful to the following people: Abdul Rahman Khoja, Jacques Renaud, Patrick Paillat, Dr. Neyerul Haque, Dr. Stephane Ostrowski, Dr. Philipe Sedone, Ahmad Al Bouq, Dr. Tomy Smith, and Mr. Kirre Ismail. Special thanks to all the rangers at Mahazat as-Sayd, and the helpers the in the mammal and bird camps. Lastly I wish to acknowledge the help of C. Abdul Rahman, M. Basheer, M. Kunhi and M. Ad-douh in explaining some of the computer packages.

Abstract

1- Food availability for the lappet-faced vultures was examined between 1993 and 1995. Several methods were used to estimate the number of ungulates in the area, such as aerial surveys, ground counts, questionnaires and the Ministry of Agriculture reports. The density of domestic livestock was estimated as 2.66 LSU's (LSU= Livestock Unit, one LSU equal one camel or ten sheep or ten goats). Based in studies in northern Saudi Arabia the expected carrying capacity of livestock in the study area is 0.3. This mean that the number of domestic livestock outside the reserve was nine times the predicted carrying capacity of the study area. A high mortality rate among the domestic herds provided a reliable food source for all the scavenging species in the study area. The wild ungulates were also examined, but their number was low, and their distribution was restricted to inside the reserve. There was no evidence of food shortage for the vulture population.

2- The pellets analysed from the lappet-faced vulture roost and nests sites at Mahazat as-Sayd reserve showed that they were heavily reliant on domestic ungulate carcasses. The birds might occasionally feed on live prey such as rodents and spiny-tailed lizards, but this was not a major source of food. However, there was no evidence of any seasonal variation in the type of carcasses used by the lappet-faced vultures.

3- The way in which different scavenging species located and exploited the carcasses was examined. Observations at carcasses placed in random sites showed that the brown-necked raven was the first species to arrive to the carcass. The lappet-faced vulture was the last species to find the carcass. They started foraging singly or in pairs and they moved in different directions, which would allow them to form a network in the sky and search effectively for food over a large areas. The number of vultures increased rapidly once the carcass had been discovered. The mammalian scavengers found few of the carcasses and were nocturnal.

4- The competition over the food supply was determined by measuring the amount of food removed by each of the scavenging species. Observations at the carcasses showed that the amount of food utilised by the avian scavengers was 30.4%, most of which was consumed by the lappet-faced vultures. The bill structures of the smaller scavenging birds are not adapted for tearing the skin of carcasses. However, different species of scavengers attended the carcasses at different times of the day. The small species fed in the early morning and late evening and the lappet-faced vulture concentrated on feeding in the midday. Therefore, there was no evidence that competition at the food sources had any effect on the lappet-faced vulture population.

5- The most important factor influencing the timing of breeding is probably the climate. Eggs are laid in winter to minimise the thermal stress on both the egg and the incubating adults. The number of active nests inside the reserve was far higher than outside the reserve, because the reserve provides an undisturbed area for breeding. Human disturbance is probably the main factor affecting the vulture population in the study area.

6- Observations at the nest suggested that the lappet-faced female may incubate the egg more than the male. The critical time in the lifetime of the lappet-faced vulture was probably the post-fledging dependence period, which could last up to 4-5 months. The majority of birds which died were found in this period.

7- During the first six months after fledging the distance covered by the fledging nestling increased significantly with age. There was a seasonal cycle of the lappet-faced vultures abundance at the reserve. The results from the movements of birds fitted with the satellite transmitters supported this cycle and suggested that some birds engage in short-distance migration within Saudi Arabia.

Chapter 1. Introduction

1.1 Vultures in Saudi Arabia

Vultures are large birds weighing 1.5- 10 kg (Mundy *et al.* 1992) and feed primarily on carrion (Houston 1979; Mundy *et al.* 1992). They have bald or sparsely feathered heads and neck, and relatively strong beaks for tearing flesh. These features are adaptations to their scavenging mode of life (Grossman and Hamlet 1964; Brown and Amadon 1968; Mundy *et al.* 1992). There are 22 species of vultures in the world, which belong to two taxonomically distinct groups of birds (Amadon 1977; Sibely and Ahlquist 1990). The Old World vultures *Accipitridae* are related to the eagles and hawks. This group contains 15 species. The seven species of vultures in the New World *Cathartidea* have a quite separate descent from stork-like ancestors.

In the Arabian Peninsula six species of Old World vultures have been recorded (Jennings 1981), and four breed in Saudi Arabia, these being the bearded vulture *Gypaetus barbatus*, Egyptian vulture *Neophron percnopterus*, griffon vulture *Gyps fulvus* and the lappet-faced vulture *Torgos tracheliotus* (Jennings 1993).

The bearded vulture is found in the western highlands as a rare resident (Jennings 1993). The breeding season for this species starts in late winter to early spring. In the late 1970's this population started to decline, and although the cause is not known it is likely to be due to a combination of disturbance at the nest sites, pollution from pesticides and poisoning (Shobrak and Rahmani 1993; Gasperetti 1994; NCWCD unpublished report).

The Egyptian vulture is the most common vulture over most of Arabia, except for the Empty Quarter and northern areas (Jennings 1993). There is both a resident and migratory population (Jennings 1993). Little is known about this species in Saudi Arabia, but the population is apparently decreasing, even on large islands where human disturbance and competition with other scavengers is limited e.g. Farasan Island (Jennings 1993; Rahmani *al. el.* 1994). The breeding season of this species starts in winter and ends in late summer (Jennings 1993).

The griffon vulture is a widespread resident in the western and south west regions. It is an occasional migrant and winter visitor to the north of Arabia (Jennings 1993). The number of birds is apparently declining, and it is no longer breeding at some former colony sites, possibly due to poisoning and disturbance (Shobrak and Rahmani 1993; NCWCD unpublished data). The breeding season starts in early winter and lasts until late summer (Jennings 1993).

Finally, the lappet-faced vulture, which is the subject of this study. Three subspecies of the lappet-faced vulture are recognized (Bruun *et al.* 1982). *T t. tracheliotus* occurs in south and east Africa. It is identified by the white thighs, large skin folds or lappets on the head and neck, and scarlet colour to the bald head. Mundy *et al.* (1992) added that the southern African members of this subspecies have yellow bills, but the East African adults have a mostly black bill. The *negevensis* subspecies occupies Israel and possibly the Arabian Peninsula (Mendelssohn and Marder 1989). This subspecies is altogether a browner and less colourful bird with a greyish face, and pink skin on the back of the head. There is usually a thick covering of down on the head, and there are also small or no lappets. The thighs are dark brown in colour and the bill is mostly blackish (Brunn *et al.* 1981).

The third subspecies, *nubicus*, is believed to be an intermediate hybrid between the other two subspecies and occurs in Egypt and Sudan where it has become endangered in recent years (Mundy *et al.* 1992; Bruun 1981; Cramp and Simmons 1980). This subspecies differs from *tracheliotus* in having inconspicuous lappets, which are much less developed, moreover, it has a pink head and brownish thighs.

The racial relationship of Saudi Arabian birds is unclear. The birds seen by King (1978) in western Saudi Arabia were considered by Bruun (1981) as *nubicus*. Jennings described the birds which once bred south of Riyadh (Jennings 1981; 1982) as *nubicus*. Gallagher (1982), however, concluded that the birds occurring in northern Oman may be intermediate between *nubicus* and *negevensis* using the racial criteria of Bruun *et al* (1981). Moreover, Jennings and Fryer (1984) think that the breeding population in west central Saudi Arabia fits into this intermediate category. Mundy *et al.* (1992) believed that the birds in Israel and Arabia both belong to the *negevensis* subspecies. Future studies of the genetics of the species is needed to establish whether these sub-species are valid, and we also need better information on their distribution.

1.2 The lappet-faced vulture in Saudi Arabia

The lappet-faced vulture is the largest of the Old World vultures found in Africa and the Arabian Peninsula (Mundy *et al.* 1992; Newton and Shobrak 1993). The first record of this species in Saudi Arabia was in 1947 located 125 km south east of Riyadh (Jennings 1982). The published status of the lappet-faced vulture has changed from being a very scarce breeding species in the Arabian Peninsula to being a widespread, almost common bird in the plains of west-central Saudi Arabia to the north of 19° N latitude (Newton and Shobrak 1993). The former distribution was largely restricted to 23-27° N, 40-43° E (Jennings and Fryer 1984), but in recent years the range has been extended on a broad front across the whole of west-central Arabia from 19° N, 45° E to 28° N 39° E (Fig. 1. 1). This change in the status has probably occurred because we now have far better information on the birds, and may not reflect any actual increase in numbers or extension of their natural range. The population size of this vulture in Saudi Arabia was estimated from available data to be probably in excess of 1000 individuals (Newton and Shobrak 1993). The population is undoubtedly small enough for there to be serious concern for the conservation of the species in Saudi Arabia.

In the neighbouring countries a small breeding population has been known for some time in Oman and United Arab Emirates (Gallagher 1977; 1982; Tourney *et al.* 1982), but some confusion in identification with the cinereous vulture *Aegypius monachus* and griffon vulture may have occurred (Gallagher 1982). Since 1984 the distribution of the lappet-faced vulture in these areas has remained virtually unchanged. There is insufficient data to estimate the population size in these areas, but few active nest sites have been recorded (Gallagher 1989). The breeding population in Israel is now extinct, and Saudi Arabia therefore contains the only viable population of the Arabian race of the lappet-faced vulture.

1.3 Feeding ecology of the lappet-faced vulture

Most of the studies on lappet-faced vultures have been carried out in Africa, such as Thomson (1974), Anthony (1976), and Pennycuick (1976) on breeding. The feeding behaviour, adaptations and interactions with other scavenging birds have also been studied by Attwell (1963), Kruuk (1967), Sauer (1973), Houston (1974a; 1976a; 1979; 1980; 1984b; 1987b) and Mundy *et al.* (1992). These studies in Africa showed that scavenging birds play a major role in the ecosystem because they utilized most of the available carrion from ungulate mortality. Despite the popular impression that vultures obtain their food by stealing it from predator kills, this is actually a minor source; Houston (1974b) estimated that in the Serengeti the vultures obtained only about 15% of their food from remains of predator kills, and 85 % from the carcasses of animals which had died from other causes such as disease or malnutrition. New World vultures play an equally important role as the dominant consumers of animal carcasses, removing 90% of the carrion available from forest in Panama (Houston 1986).

Abundant food supplies for the African vultures come in the wake of migrating herds of ungulates (Rossiter 1982; Mundy *et al.* 1992). In some areas in Africa, particularly in West Africa where the large wild herds have vanished and been replaced by domestic livestock, vultures are now heavily dependent on this livestock as a source of food. The amount of food available from wild and domestic ungulates for avian scavengers have been the focus of studies in several areas (Houston 1979; Perco *et al.* 1983; Robertson and Boshoff 1986; Komen 1986; Brown 1988; Shobrak *et al.* 1995). These studies indicated that under the present conditions there was no evidence of food shortage for vulture populations in any of the study areas.

It is believed that vultures form a network in the sky to locate carcasses and as soon as one bird spots something and drops downwards to investigate, the telltale flight movement is noticed by other vultures who fly in to join the first, and so on (Houston 1974b; Mundy *et al.* 1992). In the Old World vultures all species appear to locate carrion over long distances by sight. However, the New World Turkey vulture *Cathartes aura* uses the sense of smell in locating carcasses (Bang 1964; Stager 1964; Houston 1986; Kirk 1988), as do the greater and lesser yellow headed vultures *C. melambrotus* & *C. burrovianus* (Stager 1964; Houston 1984a; 1988). The other New World vultures however have not developed olfaction, but they fly at greater altitude and watch the activities of *Cathartes* vultures flying below and follow them to the carcass (Houston 1984a; Koester and Koester- Stowesand 1978).

Kruuk (1967) studied the East African vultures, dividing the birds into three groups on the basis of their food selection, methods of food searching and other behaviour. He described the lappet-faced vulture as territorial and specialized for feeding on skin, tendons and small carcasses. König (1974) in a study of the feeding methods used by vulture species recognized three forms of feeding: pulling, tearing, and pecking. The lappet-faced vulture fitted into the second type (tearing), having a more compact skull than the other species, with a powerful beak suitable for opening carcasses and tearing off tough and coarse parts. Hertel (1994) discussed the diversity in body size and feeding morphology within past and present vulture assemblages by discriminant function analysis of morphological variables. The results showed three feeding types can be distinguished among both fossil and modern vultures based on skull, beak, and mandibular measurements; rippers tend to feed on tougher carcass parts, gulpers on softer viscera, and scrappers on smaller scraps. The lappet-faced vulture clearly fits into the first type.

Apart from the vegetarian palmnut vulture *Gyphierax angolensis* in Africa, all vultures are carrion feeders (Mundy *et al.* 1992). However, some species occasionally act as predators, and this includes the lappet-faced vulture. In Africa the majority of the food items found in lappet-faced vultures' nests come from small animals which could have been killed by the birds (Mundy *et al.* 1992). In other areas such as Israel, studies on the pellets which have been collected from the roost and nest sites contained remains of many spiny-tailed lizards *Uromastyx sp*, suggesting that lappet-faced vultures could be predators on such species (Mundy *et al.* 1992). In Saudi Arabia preliminary studies on food supply showed that a small number of pellets of lappet-faced vultures in Mahazat as-Sayd also contained remains of spiny-tailed lizards (Newton and Shobrak 1993; Shobrak *et al.* 1995).

1.4 Social behaviour of vultures

Andersson (1872) called the lappet-faced vulture a "Sociable vulture". But Roberts (1963, In Sauer 1973) called it "less sociable" than other vultures. Nevertheless, many observers have considered the lappet-faced vulture as solitary, because the number of birds seen in pairs was greater than birds seen in groups (Mundy *et al.* 1992). During the three months of breeding the birds are usually seen alone because one partner stays at the nest with the chick while the mate forages itself. Counts done outside the breeding season showed that adults are then more frequently seen in pairs than alone (Mundy *et al.* 1992). In contrast to the social isolation of the pairs at their nest sites, Sauer (1973) mentioned that the lappet-faced vulture was gregarious outside their normal feeding range and flocked readily with their own kind. Periods spent resting outside the home range provide opportunities for social gatherings, especially at water sites (Sauer 1973; Mundy *et al.* 1992). It is not known if lappet-faced vultures actually defend a foraging territory, but this is unlikely. Although birds are usually seen as solitory individuals or in pairs when searching for food, they can congregate in large groups at carcasses or water sites. At food sources Mundy *et al.* (1992) mentioned that they prefer a small carcass, and they may attend large animal carcasses for social interaction rather than feeding. In Saudi

Arabia the largest number recorded gathering at a carcass was at Mahazat as-Sayd, when 60 birds were seen feeding on Oryx *Oryx leucoryx* carrion (Newton and Shobrak 1993).

1.5 Movements

To record dispersion and ranging behaviour it is essential to mark and track individual birds (Newton 1979). The dispersing of foraging vultures over savanna habitat is partly related to food supply (Mundy *et al.* 1992). Therefore, seasonal changes in food supply and density of vultures affects foraging movements. Some scavenging species are thought to maintain largely exclusive ranges, such as whiteheaded vultures *Trigonoceps occipitalis* and Bateleurs *Terathopius ecaudatus* (Kruuk 1967; Pennycuick 1972; Watson 1986). Other species such as griffon vultures are non-territorial and travel large distances. Houston (1979; 1984b) thought that griffon vultures could have been attracted to a carcasses at least 35 km away. Griffon vultures can maintain a cross country flight speed of 47 km/h and breeding birds could travel 150 km from the nest site to reach food among the migratory ungulates (Houston 1974a). Studies on immature marked griffon vultures showed that the birds have been resighted over 1000 km away from their ringing sites (Houston 1974b).

The lappet-faced vulture is normally considered to be a resident within a relatively small home range but individuals have been known to forage up to 150 km from the breeding locality (Cramp and Simmons 1980). Marked immatures have been resighted up to 300 km from the nest where they were marked (Brown *et al.* 1981). The longest distance recorded for dispersal of a first year bird was 700 km for a bird which moved from Namib desert to Kalahari Gemsbok National Park (Mundy *et al.* 1992). Kruuk (1967) and Pennycuick (1972; 1976) came to the conclusion that the lappet-faced vultures in the Serengeti foraged by patrolling a fixed home range of limited extent.

The use of radio-tracking to study movement patterns in birds of prey will help in understanding the biology of this group of birds. Kenward (1980) provided a review of radio monitoring of birds of prey and included information on recent applications of radio tracking in various countries. However, very few studies have been made on any vulture species. Recently a few radio-tracking studies on both New and Old World vultures have been started, such as European griffon vulture *Gyps fulvus*, bearded vulture, Cape vulture *Gyps coprotheres*, and lappet-faced in the Old World, and Turkey vulture and California Condors *Gymnogyps californianus* in the New World (Pennycuick 1983; Boshoff 1984; Brown 1988; Wallace and Temple 1987; Kirk 1988). The results have shown variation in the size of home and foraging ranges of the species at different times of the year, especially in the breeding seasons.

1.6 Introduction to the study

In Saudi Arabia no detailed study has been made on the lappet-faced vulture. The only available data on this species concerns its occurrence and general history of breeding in the Arabian Peninsula (Jennings and Fryer 1984). Initial studies started on this species at Mahazat as-Sayd reserve in 1991 to count the lappet-faced vultures and investigate the taxonomic status of the birds (Weigeldt and Schulz 1992). A description of the status and notes on the breeding cycle of lappet-faced vultures in Saudi Arabia have also been published (Newton and Shobrak 1993).

1.7 Aims and lay-out of the thesis

The National Commission for Wildlife Conservation and Development (NCWCD) drafted a policy document for conserving wildlife species in Saudi Arabia (NCWCD 1989). NCWCD started a long-term project in 1992 to study the ecology of the lappet-faced vulture in Mahazat as-Sayd and to develop a conservation strategy for the species in Saudi Arabia. This study is part of this project and has the following objectives;

- to obtain information on the availability of food for scavenging animals in general, and especially for lappet-faced vultures at Mahazat as-Sayd reserve in

Saudi Arabia, to consider whether the size of the food supply might be limiting the vulture population.

- to obtain basic data on the feeding ecology of the species, food selection, efficiency of the birds in locating carcasses and interactions with the other scavenging species at the carcasses
- to obtain data on the parental investment in breeding.
- to obtain information on the movement and dispersal patterns of young and adult lappet-faced vultures.
- to make recommendations on actions to conserve the species in Saudi Arabia.

Chapter 2 is an introduction to the study area which consists of a brief summary about Mahazat as-Sayd reserve, an outline of the main habitat types in the selected vulture study area, with a description of the climate, topography, fauna and flora and the social economy in the area. Chapter 3 will present the results of investigations into the size of the food supply for vultures from ungulate mortality in the surrounding area. This includes the size of the livestock herds and their mortality, the husbandry practices of pastoral agriculture, including the seasonal movement patterns of animals and normal practices when sick or dead animals are found. Chapter 4 includes discussion of the food selection of the lappet-faced vulture, to mainly answer the question "can the bird act as predator? if so how important is predation in obtaining food and when in the year does it occur?". The efficiency of lappet-faced vultures at locating carcasses and their foraging behaviour will be discussed in Chapter 5, this chapter also includes studies on the amount of food removed from carcasses by the lappet-faced vultures. Chapter 6 focuses on detailed interactions between the various scavengers (birds and mammals) at the carcass. In Chapter 7 the extent of parental investment during the breeding season will be discussed, to determine the time spent incubating by the two sexes, guarding the chick and the length of period young birds are dependent on parents and the importance of shading the chick from direct sunlight. Chapter 8 investigates the movement patterns of lappet-faced vultures in order to indicate the seasonal movements of the birds using the reserve. Home range and the dispersal pattern of young birds are discussed. In Chapter 9 there is a general discussion of the results and their relevance for the conservation of the species in Saudi Arabia.

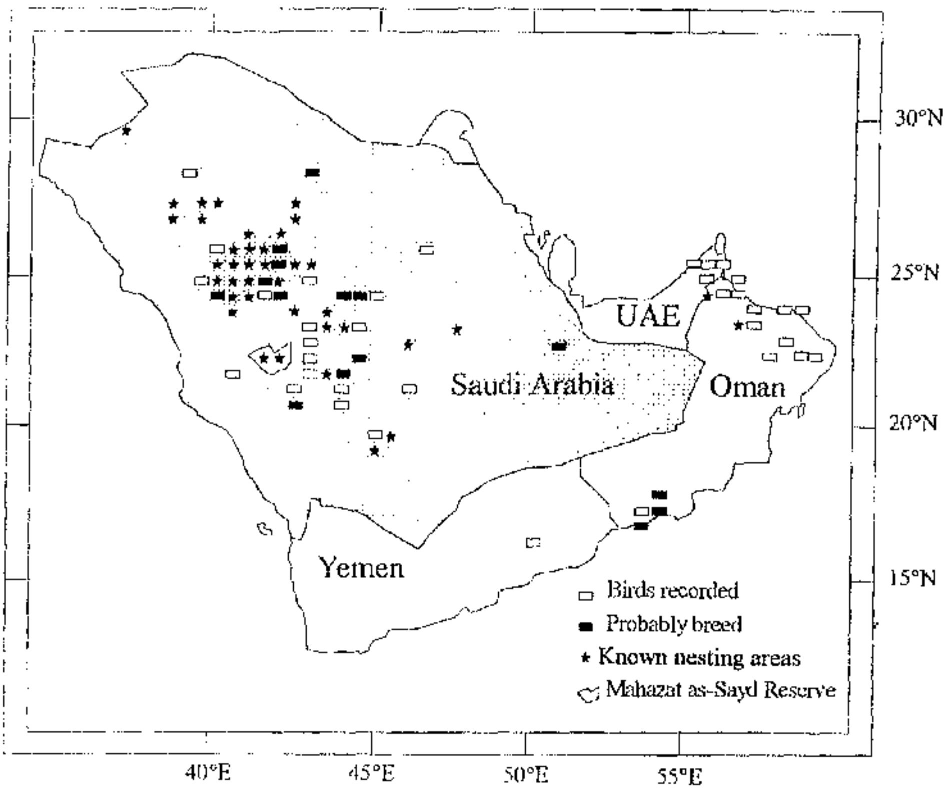


Figure 1. 1 Distribution of the lappet-faced vulture in the Arabian Peninsula (after Jennings, Atlas of breeding bird in Arabia; Newton and Shobrak 1993)

Chapter 2. Study area

2.1 Mahazat as-Sayd reserve

Mahazat as-Sayd Reserve is the second largest fenced reserve in the world located on the arid plains of west Saudi Arabia, 170 km north-east of Taif, at 22° 00' - 22° 30' N & 41° 28' - 42° 13' E, (Fig. 2.1). The reserve has been protected since 1989, and covers an irregularly-shaped area of 2321 km². A perimeter fence prevents Bedouin and their livestock from entering the reserve. The protection from human disturbance within the reserve has attracted birds to use it for breeding. Lappet-faced vultures have apparently been quick in reacting to the favourable nesting and roosting conditions in the reserve. The reserve was the first site for the reintroduction of the Arabian Oryx *Oryx leucoryx*, sand gazelles *Gazella subgutturosa*, mountain gazelle *Gazella gazella*, houbara bustard *Chlamydotis undulata* and red-necked ostrich *Struthio camelus camelus* in Saudi Arabia (Greth and Schwede 1993; Haque and Smith 1994; Smith 1994; Haque and Smith 1995).

2.2 Vulture study area

Because the number of wild animals in the reserve is low, and their mortality is also low, there are few carcasses available within the reserve, and the avian scavengers fly outside to feed from domestic livestock carrion. As a result a study area was selected to include an average of 40 km from each side of the reserve, with Mahazat as-Sayd at the center. The total size of the study area was 19,965 km². The size of this study area was not intended to represent the actual forging area used by the lappet-faced vultures, but it was selected as the largest area that I could practically survey, and is probably the main foraging area used by birds breeding in the reserve. The area outside the reseve is managed for livestock rearing using methods that are typical of the whole of the west central region of Saudi Arabia. The area is located between 21°45' - 22°50'N & 41°05' - 41°35'E, and was divided into four sectors (Fig. 2.2). A map was drawn using the

Geographical Information System (GIS) facility available at the NWRC, and redrawn using Freelance program

2.3 Topography

The study area altitude ranges from 900 m on the open plains, up to 1400 m on the rocky mountains. The topography could be divided into five habitats on the basis of the terrain and the vegetation community (Fig. 2.3); the open sandy gravel plains (Photograph 2.1), the basalt rocky area "harrat" (Photograph 2.2), the mud flat area "subkhah" (Photograph 2.3), the cultivated area (Photograph 2.4), and the sandy area (sand-dune), (Photograph 2.5)

The open sandy gravel area is the largest part of the study area. This type of habitat has been sub-divided into two, based on the size and density of trees. One area in the south has a high density of large trees. It is also characterised by scattered patches of vegetation on the slopes and small wadis. In these patches scattered *Maerua* and *Acacia* trees (50-600 cm) exist which are utilized by nesting vultures. The commonest ground cover plants in this area include *Cymbogon commutatus*, *Haloxylon salicornicum*, *Rhazya stricta* and *Panicum sp*. The second habitat-type to the north consists of low densities of *Acacia* trees (50-200 cm). The ground cover is very sparse and the only commonly found plants are *Haloxylon salicornicum* and *Rhazya stricta*, but large areas have no ground cover plants.

The basalt rocky area is located at the edge of the south east, south west and north west of the study area. *Acacia sp* is the dominant tree in this area, and is confined to depressions and wadis.

The third habitat type is the cultivated area, which occurs in Wadi Subay and the area to the north west of Al Muwayh. This area contains the majority of farms and it is the main source of water for the whole area. The main products are dates, wheat and alfalfa.

The last two habitats are the mud-flat (subkhah) and the sand-dune areas. They cover only small parts of the study area. No trees were found in either of these two areas, with low densities of annual vegetation in the sand dunes and no vegetation at all on the mud flats.

2.4 Climate

On the classification of McGinnies *et al.* (1968, in Louw and Seely 1982), the climate of the area is semi-arid. Between 8th April 1991 and December 1994, the weather data were recorded every 15 minutes from a station located inside Mahazat as-Sayd reserve at 22° 09' 50" N 41° 55' 35" E. The records were obtained by using an automatic recording station "Squirrel logger, 1200 series" supplied by Grant Instruments Ltd. - UK. The average records for the maximum, minimum and mean for each month are presented here.

The rainfall was measured using eight rain-guages dispersed evenly across the reserve. The data collected showed considerable variation in the spatial distribution of rainfall in the area. The total amount of rain received from 8th April 1991 to December 1994 was 274.3 mm, which makes an average of 91.6 mm/year (Fig. 2. 4). Rainfall usually occurred between winter and spring. However, in 1992, 1993 and 1994 the major rainfall events occurred outside this period; in November of the last three years. The rain in August 1992 was exceptional. In 1994 a substantial shower occurred in mid- October. Rainfall in this area is therefore highly unpredictable.

Due to the rainfall in the winter of 1992-1993 and 1993-1994 and high solar radiation which caused rapid evaporation, the humidity was increased at these seasons, with an average humidity of 90%. A significant decease in relative humidity was always recorded in early summer, with an average of 30% (Fig. 2. 5)

Air temperature was measured in the shade at a height of one meter. The average monthly maximum air temperature was 40°C in summer, falling to 17-18°C in winter. Air temperature usually started to increase in February and reached the peak in July and August. The maximum air temperature was 46°C recorded in July 1993. The average minimum air temperature was 26°C in summer and dropped to 9°C in winter (Fig. 2.6)

The soil temperature was measured at 10 cm subsurface. The average soil temperature varied from 20°C in winter to 39°C in summer (Fig. 2. 7). The monthly maximum measured at the surface was only recorded in August 1994 and in this month it had a mean temperature of 58°C and absolute maximum reached of 69°C.

Solar radiation was measured with a silicon cell pyrometer supplied by Skye Instruments Ltd. UK. The waveband is 300- 3000 nm. The daily solar radiation values were recorded between 180 Watt/m^2 and 300 Watt/m^2, and vary considerably with the season. The average monthly maximum radiation varied from 700 to 1000 Watt/m^2 according to season. The absolute maximum radiation was recorded in July 1993 at 1100 Watt/m^2 (Fig. 2. 8).

The average wind speed varied between 2.5 and 4.5 m/s throughout the year. The monthly maximum is usually recorded in spring and the minimum tends to occur in autumn. During sand-storms or a rainy-days the maximum went up to 15 m/s (Fig. 2. 9).

2.5 Fauna and flora

2.5.1 Fauna

Out of 23 mammal species recorded in the vulture study area (Smith 1994), 18 were wild animals, the remainder domestic livestock. As regard to mammalian scavenger species (Carnivores), I divided them into two groups, the common species and the rare. The common species include animals such as the red fox *Vulpes vulpes arabica*, Rueppell's fox *Vulpes rueppelli ruepplli*, sand cat *Felis margarita harrisoni*, feral cat *Felis domesticus* and feral dog *Canis domesticus*. The second group contains rare species that occur only in the south east of the study area in the basalt rocky area (harrat), such as wolf *Canis lupus*, hyena *Hyaena hyaena* and ratel *Mellivora capensis*. None of the species in this group are sufficiently abundant to be considered as important scavengers in the area. Regarding the wolf, one was seen in the reserve in 1989 just before the fence was finished (Asmode, pers. comm.). Another was killed in November 1993, 15 km to the east of the reserve, in an area called Zaleim. Hyena are probably extinct in the wild, one animal was found in 1993 having been killed by hunters, hanging on a tree 40 km to the south west of the vulture study area. However, there is no evidence supporting its existence in the area during the study period. The ratel has been occasionally recorded in the reserve (Smith 1994), and there are also some records of this species from the cultivated area in wadi Subay and the rocky area.

More than 159 species of birds have been recorded from Mahazat as-Sayd reserve (Newton and Newton 1993; Smith 1994). This study concerns only the avian scavengers in the study area which can be divided into three groups: resident species, those species that use the area only for feeding, and winter visitors. Firstly, the resident group includes species such as the lappet-faced vulture *Torgos tracheliotus* and the brown-necked raven *Corvus ruficollis*. The second group of avian scavengers are the species that use the area for feeding and roosting, for example, the griffon vulture *Gyps fulvus*, of which a maximum of 8 birds have been recorded in the area (Weigeldt and Schultz 1992). The Egyptian vulture *Neophron percnopterus* is also a species which feeds in the study area but probably breeds in the high mountains in the rocky habitat. This species was seen throughout the year with a maximum of 40 birds roosting in the reserve in 1993. Finally, there are the winter visitors such as eagles and black kite *Milvus migrans* and the black vulture *Aegypius monachus*. In January 1994 five black vultures were observed in the study area. Six species of eagle were recorded in the reserve (Newton and Newton 1993). Bonelli's eagle *Hieraeetus fasciatus*, booted eagle *H. pennatus*, golden eagle *Aquila chrysaetos*, imperial eagle *A. heliaca*, spotted eagle *A. clanga*, and steppe eagle *A. rapax*.

A list of known and probable reptiles in the reserve was compiled in 1994 by J. Gasparetti (Smith 1994). Twenty species of lizards and 13 species of snakes were recorded in Mahazat as-Sayd reserve.

A collection of several hundred species of arthropods were obtained from the houbara bustard investigation (Combreau and Rambaud 1994). 11 species out of 6 families were recorded as scavengers, using carcasses for feeding, (Tenebrionidea, Histeridae, Scarabidae (Coleoptera), Formicidea (Hymenoptera), Tabanidae (Diptera), and Mantidae (Dictyopetra).

2.5.2 Flora

The study area is typical desert steppe habitat of the interior of the Arabian peninsula (Mandeville 1990). A preliminary study of the vegetation in the reserve by Gillet and Launay (1990) recorded 112 species representing 38 families (Smith 1994). As a result of overgrazing outside the reserve, these areas contained lower number of grass species and forbs. Moreover, toxic plants such as *Rhazya strictia* were more commonly found outside the reserve (McShea 1992), probably because heavy grazing pressure from domestic animals had reduced the abundance of palatable plant species.

Acacia species were the most common trees in all parts of the study area, especially in the open sandy gravel and rocky areas. Five species of *Acacia* were identified: *Acacia ehrenbergiana*, *A. hamulosa*, *A. nubica*, *A. raddiana* and *A. tortilis*. The lappet-faced vulture was only recorded nesting in *Acacia tortilis*. *Maerua crassifolia* was also commonly used as a nesting tree for vultures, and this tree species was found in small wadis in those parts of the open sandy gravel with a high density of trees.

Fagonia indica and *Indigifora spinosa* were the most common herbs, and *Panicum turgidum* and *Stipagrostis* were the commonest grasses inside the reserve (Haque and Shaheen 1993). Outside the reserve the common grasses were *Cymbopogon commutatus* and *Panicum sp*, and the commonest herb was *Haloxylon saclicornium* on the open sandy gravel near wadis. *Rhazya stricta* was found in the open sandy gravel area and in small wadis in open basalt rocky areas.

2.6 Social economy

For hundreds of years the range lands of the Arabian Peninsula were occupied by self-governing Bedouin tribes. The term Bedouin is derived from the Arabic expression badu (singular: badawi), a general term for all tribesmen who live in the desert and live mainly as herders (United Nations 1970). These people engaged in pastoral nomadism for their livelihood. Nomadism is thought to be the only efficient method for utilizing the sparse vegetation in the vast desert and steppe areas of the world, and camel herders in Arabia may be considered as pure nomads (Shamekh 1975). Salzman (1967) noted that nomadism is a way of life at least partially based on the movement of people in response to the need of their herds.

These pure nomads were primarily camel herders, who did not engage in farming, lived exclusively in tents, had a strong tribal organization, and they were on the move for about nine months of the year. Their pastoral migrations were adjusted to the cycle of the seasons. For example, in central Arabia, they began moving in October, or when the rainy season started. In May when the rain pools dried out, they began to move towards their permanent wells. They were forced to spend the hot dry months (June-September) near these wells, as their livestock showed an increased demand for water. Each Bedouin tribe had its own tribal territory or *Hema*. The *Hema* system is a traditional means by which tribal groups set aside part of the range to protect it from overgrazing (Draz, 1965). The size of this territory depended on the size and power of the tribe, and could range from a few to tens of thousands of square kilometers, and their movement was confined to within these territores. (Shamekh 1975).

In the study area three tribes still exist; Subay, Utybah and Buqum. The Subay tribes inhabit all of sector 4 and most parts of sector 2 (Fig. 2.2). The Utybah tribe, which is regarded as the second largest tribe in the kingdom, inhabits sector 1 and the west side of the road in sector 3. Finally, The Buqum tribe inhabit the east side of the road in sector 3.

In the early years of this century, when King Abdulaziz was consolidating his power in Arabia, he realized that no permanent political structure could be built on nomadism and uncertain tribal loyalties. So he succeeded in bringing the nomadic Bedouins under a central government called "Kingdom of Saudi Arabia". By the ending of the tribal affinities with the introduction of technology after the discovery of oil in 1938, there was a need for local people to benefit from this development. So the government started programmes of settling the nomadic Bedouins, which resulted in a large migration to the cities and led to a decline in the nomadic populations.

During King Abdulaziz's reign 50-60 years ago the nomads comprised 60% of Saudi Arabia's population (Arab News 17 January 1990); in 1990, the same source estimated the nomadic population in Saudi Arabia at 3%. According to a United Nations report "the last nomadic Bedouin will pack his tent and migrate to the city by 1995" (Sebai, 1985).

The socio-economic studies carried out by the Ministry of Planning from 1970 to 1980 revealed significant population migration within the Kingdom; the northern and south western regions were losing people to other more prosperous parts of the Kingdom. However, from 1980 to 1985 the government improved municipal and social facilities in the rural areas which, coupled with an increase in employment prospects, meant that the local people had more chance to work and find jobs in their own areas and did not need to migrate elsewhere in the Kingdom (Farsi, 1990).

There have been major changes in recent years in farming practice. An increased demand for sheep and goat meat has led to an increase in these species and a decline in the camel population. Subsidized barley has also been provided by the government as animal feed near cities and villages. These sheep and goat herds are heavily dependent on the provided barley, and natural grazing on desert vegetation is only a supplementary form of feeding. The provision of cheap animal feed has allowed the density of domestic animals to rise far above the number that could be supported by the natural vegetation. These changes have attracted more Bedouin to settle near towns and small villages to look for a better life and to improve their economic situation.

In the study area there is no data on the date when the Bedouin started to settle. However, the government started in the early 70's to distribute lands to local people for housing and farming and provided them with money for building houses in small villages and farms around wadi Subay. Now most of the Bedouins depend entirely on the cities for their living. A social study on the effect of Mahazat as-Sayd reserve fence showed that 65% of the people who live in tents (camp) around the reserve are going daily to cities for work, and to get food for themselves or for their livestock (Ad-dosari and Al Kalaf 1989).

A typical family in the study area consists of 2-15 members and their income ranges from 2000-4000 SR./month equivalent to 333-667 £/month or 533-1067 $ (Ad-dosari and Al Kalaf 1989). A study in Turabah 80 km to the south of the study area (and similar to the study area), which discussed the changes in the economy and health care between 1967 and 1981, showed that there were big changes in Bedouin families; family income increased several fold in the 15 years because the family may now have more than one source of income including farming, trade, government employment, animal husbandry, social security and financial support from young adults working in the cities (Sebai, 1985). However, animal husbandry remained a source of income to 88% of the local inhabitants in the study area (Ad-dosari and Al Kalaf 1989).

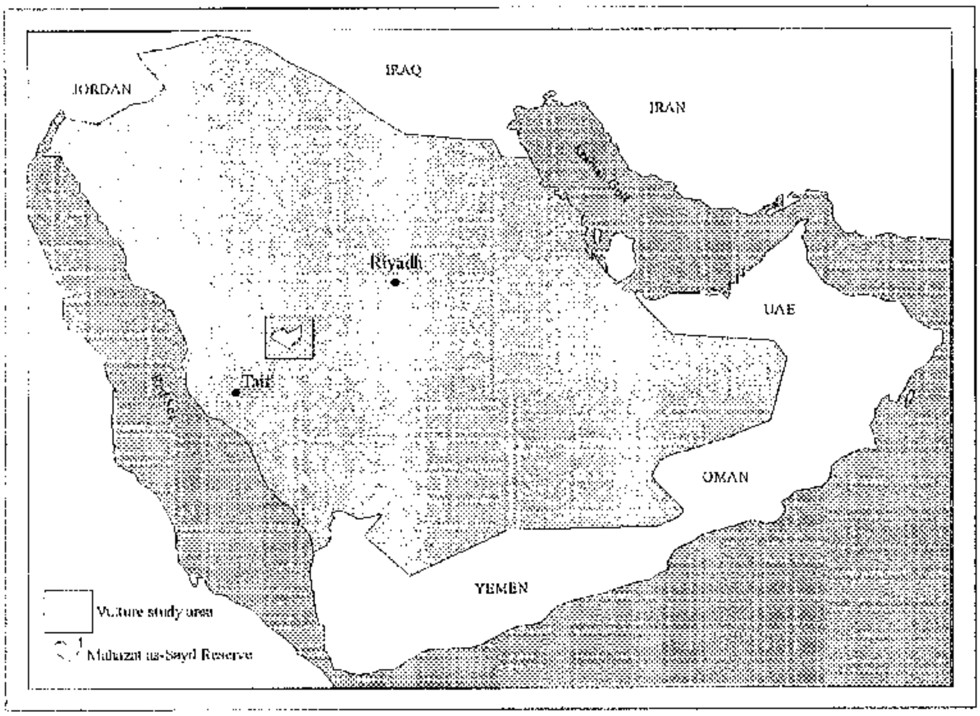
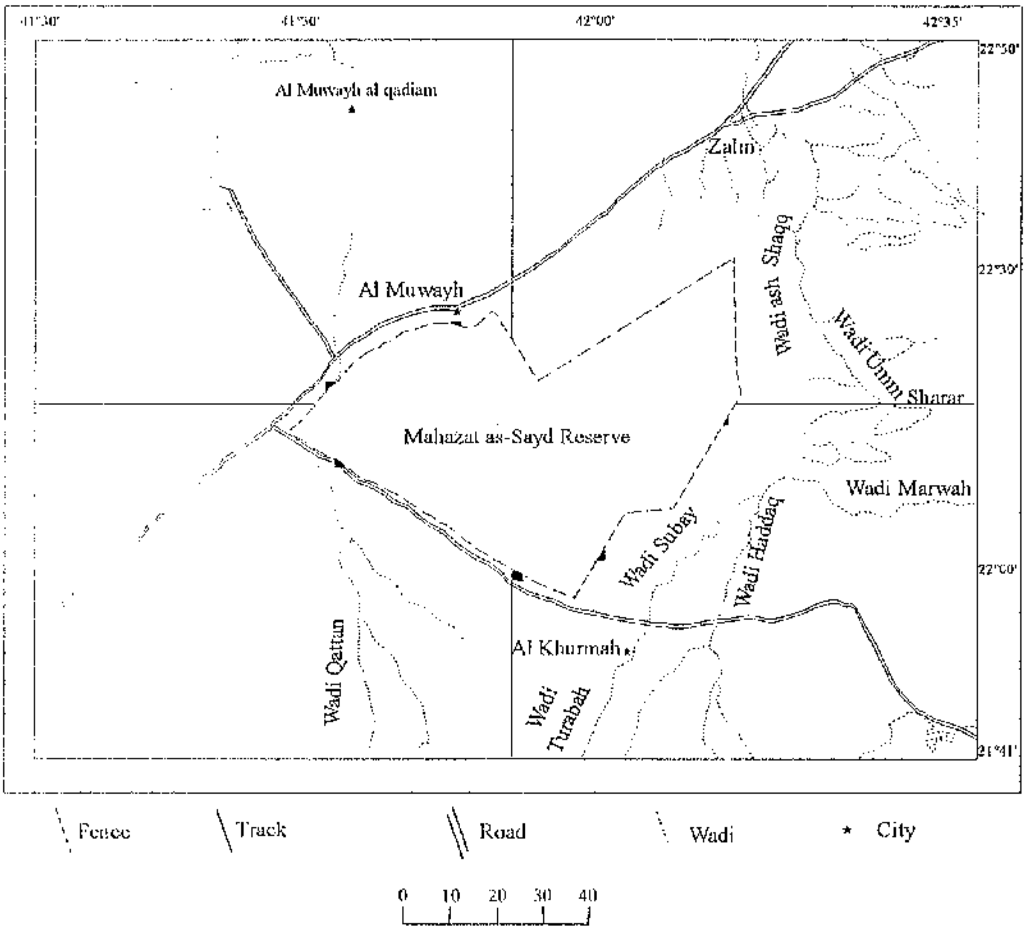


Figure 2.1: Location of Mahazat as-Sayd Protected Area in Saudi Arabia



Figuure 2.2: Vulture study area with Mahazat in the centre

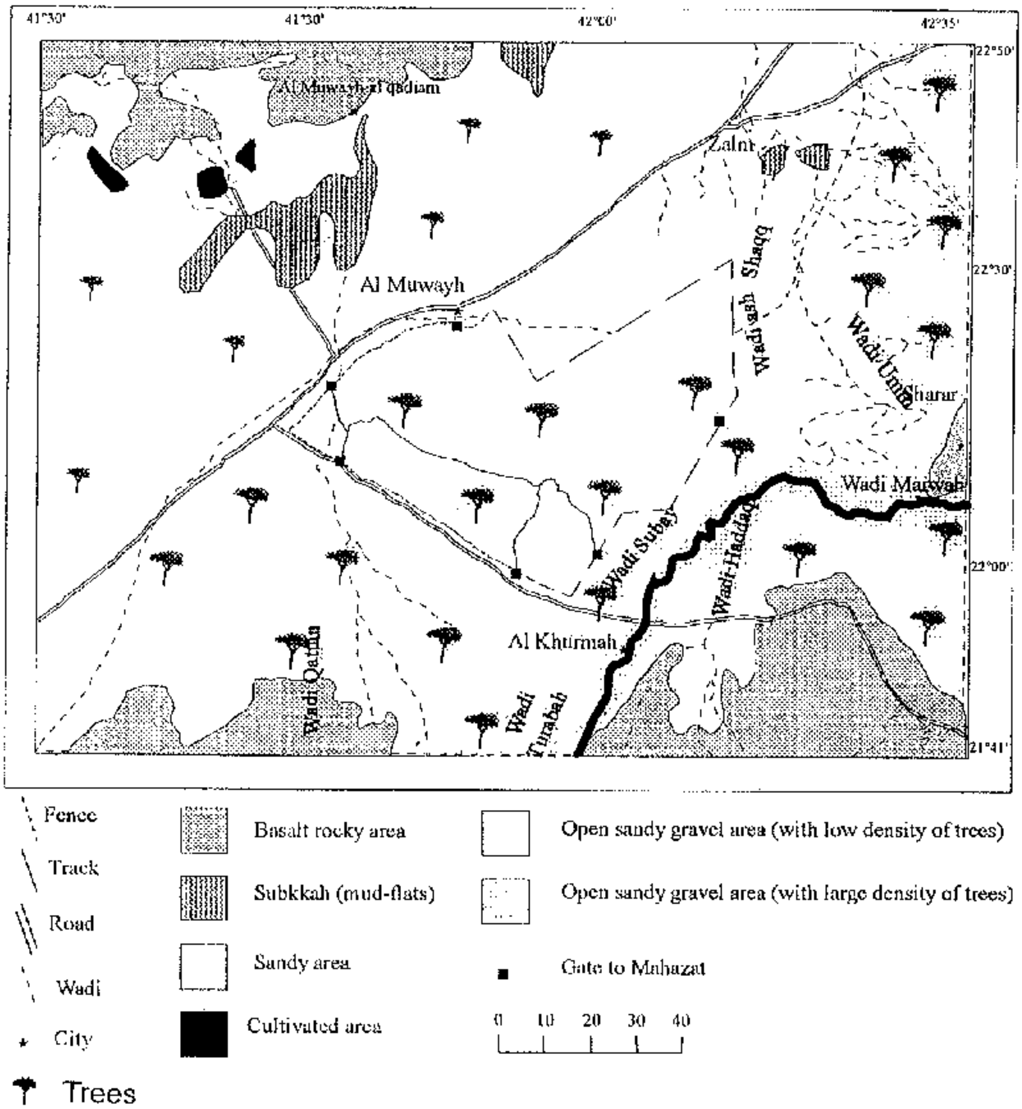


Figure 2.3: The main habitat types in the vulture study area

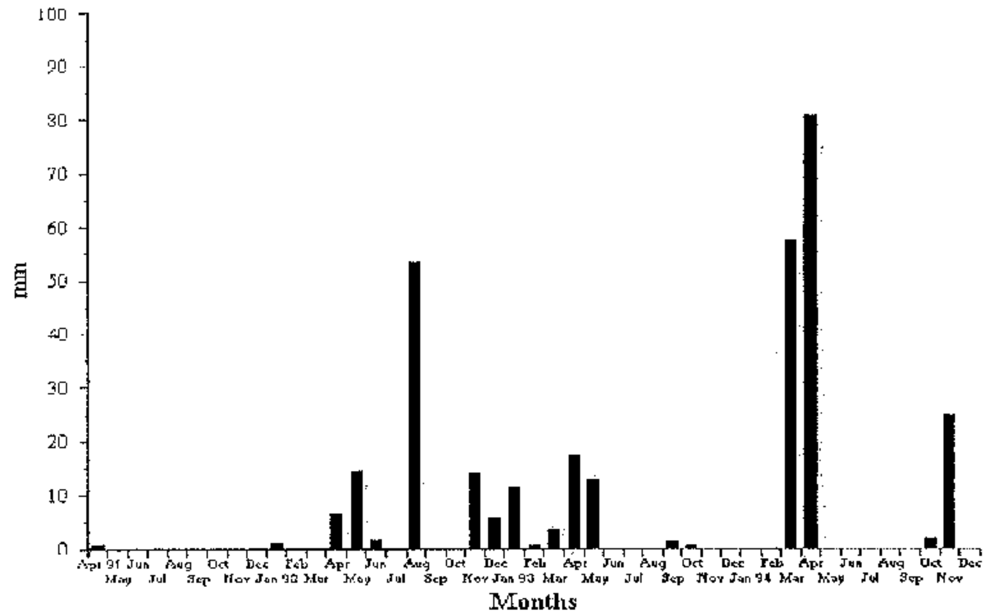


Figure 2.4: Rainfall recorded at Mahazat, between April 1991 and December 1994

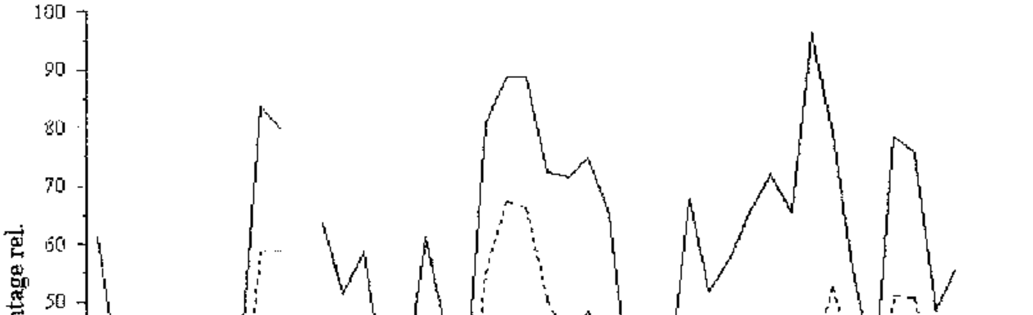


Figure 2.5: Maximum, minimum and mean Humidity recorded at Mahazat between April 1991 and November 1994

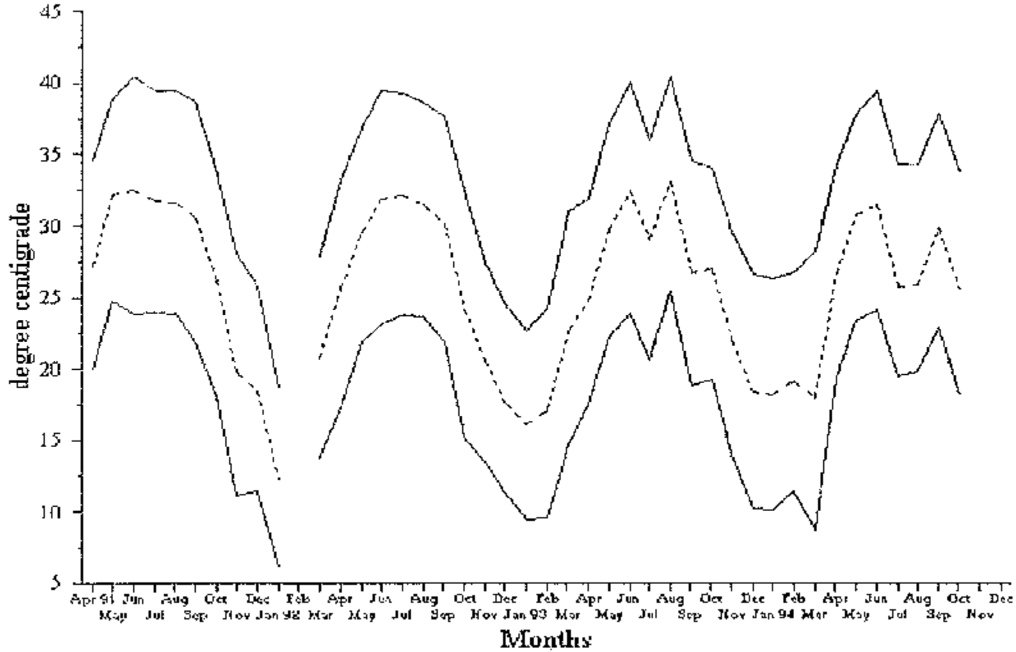


Figure 2.6: Maximum, minimum and mean air temperatures recorded at Mahazat between April 1991 and November 1994

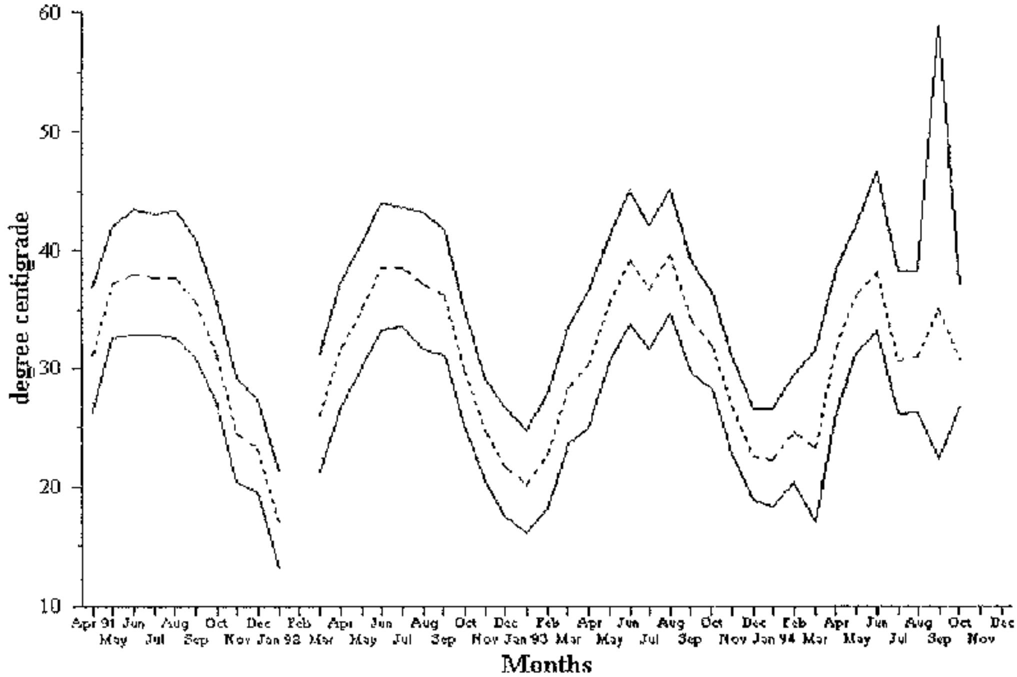


Figure 2.7: Maximum, minimum and mean soil temperatures recorded at Mahazat between April 1991 and November 1994

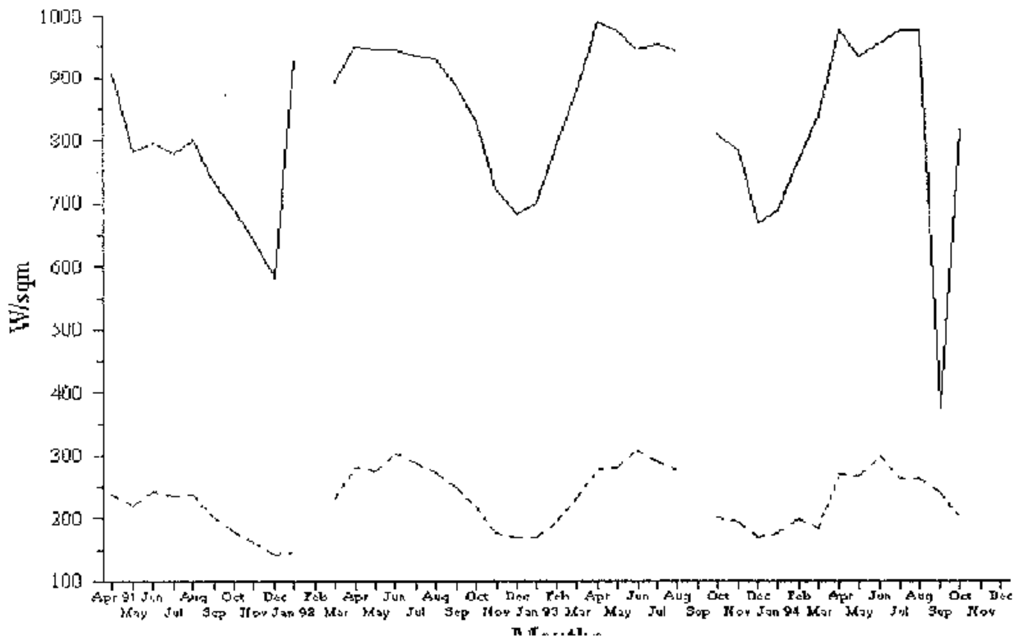


Figure 2.8: Solar radiation recorded at Mahazat between April 1991 and November 1994

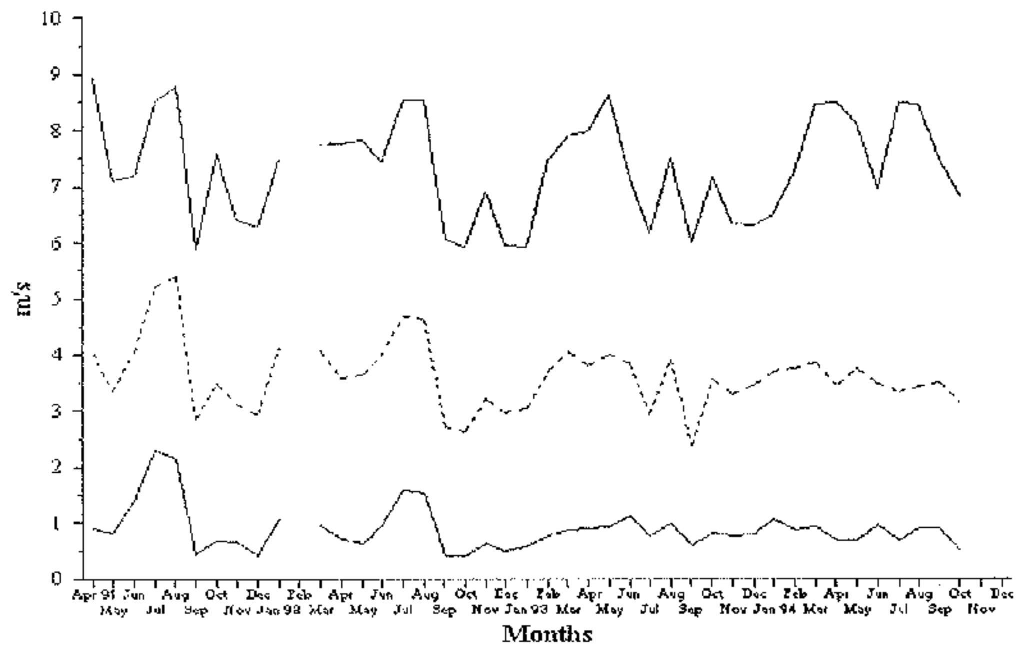
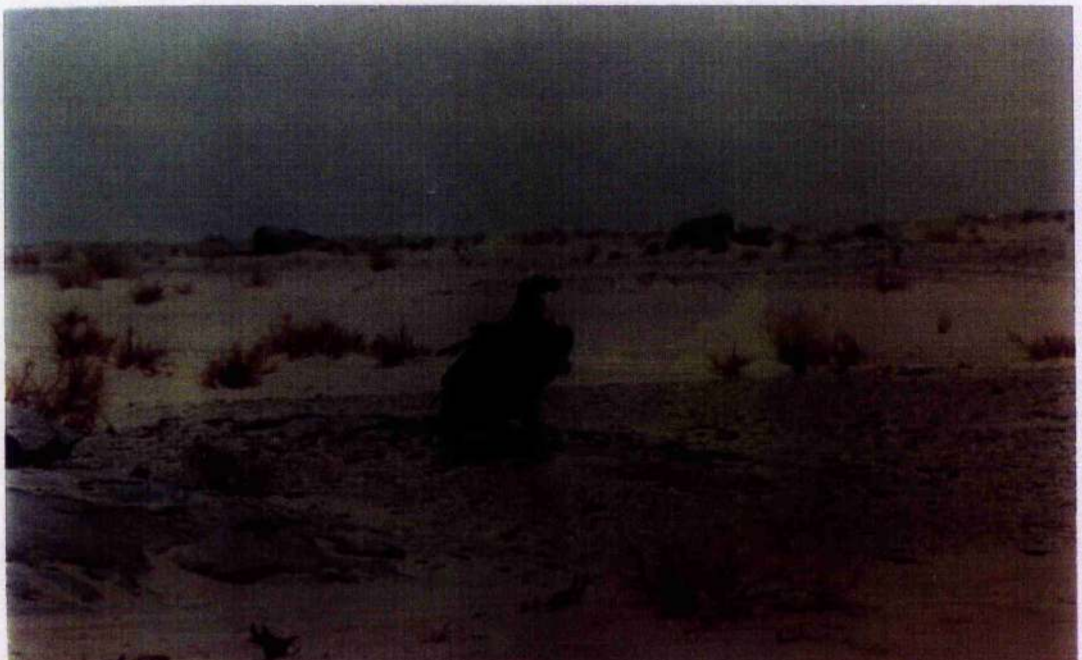


Figure 2.9: Maximum, minimum and mean windspeed recorded at Mahazat, between April 1991 and November 1994



Photograph 2.1. Open sandy gravel plains, (top) with high density of tress. (bottom) with low density of tress.

Photograph 2.2 The basalt rocky area (Harrat)

Photograph 2.3 The mud-flat area (Subkah)

Photograph 2.4. The cultivated area. (Farm)

Photograph 2.5. The sandy area (Sand-dune)

Chapter 3. Food availability

3.1 Introduction

The potential food resource of vultures has been studied in Africa. Houston (1971; 1974a, 1974b; 1976b; 1978) estimated the food requirements of adult and nestling Rüppell's griffon vultures during breeding, and compared this to the availability of food for the vultures in the whole Serengeti ecosystem. Robertson (1983) and Boshoff (1984) investigated food requirements for the Cape vulture *Gyps coprotheres* at the Potberg colony, and the same was done by Komen (1986) in the Magaliesberg area in South Africa. Brown (1988) investigated the food resource and the foraging area of bearded vultures in South Africa. Some of these authors substantiated their research with some knowledge of the size of birds' foraging areas, based on ground-truth (questionnaire surveys, reports, and radio-telemetry of a few individual birds).

Vultures are scavengers, and with a few exceptions feed only from carrion (Houston 1988). In Arabia in the past most vulture species fed from the carcasses of wild mammals such as gazelles, Arabian oryx, and other wild ungulates, though perhaps a few followed nomads to feed from carcasses of domestic ungulates. However, wild ungulates have now mostly disappeared due to hunting and habitat destruction (Child and Grainger 1990). This loss of a natural food supply has been compensated by a marked increase in the domestic animal population.

Two patterns of livestock husbandry are common in Saudi Arabia; sheep and goat herding and camel herding. The former is widespread, although traditionally it tended to be located in only watered areas and associated with village agriculture. Surveys in the early 1980's indicated that 60% of small stock owners were now settled or practiced only short range nomadism (Child and Grainger 1990). Camel herding was historically concentrated in the drier interior, using central deserts in winter and moving to northern and coastal areas in spring and summer (Shamekh 1975; Child and Grainger 1990).

Following the great drought of the 1950s &1960, the government started to support the Bedouin through provision of subsidized barley for animal feeding and attracted them to settle near the main distribution points near cities, towns and villages.

Moreover, the demand for red meat increased, especially for that of sheep and goats. Child and Grainger (1990) reported in 1987, that the red meat demand was 15.23 million per year LSUs (livestock units; one LSU= one camel or ten sheep or ten goats), nearly four times the capacity of the land. From an economic point of view, it is now more profitable to farm sheep and goats rather than camels. The reason for this is that sheep and goats usually give birth to twins, which after only 6-10 months will fetch SR 300-500 each (one USA $ = 3.75 SR, one sterling pounds = 6 SR "SR= Saudi Riyal"). But the camels seldom give birth to more than one young a year, and after a year's care their market value is only SR 1000-1500. In addition, camels eat far more each day than sheep or goats. Therefore, traditional camel herding has undergone significant decline and the sheep and goat herding has been increased markedly in recent years.

The aim of this chapter is to estimate the size of the food reserve available in the study area for scavenging animals from wild and domestic ungulate carcasses. This was obtained by estimating animal numbers, and considering the causes and rate of mortality to be found among the herds. The methods used by livestock owners in the area were investigated, to consider particularly how they disposed of dead animals. Newton (1980) pointed out that it is very difficult to determine precisely the spatial and temporal availability of carcasses. This is largely due to an over-riding number of logistic problems which a researcher has to contend with in any such investigation. It would be virtually impossible to determine precisely where, when and how many livestock carcasses are available to the lappet-faced vultures and other scavenging animals. The aim of this chapter is not therefore to attempt at an accurate estimate of the food resource available to the vultures, but only to indicate the general order of magnitude of the food supply and whether there is any evidence that food availability may be a factor limiting the size of the vulture population.

3. 2 Materials and methods

3. 2. 1 Size of the wild and domestic ungulate herds.

(I) Wild ungulates

Wild ungulates were restricted only to within the fenced reserve and no wild ungulates remain outside. Their numbers were obtained from wildlife biologists and rangers working on these species in the reserve. However, the number of these wild ungulates was very low, and increased protection of the vegetation has provided them with a good supply of food, and mortality rates are therefore also low.

(II) Domestic ungulates

It was difficult to determine the exact number of livestock in the study area because of its large size, and the large number of camps located in it. Moreover, the local people were not co-operative as a result of resentment at having their former grazing land taken from them at the time of the fencing of the reserve. In 1989 a study of the effect of the fence on local people showed that 29% of local inhabitants had a negative opinion regarding the enclosure of the area (Ad-Dosarri and Al Kalaf 1989). Also, livestock are not restricted to open desert areas, but can be found even among the houses in the small towns around the reserve. In this study two terms were used to distingiush between the livestock groups, the farm and camp. The farm is a permanent base supporting a variety of agricultural activities, including intensive grazing of livestock and cultivation, often characterized by solidly constructed dwellings and buildings, and located around the wadis and watering areas, in the cultivated area (Photograph 2.4). Secondly, the camp which is a temporary, or semi permanent base from which livestock are grazed on seasonally available natural rangelands, and characterized by the use of tents, a mobile water truck and temporary livestock shelters (Photograph 3.1).

Livestock counts were made using three independent methods: aerial survey, questionnaires, and ground survey. In addition, Ministry of Agriculture reports were used to compare their assessment of the number of domestic livestock in the area with my three methods.

1- Aerial surveys

The use of light aircraft to estimate animal numbers is well established, and total counts or randomly selected transect counts are a conventional method for recording both wild and domestic animal density (Norton Griffiths 1978). It was planned at the beginning of the study to fly transects every month. However, flying was only permitted during the week-end, and it was difficult to conduct sufficient counts for a monthly census in this short time. This was because Gwynne and Groze (1975) recommended that when counting animals by light aircraft more than one observer is needed, which was sometimes difficult to arrange, and no flights should exceed two hours. Because of these difficulties in organizing flying time, transects were flown on a three monthly basis (every season). The counts were made in late March, June, September and December.

Nineteen transects were flown in four seasons in 1993. Each series of transects counted total livestock numbers over the whole of the study area. The distribution of domestic animals is strongly clumped around farm and camp sites, which can cause estimates of animal numbers based only on sample transects to have large errors. Flights were flown with five minutes of longitude between each transect, at a height of 900 feet (300 m), and a speed of 170 km/h. It was not possible to count individual animals, because of the fast flying speed. Counts were therefore based on estimates of flock size. All flocks were centred around a farm or tented camp, which provided water from water tanks, feed for the animals and accommodation for the bedouin and their animals overnight. Initially several camps around the National Wildlife Research Center and around Mahazat as-Sayd reserve were selected randomly and visited on the ground to compare the size of the camp with the number of the livestock. As a result the livestock herds at the camps identified in aerial survey were divided into four categories:

(a) small groups of sheep or goat, which were mainly found in the villages and farms (up to 59 sheep and goats);

(b) medium herds, (up to 119 sheep and goats);

(c) large herds, (up to 176 sheep and goats);

(d) very large herds, (up to 240 sheep and goats);

(e) unknown. These were camps where it was not possible to make an accurate assessment of animal numbers, usually because the camp was not sighted early enough to get a clear view.

The camels were also difficult to count individually from the air as they range over large distances away from their camps. Data from the 20 camps and farms which were visited in the early stage in the study showed that most camps had a similar number of camels, regardless of the size of their sheep and goat numbers, and there were an average of 25 camels in each camp or farm (Table 2.1). Additionally, during the aerial survey the number of tents and water-trucks in each camp were also recorded.

Table 2.1 Camel numbers recorded at 20 camps and farms visited during the initial stage of the study.

Type	No. searched	Mean	Std. Dev.
Camp	13	26.4	21.42
Farm	7	25.4	7.76
Total	20	25	-

This method was established in March 1993 during which five hours were flown to determine optimum flying height and other details. Transects were completed in 63 hours of flying. It proved to be impossible to count animals around houses, and livestock in the towns were therefore excluded. Finally, 30 camps were selected at random from the aerial survey and visited on the ground to compare the actual number of livestock with the number estimated from the aircraft.

2- Questionnaires

As an indication of the size of farming operations and likely stock numbers, a series of questionnaires were designed to estimate the livestock numbers and their mortality rates directly from the farmers. The questionnaires were also designed to elicit reaction from farmers on whether the lappet-faced vulture caused problems for the local shepherds and farmers. The interviews were done initially through the Ministry of Agriculture in Khurmah. Information was collected from a random sample of 80 shepherds and farmers visiting the veterinary office at the Ministry of Agriculture for clinical treatment for their animals. Additionally, another 80 camps in the study area were randomly selected and visited by car and the shepherds / owners interviewed. In total 160 shepherds and farmers were questioned.

3- Ground counts

A programme of ground counts was also conducted firstly to act as an independent estimate to compare with the aerial survey results, and secondly to obtain data on the number of carcasses located. This cannot be done from the air, because from 900 feet it is not possible to discriminate between a camel which is asleep and a camel which is dead. Ground counts were difficult to do by vehicle, due to the large size of the study area. Therefore, ten transects have been driven every month with 500 m between each, in an area of 100 km^2 in sector 4, to count the number of camps, total number of domestic ungulates and carcasses. These counts started in July 1993 with the locating of the start and end points for each transect being determined using a global positioning system receiver (SONY- PYXIS). This system was used also to keep me on the transect line and to give the exact location for the camps and the dead ungulates found in the transect.

These were rechecked in subsequent months and the overall survey continued for seven seasons until February 1995.

Ministry of Agriculture reports (Khurmah branch), which cover the entire study area, were found to be unsuitable because they gave the number of animals vaccinated and thus the same animal could be reported more than once. However, another report from the Ministry of Agriculture (head quarter, Riyadh) was available presenting the number of livestock in all regions of the kingdom. It is not known how the statistics contained in this report were obtained.

3.2.2 Husbandry practices of pastoral agriculture

The above three methods were used to determine husbandry practices in the study area. During aerial surveys, camps in the study area were located in each season to investigate the seasonal movement patterns of animals. Camp locations were plotted on a habitat map using computer package Freelance (2.0. version). The size of each sector and the area of each of the different habitats were assessed by taking a map and cutting out each area and weighing the paper fragment with four decimal point balance (Sauter R 1614).

One hundred and sixty shepherds and farmers were interviewed to determine their daily work schedule and to determine their normal practices when sick or dead animals were found. Finally, in the ground survey, camps were located and the distances of livestock from the nearest camp were recorded; furthermore, changes in the number of camps with season were also recorded.

3.2.3 Rate of mortality and the cause of death

Three methods were used to determine the mortality rate and cause of death in domestic ungulates, questionnaires, ground survey and the Ministry of Agriculture reports.

Firstly, during interviews with the local shepherds and farmers, the numbers of dead animals in one month were recorded on the questionnaires. These interviews were made in two separate months, the first was in March 1993 and the second in February 1994. For the people who were questioned in the Ministry of Agriculture, the cause of death was determined by the resident veterinarian. Secondly, numbers of dead animals were recorded during the ground survey (the ten transects covering 100 km² in sector 4) to determine the seasonal variation in mortality and thus potential food available to scavenging birds. Lastly, in monthly Ministry of Agriculture reports, the main diseases causing death in the livestock were identified.

3.2.4 Crop size of lappet-faced vultures in the reserve

The crop sizes of birds in and around the roosting sites were examined in the evening to indicate how much food they had been able to obtain.. A study of a captive group of Rüppell's griffon vulture *Gyps rueppellii* classified the crop sizes into six categories as a result of the amount of food they had eaten (Houston 1976b). However, in this study it was difficult to approach birds closely, so crop size was divided into only three categories: full crop (1200g to 1500g + of food), medium crop (800 to 1000g) and no crop bulge visible or flat crop (0 to 400g). These observations were made 1-3 times a month and continued over five seasons (from September 1993 to November1994).

3.3 Results

3.3.1 Numbers and mortality rates of wild ungulates in the reserve

The reintroduction of Arabian oryx and sand gazelles at Mahazat as Sayd reserve was initiated in early 1989. Originally nine Arabian oryx were translocated to the area from the USA. Additional translocations and natural reproduction brought the estimated size of the population to 170 Arabian oryx by December 1994 (Smith and Ismail 1995). An estimate of the number of sand gazelles in the reserve in late 1994 was 300 (Haque and Smith 1995; Rangers pers. comm.).

As mentioned earlier, mortality in these wild ungulates was very low, e.g. only eight Arabian oryx adults and five young have been found dead in the last five years (Smith and Ismail 1995), of which four were eaten by vultures and the remainder collected for post-mortem examination. Mortality of sand gazelles was difficult to determine due to their small size and the large area over which they ranged, however during the last five years there have been only four identfied gazelle carcasses which were available for scavengers in the reserve. We can therefore conclude that the wild ungulate community provides a negligible amount of food for scavenging animals.

3.3.2 Size of the livestock population in the study area

1- Aerial survey

Table (3.1) shows the results of the aerial counts made of the whole study area in each of the four seasons in 1993. Counts were made of the number of camps, dividing these into four size categories (see the method). Table 3.2 shows the mean number of sheep and goats associated with each of these four camp sites, based on my randomly selected ground visits to a sample of 29 camps and farms. The mean figures given in table 3.2 have been used to convert the count of camp numbers in table 3.1 to estimates of the total number of sheep and goats. The results of aerial surveys showed that there were a mean of 186 sheep and goats (93 sheep and 93 goats) for each camp in the four seasons, with an average of 85,918 sheep and goats in the whole study area. The aerial survey showed that there were in addition 400 farms found in the study area, 103 in sector 1 and 297 in sector 4. As the farms were all categorised as small size (60 sheep and goats), therefore, the total number of sheep and goats associated with farms and camps combined was estimated as 109,918. Table 3.3 shows the total number of sheep and goats in different seasons in the whole of the study area, for both camps and farms giving a mean density of 6.3 animals per km^2, and 21500 camels giving a mean density of 1.24 per km^2 animals.

We might expect there to be changes in the size of domestic animal herds with season. For example, small herds might be merged together to make a smaller number of large herds during the summer, to economise on the number of feeding and watering sites that need to be provided. There was a highly significant difference in the size distribution of flocks with season ("Small" $X^2 = 18.39$, df =3, P<0.001; "Medium" $X^2 = 193.93$, df=3, P<0.001; "Large" $X^2 = 119.86$, df=3, P<0.001; "Very Large" $X^2 = 257.51$, df=3, P<0.001). However, there was no significant diferences between the total number of camps in the four seasons ($X^2 = 5.42$, df = 3, P> 0.10), (Table 3.4).

Table 3.5 shows the number of camels in each of the four sectors in each season. Table 3.6 gives the density of sheep and goats in each sector in each seson, and table 3.7 density of camels. There were significant differences in the distribution of domestic animals between these sectors of the study area ("sheep & goat" Kruskal-Wallis test, H= 15.88. P<0.01. "camel" Kruskal-Wallis test, H= 14.12, P<0.01), using the multiple comparison test described by Siegel and Castellan (1988) showed that there was significantly more livestock in sector four than in sector two These differences are probably due to the balance of habitats within the four sectors, and a consideration of animal density in relation to habitat is presented later.

Table 3.8 shows the results of ground checking a randomly selected number of camps which had been allocated to one of the four size categories from the air . This was done to verity the accuracy of the aerial survey. It shows that there was no significant difference between the estimated number of animals in the camp and the number actually counted on the ground.

2- Ground counts

Between July 1993 and February 1995 a monthly series of ten transect counts were driven, covering an area of about 100km^2. The map in Figure 3.1 shows the location of the ground transects in the study area. The main purpose of these transects was to obtain data on the seasonal distribution of mortality among the domestic stock, and record the number of dead animals encountered each month and how long individual carcasses remained. However, all live animals were also counted on these transects for eight months only and table 3.9 gives the number of sheep, goats and camels encountered in each month.

The mean value of 593 sheep and goats per 100 km^2 gives a density of 5.9 per km^2, which is considerably less than the 9.5 per km^2 from the aerial count in the same sector. This could be due to failure to see all animals during the ground count, because sheep and goats forage in a dense herd which makes it difficult to count them precisely, and some animals can be hidden by vegetation or other animals. It is likely that a more accurate count of numbers can be obtained from the air. If the density from the ground counts were extrapolated to the whole study area it would suggest a total number of about 104,629.

The mean count of camels on the ground transects was 450 in 100 km^2 area, suggesting a density of 4.5 camels per km^2. This is higher than the density assessed from the aerial survey of 1.24 per km^2. It will be shown later that there are marked differences in animal density with habitat, and so counts from this one small site cannot be considered as representative of the whole study area. For example, the transect study area included part of Wadi Subay, where permanent water was available all year and camels moved to this wadi for drinking. It is likely, therefore, that the density of camels in this area was higher than that of the study area as a whole.

3- Questionnaires

Out of 160 shepherds and farmers interviewed, the mean number of goats reported was 99.63 (SD ±97.48) in each camp, however, the number of sheep was less than goats, with 50.04 (SD ±53.95) in each camp. At the farms the mean number of goats reported was 76.40 (SD±24.31), and the number of sheep was also less than goats in the farms with a mean of 23.79 (SD±23.69).

From the aerial survey there were 400 farms and 461 camps in the whole study area, and we combine these figures with the livestock figures given in the questionnaiers it gives 46300 goats in all camps and 30400 goats in farms, and the sheep number will be 23,000 sheep in camps and 9,200 in all farms. This gives an overall total of 108,900 sheep and goats in the study area (Table 3. 10). The mean number of camels associated with each camp was 35.02 (SD ±27), and 16.40 (SD ±24.31) for each farm, resulting in 16,520 camels in all camps and 6,400 in the farms. This gives a total of 22,920 camels for the study area, which is close to the number estimated from aerial survey (Table 3.10).

4- Ministry of Agriculture reports

The reports I received from the local Ministry of Agriculture office in Khurmah were unsuitable because they often include the same animals more than once. However, the Ministry of Agriculture in Riyadh published a report in 1990 showing that there were 1,105,344 sheep and goats in the Makkah region, in which the study area is located. Two methods probably were used to obtain this figure, (a) questionnaires (traditional) and (b) through the register of stock at the Ministry of Agriculture offices around the Kingdom. The questionnaires were issued by the Ministry of Agriculture offices. The register of stock is used by the Ministry to base the level of subsidy and veterinary support given to shepherds and farmers, and so there may be a temptation for farmers and shepherds to exagerate the number of animals. Therefore the accuracy of these reports is not known.

However, if we compare the size of the study area excluding the reserve (17,644 km²) with the size of the whole Makkah region which is 148,750 km², this means that the study area forms 12% of the total size of Makkah region, and this suggest that the study area might contian 132,641 animals (12% of 1,105,344). The average number of sheep and goats in the study area counted by the three methods (107,603) represent 9.7% of the herds in the whole Makkah region, although they occupy 12% of the region.

The number of camels estimated by the ground survey was very high compared with the aerial and questionnaires surveys. Also, there were no other published reports giving the number of camels to compare with my results. However, the total number of camels in the study area can be estimated from the three methods above, and is assumed to be the average number between the three methods the aerial, ground surveys and the questionnaire which was 41,207 (Table 3.10).

Mirreh (1989) stated that Saudi Arabia can support, sustainably on unprotected vegetation, 560,000 livestock units over all the rangeland of the country which represents 85% of the land area or 1.9 million km² of the total size (Allred 1968). This means that the carrying capacity of the study area outside the reserve should be around 5,200 LSU's, (LSU = Livestock Units; one LSU= one camel or ten sheep or ten goats). But the number of LSU's estimated in the study area was nine times the predicted carrying capacity of the land.

3.3.3 The husbandry practices of pastoral agriculture

1- Aerial survey

The camps were more concentrated in three sectors 1 & 3 and 4 (Fig. 3.2). This was apparently due to the need of local people to use the main tarmac roads to take their children to schools or to go to their jobs in towns and larger villages (Ad-Dosarri and Al Kalaf 1989). Moreover, the shepherds and farmers depended on subsidized barley for feeding their livestock, which was only available at the main distribution points located in cities and small towns. Additionally, the main water source comes from wells located in farms which were concentrated in Wadi Subay (sector 4), and an area north-west of the study area called Om-addom (sector 1), or from government stations in the towns.

In order to investigate whether there were differences in the distribution of livestock in the different habitats of the study area, I calculated animal density for each habitat type. Table 3.11 shows these results, together with the percentage of the total study area occupied by each habitat type. This shows that the distribution of livestock is not uniform over the study area. Some habitats have high concentrations, such as the cultivated areas which have water freely available and other food sources such as alfalfa. Others, like the mud-flat habitat, have no livestock or camps because there was no vegetation. Among the natural habitats, the open sandy gravel areas with large and small trees and the basalt larva areas also support most domestic ungulates and are the main areas for grazing the livestock from the farms and camps (Fig 3.2).

Finally, the majority of camps (99%) seen from the aircraft had a water truck, and as a result shepherds did not need to roam around as much as in previous years looking for grass and water. A survey in 1978 recorded eight trucks, including water-tankers, for every 10 Bedouin tents (Duba and Ellis 1978). As the lifestyle of the local people has changed in the last 20 years (Sebai 1985), they have become more dependent on towns and villages to get groceries, to go to hospital, or visit the veterinarian in the Ministry of

Agriculture where they can get medicine for their livestock. They consequently settle in or around the towns and villages. Virtually all livestock settlements now have stored water and this makes the movement of animals with seasons no longer necessary.

2- Questionnaire

The shepherds and farmers keep one or two rams with each 70 sheep or goats. The majority of camel owners keep no male in the herd and if they do they will keep only one whatever the size of the herd. Seventy percent of herd owners employed a shepherd to take care of their livestock, with an average salary of 750 SR/month. The shepherd moves a maximum of 5 km/day with sheep and goats for grazing. Camels move alone and it is very rare that shepherds accompany them as they need to move long distances, estimated at an average 30 km a day. However, all shepherds interviewed said that they do not move long distances and they keep each camp in one area until the place becomes dirty or they have problems with disease which forces them to move. The average distance a camp moved was 4 km from the previous location. Moreover, the majority of shepherds questioned mentioned that they take their children to schools in the towns and villages, which restricts them to camp near such towns (Fig. 3.3).

The average age of sheep and goats when sent for sale was 6 months whereas for camels it was one year. The average prices of livestock were 350 SR for goat (93$, 58£), 600 SR for sheep (160$, 100£), and 1,500 SR for a one year old camel (400$, 250 £). Most of the herd owners take their sick animals to a veterinary clinic in the local Ministry of Agriculture where services and medicine are free of charge (if it is available), otherwise they will take a prescription to a veterinary pharmacy where they have to pay. Most of the shepherds and farmers interviewed said that they dispose of dead animals by throwing them away about 1-2 km from the camp. Very few reported burial or burning of carcasses. The method of carcass disposal therefore provides a good source of food for vultures (Fig 3.4).

3- Ground survey

During the ground survey the distance between the herds and the nearest camps or farms was estimated. The maximum distance sheep and goats were located away from their base was 2km. With respect to camels, it was difficult to estimate the distance by this method as they moved long distances and so it was not clear to which camp any camel belonged. The majority of camps had not moved during the ground survey period. However, there were some abandoned camps where a shepherd had moved a short distance (200-3000m) from the original location before the ground survey period began.

3.3.4 Mortality rates and causes of death in the domestic ungulates.

1- Questionnaire

Interviews with local shepherds and farmers gave a mean value of 4 (SD= $\pm$3.05) goats, 1.38 (SD $\pm$1.1) sheep, and 0.078 (SD $\pm$0.05) camels which died every month in each camp; in farms the corresponding figures were 0.2 sheep (SD $\pm$0.3), 0.8 goats (SD $\pm$ 0.5) and 0.01 camels (SD $\pm$ 0.02). According to Al-Nafie (1989) the average weight of a camel is 500 kg, that of the sheep and goats 10 kg. The resulting estimate for the biomass of animals dying in the study area is shown in Table 3.12 as 570,404 kg per year with an average of 1563 kg per day. 91% of these people mentioned that they throw the carcasses away in the open desert, where they would be available to scavenging animals and we can therefore conclude that domestic livestock provide a potential food supply of around 1422 kg per day for vultures.

Interviews with veterinary officers and farmers at the Ministry of Agriculture showed that there were several potentially fatal diseases that occurred in livestock in the area: Pasteurellosis, Caprine Pleuropneumonia (contagious), Enterotoxemia, foot and mouth disease, Brucellosis, Septicemia and P.P.L.O. Brucellosis and foot and mouth disease are spreading quickly among domestic ungulates. Reports from Office International Des

'Epizooties in France showed that foot and mouth disease is endemic throughout Saudi Arabia. The Ministry of Agriculture in Riyadh recently reported a new type of foot and mouth virus and sent letters to all its branches around the Kingdom to vaccinate livestock against this disease. However, the vaccine is not available in most of the Ministry of Agriculture branches.

2- Ground survey

Table 3.13 shows the mean number of fresh carcasses counted on the 100 km^2 ground transects each season. These counts only include animals which had died since the previous transect count. The location of each carcass was recorded, and some remained for many months. If we assume the number of live animals recorded on the transect counts to be correct for this part of the study area, we can calculate the percentage mortality for each species.

Mortality rates in domestic herds were high and ensured that sufficient food was available for scavengers in the area. Absolute food availability increased during the period of the study (Fig. 3.5). However, in the winter of 1994-1995 there was a fall in the amount of food available to scavengers. The annual estimate of food available to scavengers in the first year over the whole study area was 322,200 kg. But in the second year the amount of food estimated was four times the previous year (1,374,930 kg). This means that the average annual food availability for scavengers deduced from by the ground survey was 848,565 kg, but there is clearly great seasonal and annual variation.

The weight of carcasses as a percentage of the livestock biomass was low, although the mortality of livestock apparently increased during the study period (Table 3.14). The mortality of camels increased in 1994 (Fig. 3.6). However, it will be shown later that the lappet-faced vultures were only able to utilize the soft tissue in the head, part of the neck and some of the belly of a camel, whereas sheep and goats were consumed in entirety.

3- Ministry of Agriculture

- Cause of death

The Ministry of Agriculture reported 127 cases from March 1993 to February 1994. With the help of the veterinarian in the clinic I divided the reported diseases into two groups fatal and non-fatal. (Table 3.15): the first group causing mortality among the livestock was also subdivided (I) diseases causing rapid death such as foot and moth disease, brucella, rabies, entrictoxamia and chronic inflammation of the lung; (II) diseases causing death more slowly for example, bronchitis and Q- fever. The second group of diseases were those not fatal to livestock e.g. mostly skin infections and other minor ailments. The cause of mortality in livestock is often difficult to determine as it needed a separate post-mortem study involving a team of veterinarians. However, the data presented at the Ministry of Agriculture reports at Khurmah suggests that viral diseases and poor-nutrition (10%) are the main factors causing mortality in domestic ungulates in the study area.

In conclusion, the annual food available for scavengers was estimated as the average of both the questionnaires and ground surveys, which was 709,485kg. Mortality in livestock resulted from disease and no records of mortality due directly to starvation were recorded.

3.3.5 Crop size of lappet-faced vultures roosting in the reserve

The proportion of birds which are able to fill their crop each day is an indication of availability of food. The results of the observations of the crops sizes showed that there was no evidence of food shortage in the study area (Fig. 3.7). It was rare to encounter a bird without food in the crop. The maximum number of lappet-faced vultures recorded in the reserve was 162 individual (Newton and Shobrak 1993), outside the breeding season. The annual food requirements of the lappet-faced vulture population using the area could be estimated, if we assumed that each bird requires one kg per day (medium crop). Overall, this means that the birds using the reserve require approximately 59,130 kg annually.

3.4 Discussion

3.4.1 Livestock population

It is apparent from the data presented above that the number of livestock in the study area was very high and this could be related to several factors. Firstly, a government subsidy, which started in the late 1950's (Shamekh 1975; Child and Grainger 1990), as a result of a drought in northern and eastern Saudi Arabia. The overall estimate of the destruction in perennial grasses and shrubs during that period was 70 to 80% (Kingery 1971). An animal subsidy scheme was instituted at that time and continued until 1980, to encourage the bedouins to rebuild their herds. Animal numbers increased rapidly before the "stressed" rangeland had had a chance to recover.

In addition, a subsidized feed program was introduced. Supplementary feed in the form of imported barley was used to support the range animals. In 1984 Saudi Arabia imported 5.7 million tonnes of barley and sold it to stock owners at less than 50% of its import cost (Child and Grainger 1990).

Secondly, many changes have occurred in the Bedouin's lifestyle as they started to settle near towns and small villages to generally improve their economic situation. They started to obtain jobs in government departments or learn new trades or start arable farming in or near towns. But animal husbandry remained a significant source of income. Surveys in the early 1980's indicated that 60% of small stock owners were now settled, semi-settled or practice only short range nomadism (Child and Grainger 1990). The Saudi Arabian government deliberately encouraged nomads to settle during the 1950's (Shamekh

1975). The proportion of settled stock raisers is probably now even greater (Ad-dosari and Al Kalaf 1989).

The above factors have led to an increase in the number of domestic ungulates which has had a negative effect on ground cover. Based on experiments in wadi vegetation near al Jouf in northern Saudi Arabia (Mirreh 1989, citedd by Thouless *et al.* 1989) stocking of 1.3 LSU per km^2 in areas totally protected from grazing for two to three years was recommended and of 0.3 LSU's per km^2 where vegetation remained unprotected. In the study area there were 2.66 LSU's per km^2, which is nine times the expected carrying capacity of the area.

3.4.2 Livestock mortality

The increase in numbers of domestic ungulates has resulted in a higher food availability for scavengers due to the large numbers of dead animals. The apparent increase in livestock mortality in the study area could be related to several factors. First, the decline in natural vegetation and dependence on barley reduces the immunity of livestock against disease, (Fawzi pers. comm.). Moreover, shortage of food and above all water are major factors that reduce the population size of ungulates in arid areas (Grenot 1992).

In the study area the shortage of natural food was initially compensated for by the provision of subsidized barley. However, this resulted in high demand for this source of food, which led to an increase in barley prices in the market and also to a reduction in the quantity of barley allocated by the government to each shepherd, to ten bags for one person every 20 days. A typical herd utilized these ten bags in five days. So shepherds were faced with two possible ways to feed their livestock (a) to buy more barley from the open market, though the price can reach as much as three times the government price (17 SR) or (b) reduce the quantity given to each animal. The second option was the course most people followed. Furthermore, barley has a limited nutritive value and cannot replace natural vegetation which provides the animals with most of the vitamins and trace elements the animals need. There are some records of sheep dying due to the effects of eating too much barley; this could happen even in years when rainfall is reasonable (Child and Grainger 1990).

Second, the spread of diseases among livestock is greater when they gather around food troughs as they are forced to do when fed entirely on barley. There are about 10 diseases which cause livestock mortality in the study area, many of them highly contagious. However, the Ministry of Agriculture only can vaccinate animals and they are not permitted to destroy infected animals which can transfer disease to other animals in the herds.

The local Ministry of Agriculture office in Khurmah receives a poor supply of vaccine (Fawzi pers. comm.) and it is not sufficient to vaccinate all livestock in the area. Thus, disease can spread easily among herds. Additionally, some animals found in the area come from outside the Kingdom, and they could carry diseases which are not endemic to the region (Fawzi pers. comm.). Finally, some animals in the summer chew bones to replace salt lost during dehydration; if the carcass was that from an animal which had died from a disease such as Anthrax or Botulism spores can stay on the animal and transmit the disease.

3.4.3 The availability of food and the vultures requirements

It may be argued that in the conservation poit of view a food resource should well exceed the food requirements of a species or population to provide resource "insurance" for continued existence, reproduction, and recruitment of new individuals into the population (Drent and Daan 1980; Newton 1980; Newton and Marquiss 1986). However, in the study area there was a substantial excess of food for the scavengers. The amount lappet-faced vultures require annually (59.13 tonnes) was 12 fold less than the amount of food available for them.

In conclusion, the livestock population in the study area was estimated as nine times the predicted carrying capacity of the study area. Due to change in husbandry practices in the study area and the rapid disappearance of the natural vegetation and its replacement with subsidized barley, diseases have started to increase mortality rates in domestic ungulates. This increase represents a good source of food for avian scavengers in the area, especially the lappet-faced vulture. The estimated food availability greatly exceeded the food requirements of scavengers in the area.

Table 3.1 The number of livestock herds in the study area in 1993 in camp sites of differents size. Data from table 3.2 on mean number of sheep and goats per camp are used to derive animal numbers.

Seasons	Small	Medium	Large	very large	Unknown	Total
Spring	35	158	128	64	39	424
Summer	10	70	293	99	1	473
Autumn	14	24	178	239	1	456
Winter	26	17	95	335	19	492
Total camps	mean = 21.25 SD = $\pm$11.41	mean = 65.25 SD = $\pm$61.20	mean =173.5 SD = $\pm$86.67	mean = 184.25 SD = $\pm$125.77	46	mean =461.25 SD=$\pm$28.86
Mean No. of sheep and goat	1254	7765	30536	44220	2139	85918
Mean No. of camels	532	1683	4338	4608	289	11500

Table 3.2 Mean value for the number of sheep and goats counted at camp sites visited on the ground in the initial stage.

Type	Eatimated Mean	Std. Dev	No. of sample	95% Confidence interval
Small	59	2.12	2	± 19.1
Medium	119	21.51	4	± 34.24
Large	176	7.01	9	± 5.4
X-large	240	18.48	7	± 17.4
Farm	60.28	17.10	7	± 16.1

Table 3. 3 Number of sheep and goats in different seasons in the four sectors

	Sector 1	Sector 2	Sector 3	Sector 4	Total No.
Spring	31104	10802	24366	36792	103064
Summer	31662	13206	29760	37350	111978
Autumn	28500	11160	26784	42372	108816
Winter	35940	14322	22392	40512	113166
Mean	31801.5	12372.5	25825.5	39256.5	109918
St. Dev	3084	1741	3073	2645	4697

Table 3. 4 Number of camps in each sector by seasons

Seasons	Sector 1	Sector 2	Sector 3	Sector 4	Total
Spring	134	57	131	102	424
Summer	137	71	160	105	473
Autumn	120	60	144	132	456
Winter	160	77	128	122	492
Mean	137.75	66.25	140.75	115.25	461
St. Dev.	16.58	9.36	14.59	7.11	28.9

Table 3. 5 The Number of camels in different seasons in the four sectors

	Sector 1	Sector 2	Sector 3	Sector 4	Total No. of camels
Spring	5925	1425	3275	9975	20600
Summer	6000	1775	4000	10050	21825
Autumn	5575	1500	3600	10725	21400
Winter	6575	1925	3200	10475	22175
Mean of No. camels	6019	1656	3519	10306	21500
St. Dev.	415	234	365	356	679

Table 3. 6 Density of sheep and goats per km² in different seasons in the four sectors

	Sector 1	Sector 2	Sector 3	Sector 4	Total mean
Spring	6.8	2.4	5.8	8.9	6.0
Summer	6.9	3	7.1	9	6.5
Autumn	6.2	2.6	6.4	10.2	6.3
Winter	7.8	3.3	5.7	9.8	6.7
Mean	6.925	2.825	6.250	9.475	6.3
St.Dev	0.660	0.403	0.645	0.629	0.299

Table 3.7 Density of camels per km² in different seasons in the four sectors

	Sector 1	Sector 2	Sector 3	Sector 4	Total Density
Spring	1.3	0.32	0.8	2.3	1.18
Summer	1.3	0.4	0.9	2.4	1.26
Autumn	1.2	0.34	0.8	2.6	1.25
Winter	1.4	0.43	0.75	2.5	1.3
Mean Density	1.3	0.37	0.81	2.45	1.24
St. Dev.	0.0816	0.0512	0.0629	0.1291	0.0492

Table 3.8 The number of sheep and goats counted by ground visits in a randomly selected group of camps.

Camp category	Small	Medium	Large	X-Large
	63	79	150	225
	48	100	160	170
	50	81	215	202
	55	120	225	250
	71	95	160	264
Actual mean (Std. Dev)	57.40 (SD=9.56)	95 (SD= 16.60)	182 (SD= 35.11)	222.20 (SD= 37.62)
95% confidencce interval	±11.85	± 20.54	± 43.51	± 46.6

Table 3.9 The number of domestic animals counted during the ground counts covering 100km^2

Month	Sheep & Goat	Camel
July 1993	642	420
August	674	511
September	766	501
December	601	505
January 1994	614	621
February	471	331
March	541	420
April	435	395
Mean Value	593	447.5
Std. Dev.	108.20	76.79

Table 3.10 Summaries of the resultes of livestock estimates from the three methods

Type	Aerial survey	Ground count	Questionnair Survey	Ministry of Agriculture	Overall estimate
Sheep & Goat	109,281	104,629	108,900	132,641	107,603
Camel	21,500	79,200	22,920	------	41,207

Table 3.11 The distribution of sheep and goats in different habitats in the study area, based on aerial survey

Habitat type	Size (km^2)	Percentage of the total area	No. Sheep & Goat	Density of Sheep & Goat per km^2	No. of Camel	Density of Camel per km^2
Basalts lava area (harrat)	2362	13.4	13020	5.5	1750	0.7
Mud-flat (subkkah)	466	2.6	0	0	0	0
Sand-dune	83	0.4	372	4.5	50	0.6
Open sandy gravel plain with bushes	7082	40.1	33208	4.7	4500	0.6
Open sandy gravel plain with trees	7558	43	39418	5.2	6950	1
Cultivated	93	0.5	24000	259	10000	108

Table 3. 12 The daily spatial availability of all livestock carcasses (kg per day) in different seasons as suggested by the questionnaire results.

Season	Sector 1	Sector 2	Sector 3	Sector 4	Total kg/day
Spring 93	446	167	390	453	1456
Summer	457	212	471	458	1598
Autumn	406	178	428	541	1553
Winter 93-94	529	228	379	508	1644
Mean	459.5	196.2	417	490	1562.8
St. Dev.	51.3	28.5	4.7	42.1	80.3

Table 3.13 Number of fresh carcasses counted on the 100 km² ground transects (* indicates the number of young animals). All seasonal counts are based on three transects except for the Autumn of 1993 where only one transect was under taken.

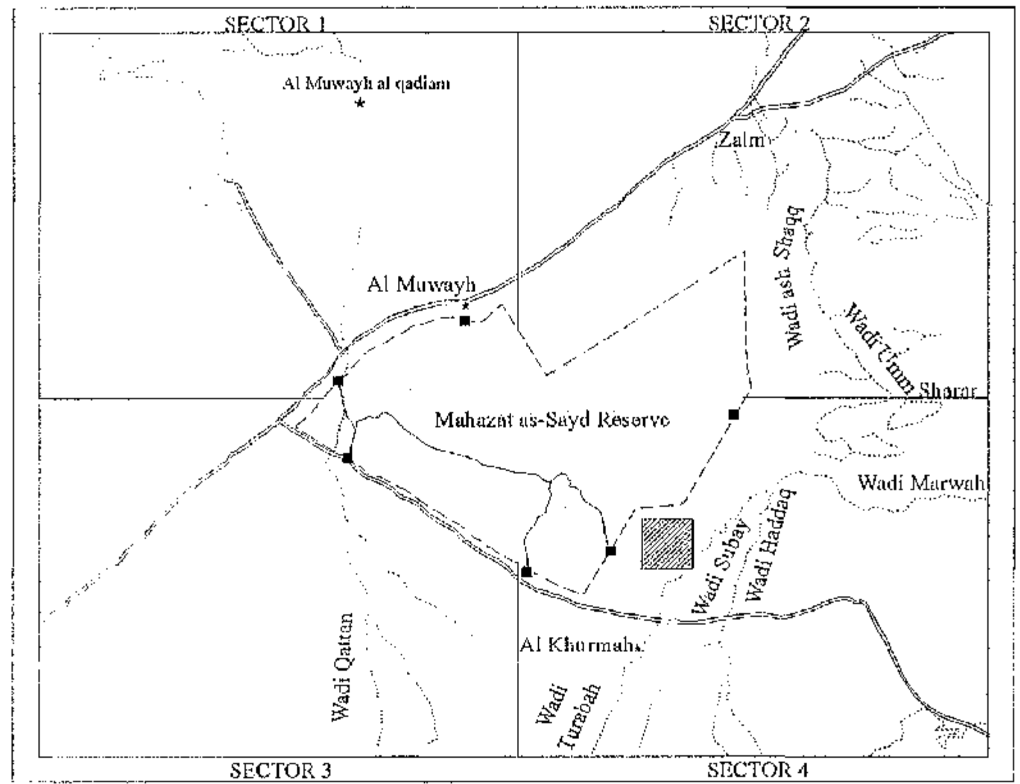
Season	No. of Sheep (mean)	No. of Goat (mean)	No. Camel (mean)	No.Other
Summer 1993	3 (1.5) SD=+0.71	1 (0.5) SD=+0.5	0	0
Autumn (Sep.)	3	0	0	0
Winter 1993-94	2 (0.67) SD=+0.58	15 (4.67) SD=+4.04	3^{*2} (0.67) SD=+0.58	1 dog
Spring 1994	7(2.3) SD=+3.21	18 (6) SD=+2	2^{*1} (1.33) SD=+1.5	1 cow
Summer	3 (1) SD=+1	27 (9) SD=+2.65	4^{*1} (1.33) SD=+1.53	0
Autumn	8 (2.67) SD=+0.58	26 (8.67) SD=+2.31	10^{*4} (3.33) SD=+2.08	0
Winter 1994-95	10 (3.33) SD=+1.53	20 (6.67) SD=+2.52	13^{*10} (4.33) SD=+1.15	0

Tble 3.14 Carcass weight as percentage of livestock biomass by season

Species	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Camel	0	0	0.8	0.5	2.5	5.6	2.9
Sheep & goat	1.6	3.71	4.6	5.8	6.9	6.9	4.7

Table 3.15 Summary of Ministry of Agriculture reports from 1993-94 showing the percentage occurrence of diseases causing mortality in the livestock in the study area

Month	Causing rapid death (acute)	Causing eventual death (chronic)	Curable ailments	Total No. of consultations
March 93	33.7	14.0	52.3	306
April 93	40.5	9.0	50.5	357
May 93	37.8	11.1	51.1	354
June 93	29.3	3.1	67.6	259
July 93	33.4	13.0	53.0	179
August 93	28.0	4.0	68.0	50
September 93	35.5	7.3	57.2	245
October 93	48.1	13.1	38.8	183
November 93	44.0	8.2	47.0	301
December 93	75.9	11.6	12.5	311
January 94	38.6	9.1	52.3	44
February 94	55.5	14.3	30.2	128
Mean	41.7	9.8	48.4	–



The area of the ground census transects

Figure 3.1 The area in which 10 transects were made for the ground census.

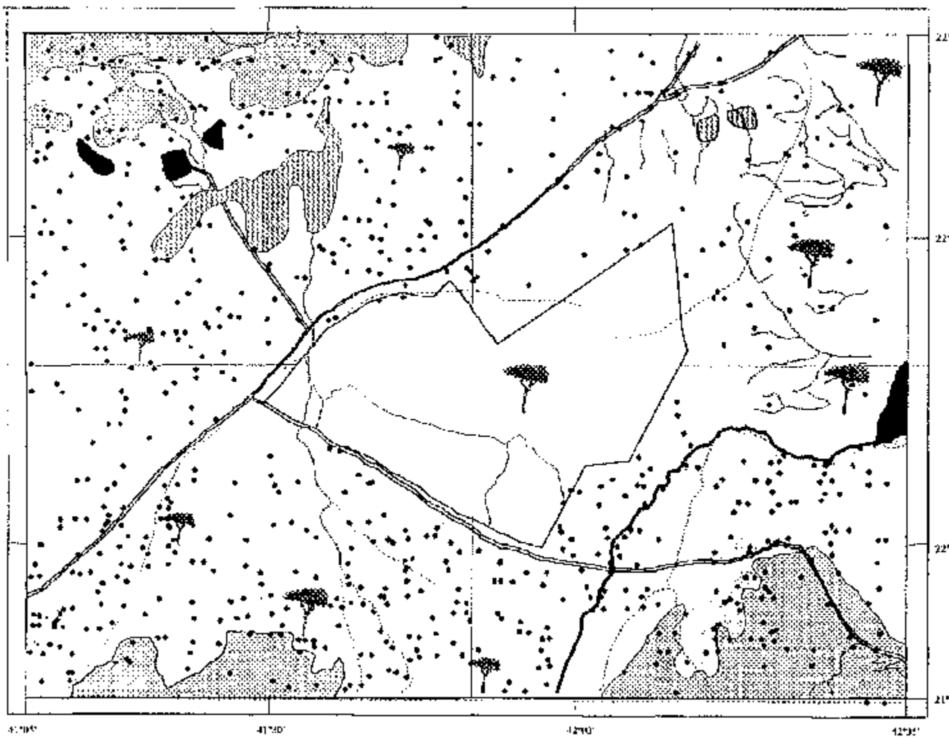


Figure 3.2 The distribution of camps in the different habitats (Spring)

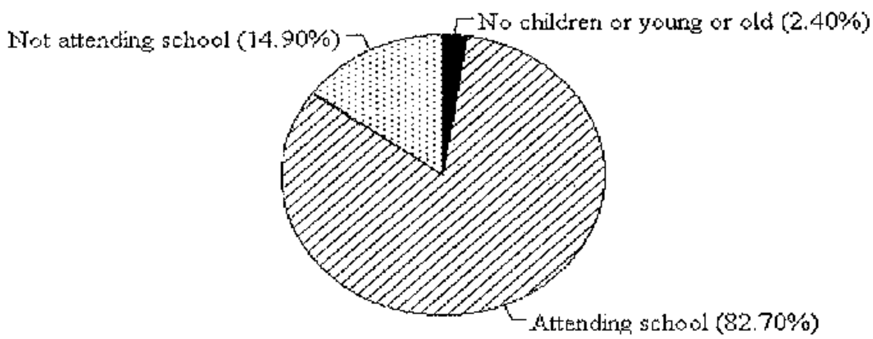


Figure 3.3 Percentage of children attending school in the study area

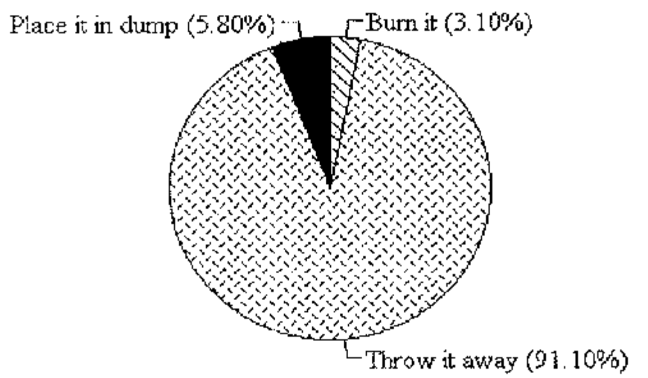


Figure 3.4 Methods of disposal of dead animal reported by shepherds and farmers

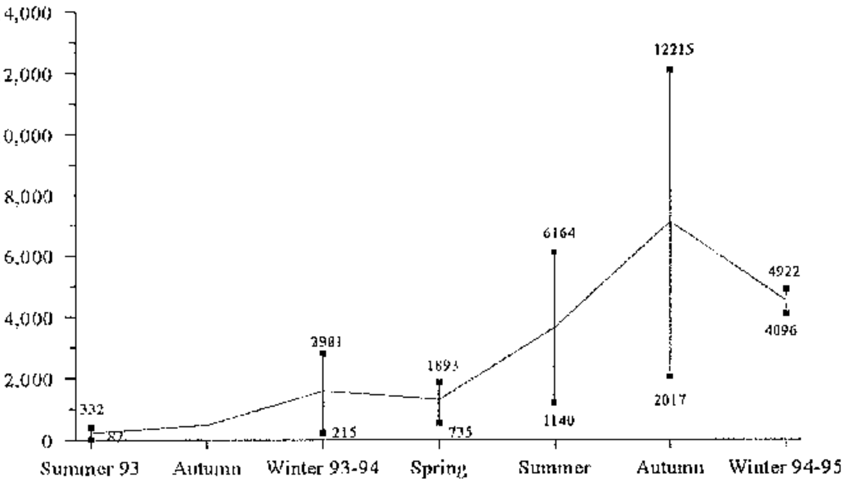


Figure 3.5 The availability of food per day for scavengers in the study area (vertical bars indicate standard deviation)

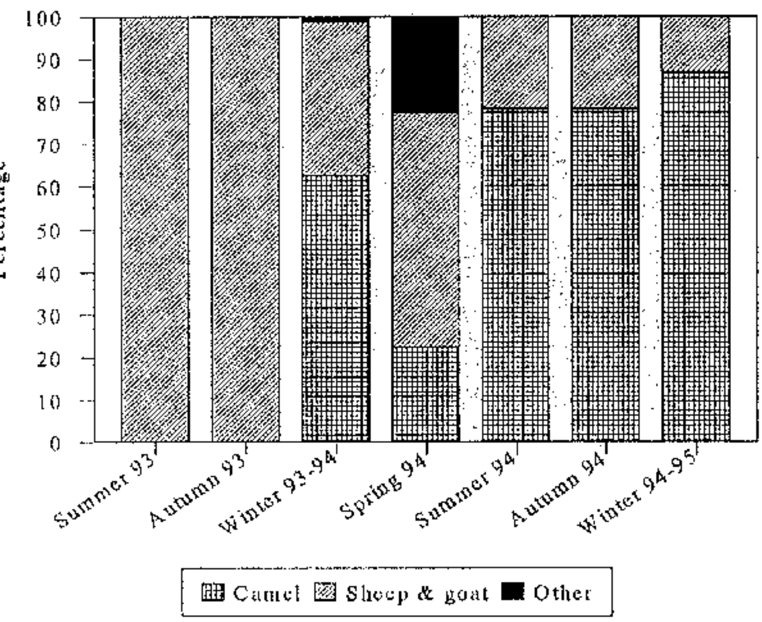


Figure 3. 6 Type of carcasses available to scavengers in the study area (other indicate to the one dog & one cow)

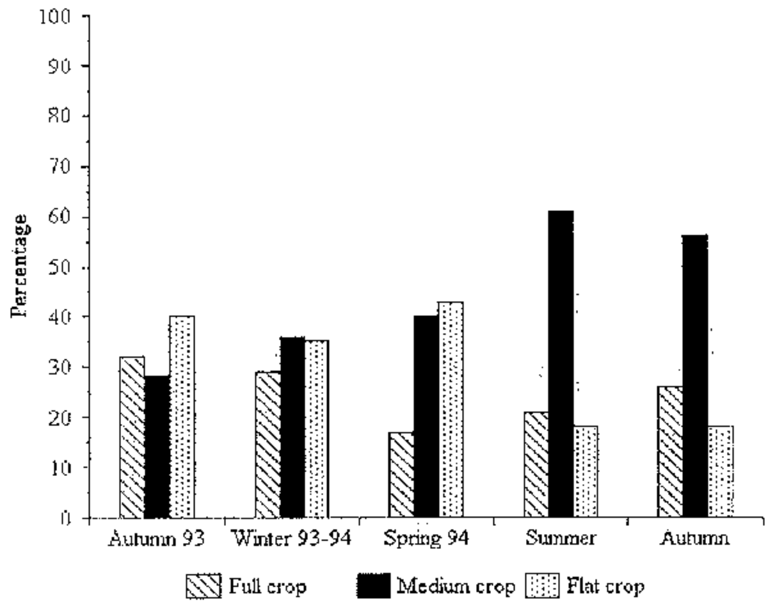
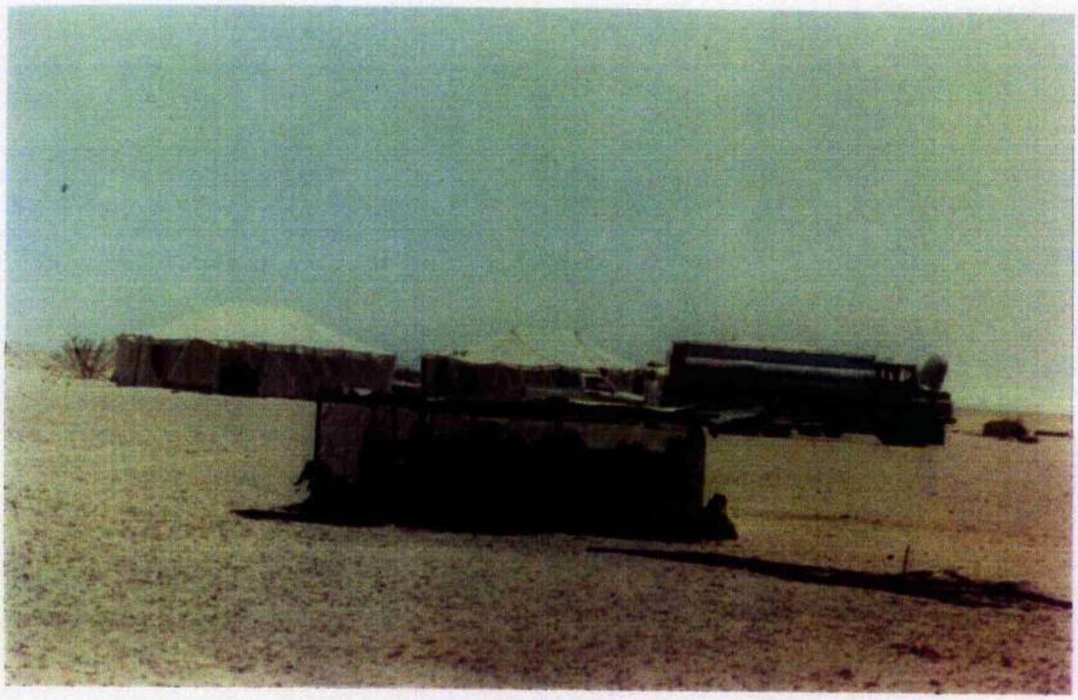


Figure 3.7 Variation in crop size of the lappet-faced vultures in the reserve



Photograph 3.1. A typical camp, which is characterized by the tents, a mobile water truck, and temporary livestock shelters.

Chapter 4. Food selection

4.1 Introduction

Early work on diets of birds of prey was based largely on post-mortem analysis of stomach contents (Fisher 1893, McAtee 1935, Arnold 1954). More recently, investigations have concentrated research efforts on assessing the food habits of free-living raptors. The vast majority of these studies depended on interpretation of pellet and prey remains collected at nests and roost sites (Craighead and Craighead 1956, Smith and Murphy 1973). Studies of vulture pellets from nests and roost sites, and also studies from analysis of stomach contents, have shown that they take meat from carcasses of large ungulates that they could not have killed themselves, and they are therefore scavengers from carrion. The exception is the palmnut vulture, which feeds predominantly on oil palm fruits (Houston 1976a, 1979, Mundy *et al.* 1992).

Analysis of pellets and the remains of food found in African lappet-faced vultures' nests suggests that in this species predation on small animals occasionally occurs (Mundy *et al.* 1992). They have also been known to raid flamingo colonies to kill adults and young and eat eggs (Brown *et al.* 1982), and there are also records of them eating locusts, termites and eggs of terrapins (Cramp and Simmons 1980). Mendelssohn (1972) suggested that the decline of the lappet-faced vulture in Israel was due to its feeding on rodents poisoned by thallium for agricultural purposes. Moreover, some pellets which had been collected from nests and roost sites of *negevensis* lappet-faced vultures contained spiny-tailed lizards which had probably been killed by the birds (Mundy *et al.* 1992). This is also recorded for birds in Saudi Arabia (Newton and Shobrok 1993)

The remains in pellets are not totally representative of the actual diet of the vultures, because much of the soft tissue and bones of small prey such as lizards, small mammals, and insects will be digested. The remains present in pellets show the items which the birds cannot digest, such as hair, large bones and other indigestible items. However, analysis of pellets and food remains brought to the nestling in the nest could help further our understanding of the lappet-faced vulture diet.

This chapter sets out to investigate some aspects of the diet of the lappet-faced vulture at Mahazat as-Sayd reserve in Saudi Arabia. The aims of the study were: firstly, to consider whether or not the bird acts as a predator; and secondly, to relate prey items selected by the birds to the range of prey species available within the foraging area.

4.2 Material and Methods

Three nests and two quadrats, each measuring 50 x 50 m ($2500m^2$), in a roosting area used by non breeding birds were selected for collecting pellets. In total approximately 1245 pellets were collected. After clearing the site in March 1993, collections were made on a monthly basis, and continued until early autumn 1993. The collection made in early March represented the winter period. However, collections were stopped in October 1993 as it proved very time consuming to analyze them. Additionally pellets were collected from in and around three active nests in July 1992 and in January and February 1993.

Two methods were used to identify hair and the other items in the pellets: direct determination and microscopic identification. In the former, identification of items other than hair, such as barley, was straight-forward. Hair samples could often be identified by their colour and texture, and to aid identification I collected hair from most of the mammals in the study area and compared them with samples in the pellets. With regard to microscopic identification, it is known that hair can play an important role in mammalian taxonomy and mammalian species can readily be identified by hair samples (Hausman 1930). Hair samples were mounted after treatment with detergent and hot water for five to ten minutes to clean them of all dirt, air dried thoroughly before passing them through Ether and Xylol for three to five minutes each. This method was based on methods used to identify hair of some Indian mammals (Koppikar *et al.* 1975). In total 257 specimens which had been difficult to identify directly were mounted and examined under a light microscope; they were then compared with slides made from the hair of the mammals present in the study area.

Under the microscope the colour, cuticle surface, medulla and the shape of the scales in the medulla were observed. These were most clear in the small mammals such as *Gerbillus nanus,* whereas in large mammals (sheep, goat, camel etc.), the hair surface (cuticle) was checked, but the medulla was difficult to see due to the thickness and the heavy dirt often present on it, and observations were limited to the scales in the medulla. However, to solve the problem of dirt on the samples I consulted Dr. El Gohary at King Abdulaziz University (Jeddah, Saudi Arabia), who has studied mammal hair under the electron microscope. He suggested cleaning the hair ultrasonically for 15 seconds to give better results or to clean the sample for a longer time with the detergents. Ultrasonic apparatus was not available and consequently I cleaned the specimens for longer time periods with detergent and hot water. Also, the slides were compared with photomicrographs for different hairs taken under the electron microscope (Mahmoud 1992).

4. 3 Results

The lappet-faced vulture pellets were variable in size and shape. The majority of pellets were the size of a tennis ball with an oval shape. The measurements of pellets are presented in Table 4.1.

Under the light microscope there were differences between the hair structure of mammal species. Hair morphology could vary between the three basic regions of each hair fibre namely proximal, median and distal. I used the median region for identification, because complete hairs were rare. A problem found in quantifying the hair types during the analysis was the widespread occurrence of sand inside the pellets. In December 1993, a two month old camel was found as a fresh carcass and was visited, but one week after its discovery it was buried under sand following a storm. Birds feeding on such a carcass would probably swallow sand accidentally. Vultures were often observed eating from carcasses partly covered by sand, caused by sand storms which are very common in the study area. Sand was also found in fresh pellets. Therefore, pellet weights include an unknown amount of sand in some cases, and are an unreliable indicator of the amount of food eaten from different species.

The observed differences between sheep and goat hairs were that the sheep hair was thicker than that of goats. The margins between cuticular scales in sheep were larger than the margins in goats under the microscope (Photograph 4.1). The colour of belly hair in goat was reddish black, but in sheep hair was yellow red. Moreover, the hair stems in goat are more curved and slightly wavy and the medulla was fragmented and easy to see. By contrast the medulla of sheep hairs was difficult to see. The scales of the medulla of sheep hairs were oval in the middle and elongated at the side. The scales in the medulla of goat hairs were elongated.

Camel hair was recognized visually by the colour, size, and thickness. The colour was brown to black brown, and they were smaller, thinner and smoother than both sheep and goat hairs. Under the microscope the camel's hair was identified by large spaces between the scales along the hair shaft (Photograph. 4.2). Moreover, the cuticle was imprecate type, and scales in the medulla were elongated and had serrated margins with a narrow space in between. The medulla was smaller in the proximal and larger in the medial regions, and overall was smaller than in both sheep and goats. Camel hair colour under the microscope was white to yellow.

The hair of other species of mammals were distinct under the microscope, for example, the cuticle in oryx and sand gazelles was elongate and flattened. Also the medulla scales in the sand gazelle were a mushroom shape, whereas in oryx it was a flat ellipse. Moreover, the scale margins in the sand gazelles were thicker than those of the oryx and had jagged edges (Photograph 4.3). Finally the colour of the hair in the gazelles was blackish red, whereas in the oryx it was whitish yellow. Red fox hair was thinner than the Rüeppell's fox hair and the colour of the former was more reddish black, in contrast to the Rüeppell's fox which had a yellowish hair. Moreover, the space between medulla scales in the red fox hair were larger than those in the Rüeppell's fox.

The previous chapter showed that the number of livestock in the study area was high and the mortality rate among the domestic ungulates was also high. The results of the pellet analysis shows that domestic stock are the major source of food in the study area. Out of 1245 pellets analyzed, sheep and goat hair occurred most commonly (Table 4.2). Unfortunately there is no accurate data on the proportion of sheep and goats in the livestock herds, although the questionnaire results suggested that goats are probably slightly more numerous. At nest sites, significantly more pellets were found containing goat hair than pellets consisting of sheep hair only ($G = 10.72$, $df = 1$, $P < 0.005$). But at the roost site, there was no significant difference between the frequency of goat hair and sheep hair in the pellets (G. test = 1.86, $df = 1$, $P > 0.05$). Furthermore, the percentage of pellets containing only sheep hair or only goat hair at the nest sites and roost site were not different ("sheep hair" $Z = -0.065$, $P > 0.05$; "goat hair" $Z = 1.464$). In these analyses the number of pellets used were those consisting only of sheep hair or goat hair. The pellets with mixtures of hair of the two species were excluded because their percentage occurrence was very low, and it was difficult to determine the exact percentage of hair from each species in the pellets. Camel hair was found in 5.95% of the pellets analyzed (Table 4.3), and the percentage of pellets containing only camel hair at the nest sites and the roost site was also not different ($Z = -1.785$, $P > 0.05$).

Both spiny-tailed lizards *Uromastyx aegyptius* and rodent remains were seen in a small proportion of pellets. On two occasions lappet-faced vulture tracks (foot prints) and pellets with spiny-tailed lizard remains were seen near a *Uromastyx* burrow. *Uromastyx* remains were observed in the pellets during April, May and June; rodents were observed only in April.

The number of pellets at nest sites with spiny-tailed lizard remains were significant greater than the number of pellets which had rodent remains ($G = 4.81$, $P < 0.05$). There were no significant differences between the number of pellets with spiny-tailed lizard and rodents at the roost sites (G. test = 2.67, $P > 0.10$). The percentage occurrence of spiny-tailed lizard remains in the pellets at the nest was therefore higher than at the roost site (Table 4.3). Rodent remains occurred more frequently in the pellets collected at the roost site.

Other items occurring commonly in the pellets included barley (Table 4.4), sand and small stones. The claws found in the pellets probably belonged to spiny-tailed lizards, and feathers were from the bird itself (down feathers) swallowed while preening.

4.4 Discussion

4.4.1 Predation and seasonal variation in the lappet-faced vultures

The presence of small, or non-domestic livestock animals in the pellets could arise in two ways. Firstly the vultures may have caught and killed the live prey themselves or secondly, and more likely, the small animal carcasses were scavenged. Both rodents and spiny-tailed lizards use car tracks, and are sometimes hit by vehicles. It is unlikely that a lappet-faced vulture could catch a healthy rodent, but they might be able to catch live *Uromastyx*, as this animal stands motionless outside its burrow in the mid-day sunning itself, at a time when the vultures were active. The tracks of a lappet-faced vulture and remains of *Uromastyx* skin were seen near a spiny-tailed lizard burrow. Moreover, the time such remains were observed in the pellets was in the spring which coincided with the emergence of this lizard from hibernation (As-Sadoon *et al.* 1994). However these small animals died, it is clear that lappet-faced vultures sometimes feed on small food items. But these form a tiny proportion of food items, and so even if predation does occassionally occur it cannot make a substantial contribution to their diet.

The normal diet of many adult birds is often nutritionally unsuitable for the growth of their offspring (O'Connor 1975). This can occur in vultures, because the normal diet of adult birds consists of the soft tissues from large mammal carcasses, which does not contain sufficient calcium for the growth of chicks, and birds may need to seek calcium-rich food items during the breeding season (Houston 1978). Observations of lappet-faced vultures in Africa have shown that they feed from medium sized mammals, from which they can swallow bones and hence supply their chicks with the calcium they need (Houston 1978). They also have been recorded in Africa preying on other small live animals (Mundy *et al.* 1992).

By contrast, the lappet-faced vultures in the study area fed mainly on sheep and goat carcasses, and probably preyed on spiny-tailed lizard whenever they had the chance, because they provide a convenient source of calcium. Rodents are unlikely to have been caught directly by the lappet-faced vultures as they are mostly active at night. The vultures may find them as road kills in the morning when they themselves become active. These small carcasses may therefore be nutritionally important to breeding birds even if they are infrequent in the diet.

The increase of domestic ungulates and their higher mortality has given benefits to the scavengers, especially the lappet-faced vulture which takes advantage of the large number of domestic ungulate carcasses available in the study area. The availability of so much medium size carrion (sheep and goats) perhaps makes it unnecessery for the birds to prey on smaller animals to the extent that some birds in Africa seem to do.

4.4.2 The relationship between the prey items selected by lappet-faced vultures and the range of prey species within the foraging area.

The extinction of wild ungulates in the study area and the increase of domestic ungulates demonstrated in the previous chapter have had a detrimental effect on the native ground vegetation. Nearly all of the range land of the country is overgrazed to some extent or another; much of the land has succumbed to desertification (Child and Grainger 1990; Gasperetti 1994). Moreover, many previously undisturbed areas have become accessible to hunters due to the construction of new roads, and the availability of 4-wheel drive vehicles. These changes have resulted in the decline of wild ungulates such as gazelles and also in the small mammals which in the past the lappet-faced vulture may have preyed on. However, the lappet-faced vulture in the study area is now heavily reliant on domestic ungulate carcasses (sheep and goats) which are available all over the country. There was no evidence of any seasonal variation in the type of carcass used by lappet-faced vultures, but sheep and goats were selected more frequently than were the carcasses of camels. The previous chapter showed that numbers of sheep and goats combined were about three times greater in the study area than were the number of camels. There are many potential sources of bias in data from pellet analysis. For example, vultures are less likely to eat the skin from a camel carcasse, because they mostly only feed on the head and skin on the body is rarely eaten (Photograph 4.4), while with sheep and goats the whole skin is usually consumed. The frequency with which hair of camels, sheep and goats appears in pellets may therefore bear little relation to the proportion of carcasses visited. However, there is no evidence that vultures avoid any species of large mammal, and they probably visit any carcass that becomes available.

Table 4.1 Measurement of pellets for lappet-faced vulture

Measurement	Average	Standard deviation	Number of samples
Length	48.6 mm	19.5	115
Width	13.9 mm	10.4	115
Weight	10.6 g	11.8	92
Volume	33.9 ml³	17.8	30

Table 4.2 Percentage occurrence of food remains in Lappet-faced vulture pellets (n= 1245)

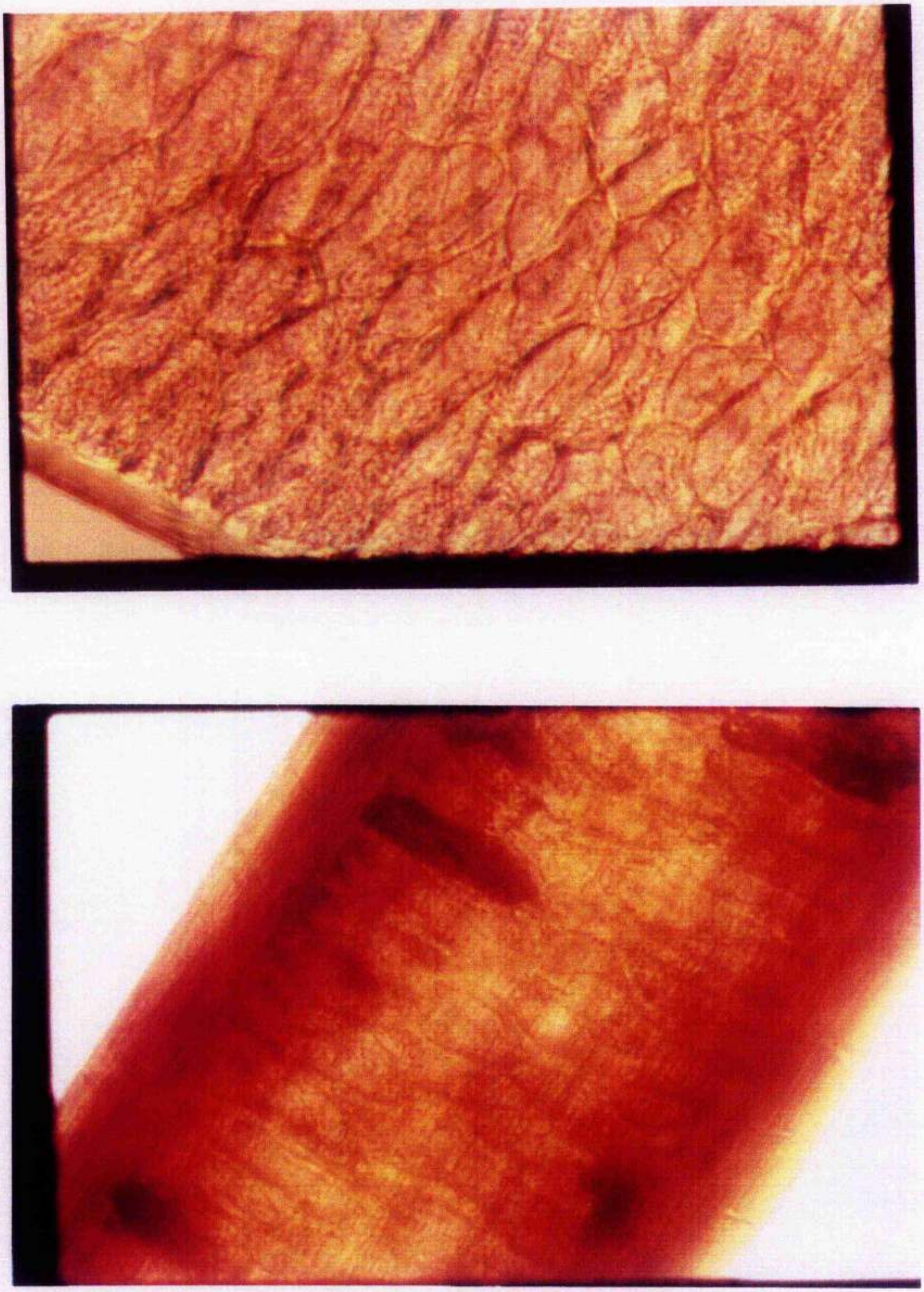
Species	Percentage	Species	Percentage
Sheep	36.68	Rodent and sheep	0.24
Goat	44.57	Rodent and goat	0.48
Sheep & goat	2.57	Cat & sheep	0.08
Camel	5.95	Dog & sheep	0.08
Camel & goat	1.36	Dog & sheep	0.08
Camel & sheep	1.04	*Uromastyx* and goat	1.00
Uromastyx and sheep	0.32	Unknown	5.55

Table 4.3 Percentage occurrence of food items in Lappet-faced vulture pellets (n = 1077) from nest sites and the roost site

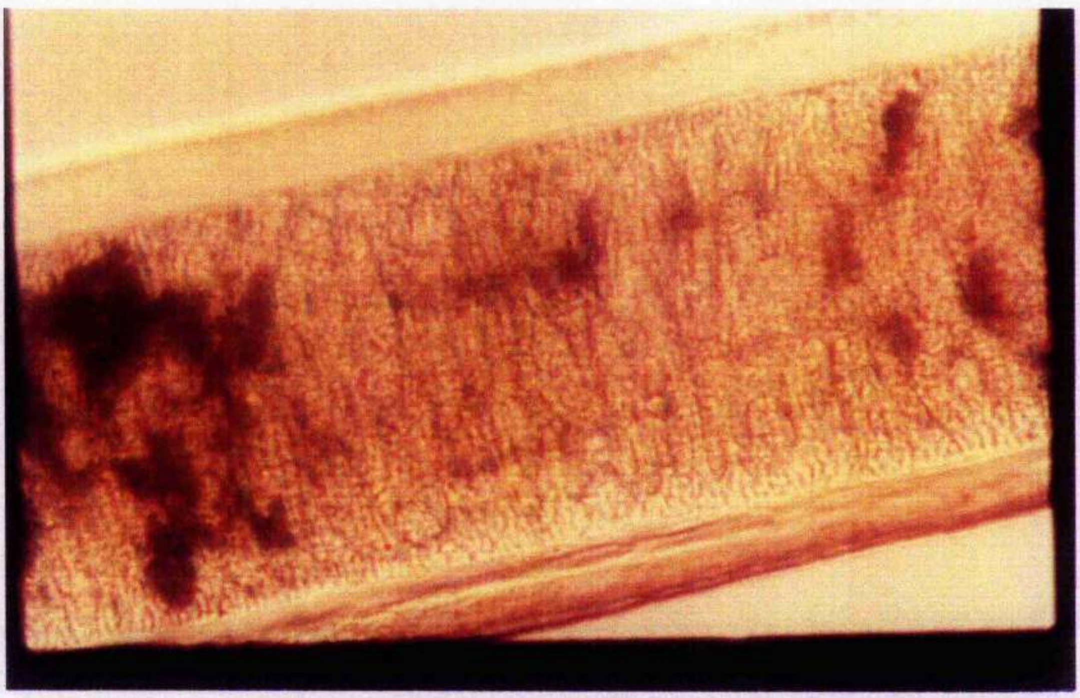
	Nests sites		Roost sites	
Species	**No. of pellets**	**Percentage**	**No. of pellets**	**Percentage**
Sheep	114	37.90	310	42.65
Goat	205	53.90	345	47.46
Camel	20	5.28	57	7.85
Uromastyx	9	2.38	4	0.5
Rodents	2	0.54	8	1.11
Others	0		3	0.43

Table 4.4 Percentage occurrence of secondary items found in the pellets for the lappet-faced vulture (n= 1245)

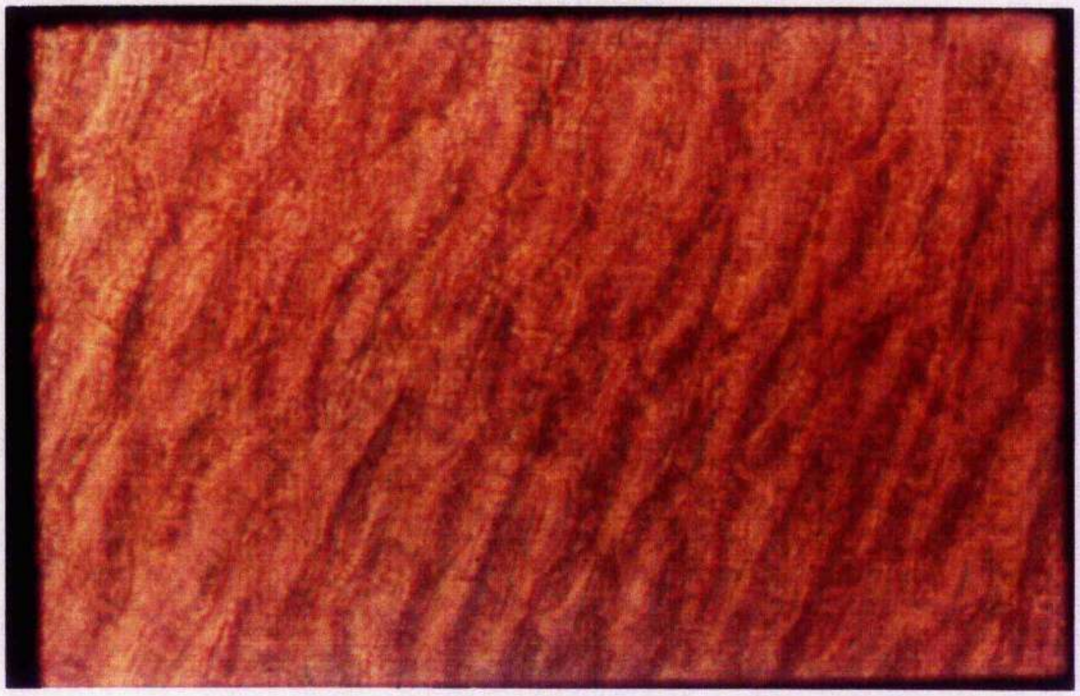
Items	Percentage	Items	Percentage
Barley	27.87	Claw	0.91
Stone or sand	30.87	Cloth	2.5
Hooves	6.31	Skin	3.48
Feather	10.96	Grass	5.94
Plastic	2.1	Insect	1.35
Bone	7.81		

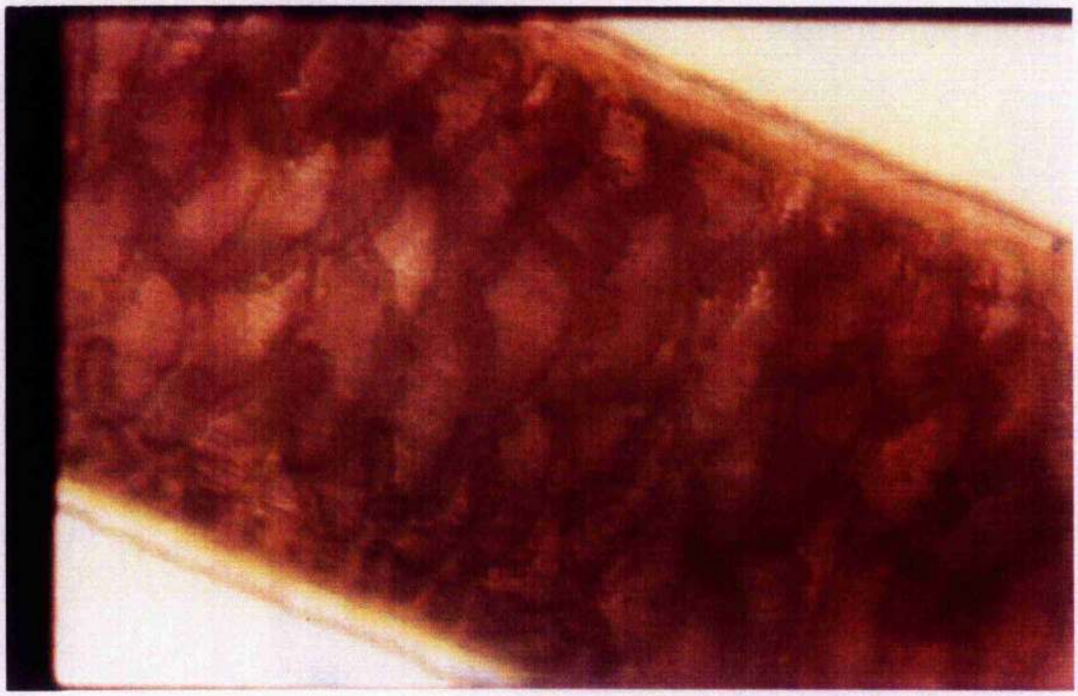


Photograph 4.1 The sheep (top) and goat (bottom) hair under the microscope.



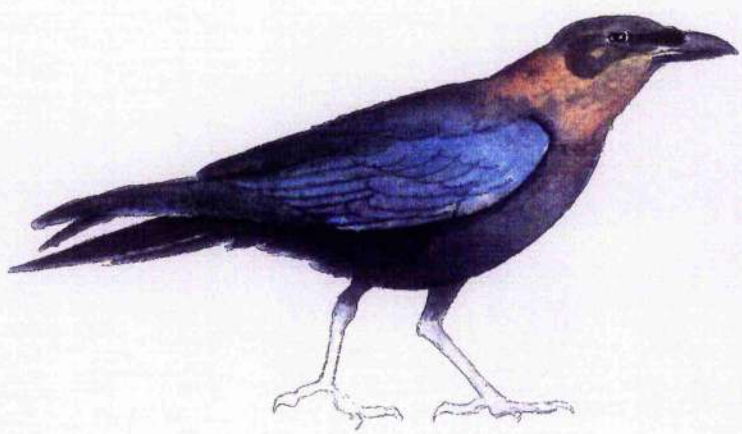
Photograph 4.2 Camel's hair under the microscope.





Photograph 4.3 Oryx (top) and gazelles (bottom) hair under the microscope.

Photograph 4.4 The lappet-faced vulture feed mainly on the head of camel carcass, and rarely from other parts.



Chapter 5. Locating and exploiting the carcasses

5.1 Introduction

Vultures are large flying birds which feed mainly on carrion, and they can locate carcasses quickly even over long distances (Mundy *et al.* 1992). The Old World vultures are known to locate carrion only by sight, while among the New World vultures the three species of *Cathartes* also use olfaction (Stager 1964, Houston 1984b, Mundy *et al.* 1992). In searching for carrion vultures form a network in the sky, and as soon as one bird spots something and drops downwards to investigate, the adjacent birds will follow (Houston 1974b, 1979). Although Mundy *et al.* (1992) emphasizes that the first bird to spot a carcass does not signal deliberately to the others, it is a consequence of the vultures flying style, and the ability to interact as a group like this, which gives avian scavengers a considerable advantage over mammalian competitors in locating transient, isolated sources of food (Houston 1974a; 1979).

Some species also specialize in following predatory mammals to locate carcasses. For example, in studying the carcasses of animals killed by predators in East Africa, Kruuk (1967) found that in 50% of cases the first vulture species to arrive was the whiteheaded vulture. By contrast in a study of 64 carcasses placed in the field to record the sequence of arrival by vultures, Houston (1971) showed that the whiteheaded vulture never arrived first.

In this chapter I aim to examine the foraging behaviour of the lappet-faced vulture. I aim to determine firstly the time of day lappet-faced vultures search for food, secondly the time at which the other scavenger species arrive at the carcasses, thirdly the length of time each species spends feeding at a carcasses, and fourthly I aim to examine how the numbers and species composition of scavenging birds feeding at particular carcasses changes through time. Lastly I look at whether different species of scavengers specialize on different parts of a carcass. The amount of food that lappet-faced vultures consume will be considered in the following chapter.

5. 2 Material and Methods

5.2.1 At what time of day do lappet-faced vultures commence foraging?

By visiting both nesting and roosting sites in the early morning, it was possible to determine the time at which both non breeding and breeding lappet-faced vultures left to forage. Observations of nest sites were made on a total of 41 days over three years. Roost sites on eight days in 1993 and two days in 1994. I visited roosts in the Summer and Autumn when numerous non-breeding birds were present. All observations were commenced before first light (around 05:30-06:00) and continued until all birds had left to search for food; a period of 6-8 of hours. As well as noting the time of departure of each individual I noted the number of birds which left together in a group.

5.2.2 The factors effecting the presence and abundance of scavengers at carcasses

The behaviour of birds locating and exploiting carcasses was examined firstly by putting out carcasses randomly and monitoring these continuously for 2-3 days, secondly by visiting a rubbish dump where butchers' waste was regularly discarded, and thirdly by observing birds opportunistically at natural carcasses.

Carcasses were put out both inside and outside the Mahazat as-Sayd reserve in order to compare scavenging behaviour between undisturbed and disturbed areas respectively, and between areas close to and far from nesting / roosting sites respectively. All carcasses were collected from the road side near the National Wildlife Research Center 30 km to the south east of Taif city, and were freshly dead apparently from natural causes. Local shepherds and farmers around the center quickly remove dead animals away from the vicinity of the other livestock and dump some of them on the roadside where the rubbish dump truck from Taif Municipality collects them about every three days. Consquently, fresh carcasses were available most of the time.

Inside the reserve three sand gazelles and two Arabian oryx which had died from natural causes were used for observations, as well as the guts and legs of butchered sheep and goats which I provided as bait. The use of sheep and goat carrion inside the reserve later had to be discontinued because of the risk of introducing disease to the oryx and gazelles. A total of 16 days were spent monitoring carcasses inside the reserve. Twelve goats, 13 sheep and three camels were put out and monitored over a total period of 45 days outside the reserve.

In both areas carcasses were provided at dawn and the observations were made from a vehicle which served as a hide. Random sites were selected in open areas where vegetation did not impede visibility. The distance between the sites varied between from 500m to 10km inside the reserve and 5 to 70km outside the reserve. During the observations I recorded how quickly vultures arrived, how many individuals found each carcass, and how much time each individual spent feeding. I also noted the number of birds of each species at different times of the day.

By visiting the butchers' rubbish dump at Zalm town (Fig. 2.2), once a month from February 1994 onwards, it was possible to watch the behaviour of scavengers at this permanent food source for up to 8 hours per day, and to note the sequence in which different species arrived and the number of birds feeding at any one time.

Similar observations were made when natural carcasses were encountered during censuses or during radio-tracking of lappet-faced vultures, and when carrion was found discarded at other rubbish dumps. All birds except eagles were identified to species: the field identification of the *Aquila* eagles (steppe *nipalensis*, spotted *clanga* and imperial *heliaca*) is often difficult, and these species are considered collectively.

5. 3 Results

5.3.1 At what time of day do lappet-faced vultures commence foraging?

Observations of the time of departure from the roost site for a total of 78 birds showed that most lappet-faced vultures left to forage between 9 and 10 am (Fig. 5.1). The majority of lappet-faced vultures left the roost area singly or in pairs and flew directly towards a thermal and started to gain allitude (Fig. 5.2). The average number of birds soaring together in a thermal was 2.9 (SD $\pm$2.0), and no group of more than seven were seen flying.

5.3.2 Factors effecting the presence of scavengers at carcasses

(I) Lappet-faced vulture

Nine out of 21 carcasses put out randomly and three natural camel carcasses were located and utilized by at least one lappet-faced vulture. Lappet-faced vultures were seen arriving only at carcasses where other scavengers were already present; it was never the first species to arrive (Table 5.1). After the first lappet-faced vulture landed, others followed with an average interval of 17.25 minutes duration between the arrival of each bird (SD $\pm$ 8.60).

From Figure 5.2 birds leave the roost mainly as single birds or pairs. I scored whether when birds first arrived at a carcass they were solitary individuals or in pairs. I found on 86% of occassions it was a solitary bird, and this is significiatly different from the proportion of single birds and pairs leaving the roost (X^2= 8.01, P<0.005). This therefore shows that although vultures may roost and leave in the morning in pairs, they may then separate for searching for food and usually locate carcasses independently.

Figure 5.3 shows that on the first day lappet-faced vultures outside the reserve usually arrived after 12:00. On this day there was a highly significant difference between the number of lappet-faced vulture attending the carcasses in different hour of the day (One-way ANOVA, $F_{4, 74} = 5.90$, $P<0.001$). Similarly inside the reserve, the numbers changed with time, and there were a significantly more birds attending the carcass later in the day (One-way ANOVA, $F_{9, 176} = 34.96$, $P< 0.001$) (Fig. 5.4). However, on the first day the birds inside the reserve arrived much later than outside the reserve. 78% of birds arriving to carcasses outside the reserve arrived after 15:00, compared to only 5% at carcass inside the reserve. This probably mean that although birds bred and roosted in the reserve, they did not search for food there but concentrated on the areas outside the reserve. When birds returned to the reserve to roost later in the day they might then find a carcass located there. At all observations the birds did not start feeding from the carcasses on this day, but they were seen resting near the carcass and then roosting in near-by trees overnight. Presumably these birds started feeding from the same carcass the next day.

On the second day the birds returned at first light, although they did not start feeding from the carcasses immediately. The number of birds present at carcasses inside the reserve was significantly greater on the second day than the first day (Mann-Whitney, *U*-test, W= 33.5, $P<0.01$). But outside the reserve this pattern was not found, and there was no significant difference in the number of birds present at the carcass on the first and second days (Mann-Whitney, *U*-test,. W= 140, $P>0.05$) (Fig 5.3 & Fig. 5.4). Birds are obviously returning to carcasses they had located the previous day, and in the case of carcasses inside the reserve some new birds may have been led to the carcasses by following others as they left the roost.

At the butchers' rubbish dump near Zalm city, where food is permanently available, the lappet-faced vultures arrived between 08:00-13:00. The number of feeding lappet-faced vultures varied significantly with time of day (One-way, ANOVA, $F_{7, 263} = 19.90$, $P<0.005$). The maximum number were observed between 13:00-14:00 pm (Fig. 5.5)

(II) Brown-necked raven

Among all scavengers the brown-necked raven was usually the first species to arrive at the carcasses (Table 5.1). The first arrival time of ravens at carcasses was normally between 5:30 - 9:30am on the first day. But on one occasion they arrived late in the evening at 17:00 pm. Out of the 17 occasions on which ravens arrived first at the carcasses on 12 occasions the birds were in pairs, and on 3 occasions they arrived as trios; on only two occasions did a single bird arrive at the carcasses.

There were no significant differences between the maximum numbers of brown-necked raven attending carcasses on the first and the second days inside and outside the reserve (Wilcoxon Mattched-pairs test, $Z= -1.7529$, $P > 0.05$, $n= 8$ "inside"; $Z= -1.2741$, $P > 0.05$, $n= 13$ "outside"). Fig.5.6, 5.7). Ravens, therefore search actively for carcasses both within and outside the reserve.

At the Zalm rubbish dump, ravens were seen most of the time. They arrived before 06:00, suggesting that they might roost in the area. There was no evidence that the number of ravens at the dump varied with the time of day (One-way ANOVA, $F_{10, 1081} = 1.27$, "N.S", $P > 0.05$), (Fig. 5.5). The maximum number observed at the rubbish dump was 54 birds, they were mostly young and non breeding birds.

(III) Eagles

The number of eagles at a carcass increased through the first day (One-way ANOVA, $F_{7,190} = 13.24$, $P<0.001$). They were seen roosting near the carcasses, and on the second day they started feeding at first light (Fig. 5.8), and numbers declined through the day, (One-way ANOVA, $F_{7, 216} = 14.47$, $P<0.001$). Comparing the number of eagles which attended the carcasses in the first and second days outside the reserve, there were no significant differences between the two days (Mann-Whitney test $W= 95.5$, $P>0.05$). In the reserve I had one observation of a single bird which arrived on the first day. However, on the second day the number of birds attending the carcass had increased and there was a significant difference in the number of eagles present at different hours of the day (One-way ANOVA, $F_{11, 226}$ =16.55, P<0.001), (Fig. 5.9).

At the Zalm rubbish dump eagles arrived before 06:00 indicating that they may roost there. There was no evidence that the number of eagles varied with the time of day (One-way ANOVA, F= 1.23, P>0.001),(Fig. 5.5)

(IV) Egyptian vulture

The number of Egyptian vultures feeding in the study area was low compared to the others species, and no more than eight birds were recorded at any one time. They usually arrived at carcasses between 9-11. Outside the reserve, the number of Egyptian vultures increased during the day, (One-way ANOVA, $F_{10, 223}$ = 11.16, P<0.001) (Fig 5.10). Inside the reserve, numbers similarly changed through the day. (One-way ANOVA, $F_{9, 185}$ = 20, P<0.05) (Fig. 5.11). On the second day the birds were only present in the morning, and had usually left the carcass by midday. Egyptian vultures were seen only twice at the Zalm city rubbish dump, and the maximum number was two (Fig. 5.5), and these birds were only present between 09:00-14:00 hours.

(V) Mammalian scavengers

The mammalian carnivores which could scavenge in the study area are the fox, feral dog and wild cat, sand cat, and feral cats. Most of these species are noctural in their activity, and were not seen to visit the carcasses during the day. Tracks of foxes and cats were found close to carcasses in 5 of 24 cases, indicating nocturnal feeding. These tracks were found in the late Summer and Autumn, when the numbers of rodents and insects are known to be low and foxes then have to seek alternative food, (Olfermann 1993; Olfermann 1994). However, feral dogs are becoming a target for persecution as the shepherds complain that these animals attack their livestock, and they may not be as abundant now as in previous years.

5.3.3 The feeding behaviour

(I) Smaller scavenging birds

The smaller scavenging birds in the study area such as ravens, eagles and Egyptian vultures were seen at carcasses feeding on the soft tissues of the head and rectum. The bill structure in these birds is not adapted to tearing tough skin, but they did succeed in opening small carcasses, especially those of young sheep, goats and gazelles. Only 3 of the 24 carcasses observed were opened by these small scavenging birds and in all cases these were carcasses of young animals. Ravens were observed three times pecking vigorously at bloated carcasses, but succeeded only once in penetrating the skin. A steppe eagle was seen once opening the carcass of an adult gazelle. It started with the soft tissue on the head and back before ripping open the belly area between the back legs. Egyptian vultures were seen tearing the skin around the skull, but not on other parts of the carcasses. These smaller scavenging birds were often the first to arrive and made efforts to penetrate the skin. After the carcass had been opened by larger species all of these species were observed feeding from the opened area.

Small scavenging species were seen at all types of carcasses (Fig. 5.12), but there was a highly significant increase in the mean maximum number of ravens recorded at larger carcasses (One-way ANOVA, $F_{3, 34} = 20.99$, $P<0.001$). However, even small carcasses attracted a few ravens. But for Egyptian vultures significantly more birds were recorded at small carcasses than at large ones (One-way ANOVA, $F_{3, 14} = 5.04$, $P<0.02$), whereas the maximum number of eagles observed at one time attending carcasses did not differ between carcasses of different size (One-way ANOVA, $F_{3,12} = 0.482$, "N.S", $P>0.05$).

(II) Large scavenging species

The lappet-faced vulture, griffon vulture, and the cinerous vulture are larger than other scavenging birds. The black vulture is a rare winter migrant species (Jennings 1981; Newton and Newton 1993), and was seen only three times roosting in the reserve, and twice near a rubbish dump. No observations were made of this species feeding. Only a single griffon vulture was seen feeding. This was at an oryx which had been opened already by other scavengers. The lappet-faced vulture was the only abundant large scavenging bird in the study area, and being the major scavenger it forms the focus of attention in this study.

The lappet-faced vulture was seen feeding on most types of carcass. In the reserve, lappet-faced vultures were most abundant at carcasses of medium size (30-60kg) such as those of Arabian oryx (Fig. 5.13) but overall there was no evidence that the size of carcass affected the number of birds feeding at it (One-way, ANOVA, $F_{3,9} = 3.12$, $P>0.05$). At the carcasses the lappet-faced vultures were seen feeding first from the head and from the exposed meat if the carcass was already open. Dominant birds stood on the carcasses before starting to tear the skin. This species can tear through the skin of adult sheep and goats often by pulling powerfully with the bill while holding the skin by the feet. At camel carcasses lappet-faced vultures were seen feeding only from the head, part of the neck, the rump and rarely from the belly. After these parts had been consumed, vultures were not seen at carcasses, even though other edible parts remained. They are probably unable to tear the thick skin on a camel.

5. 4 Discussion

5.4.1 Lappet-faced vulture departures from roosts.

Like other vultures in open, semi-arid country the lappet-faced vulture in the study area uses thermals to get aloft. The observations showed that the majority of birds started flying between 09:00-10:00, which is the time when the sun's radiation heats the ground sufficiently to generate strong thermals (Pennycuick 1972). Mundy *et al.* (1992) suggested that vultures can see other birds using a thermal from a kilometer or more away and will fly straight towards the thermal. During the observations birds were seen flapping toward the thermal direction before it started to glide. On windy days the birds were also observed using rising air off small hills to gain height.

The adult lappet-faced vulture in Africa is described as a "Sociable Vulture" (Andersson 1872), but many observers have considered the birds to be solitary especially during the three months of the breeding season (Mundy *et al.* 1992). In the study area, the non breeding lappet-faced vultures also set out to forage alone. They are by contrast gregarious when roosting, feeding at carcasses, or drinking at a water hole. Although apparently solitary and widely separated when searching for carrion, vultures maintain visual contact and thus interact efficiently as a widely dispersed group rather than a series of independent individuals.

5.4.2 Locating the carcasses

<u>(I) Lappet-faced vulture</u>

The results showed that in the study area the lappet-faced vulture was usually the last species to arrive or to approach a carcass. These birds also appeared hesitant near carcasses. Their large size makes it difficult for them to take off and they are therefore more liable to predation than the smaller scavenger species, such as ravens. This shyness at food has been observed in other small and large scavenging birds (Heinrich 1988; Mundy *et al* 1992). In Africa, Mundy *et al.* (1992) found that the whiteheaded vulture was normally the first to arrive, though in areas where this species was scarce, they found that lappet-faced vultures were first.

Because the birds roost inside the reserve, they might be expected to locate carcasses within the reserve very quickly. But in fact very few vultures locate carcasses inside the reserve before late afternoon, probably because there is so little food usually found within the reserve that it is not worth their time to search there and they go immediately outside the reserve as soon as they leave the roost.

Communal roosts could function as centers for the exchange of information on the location of food (Ward and Zahavi 1973; Weatherhead 1983). Studies on the New World turkey vulture in southern Ontario, Canada, show that roosts do not function in this way (Prior and Weatherhead 1991), but there is good evidence that they do for the New World black vulture (Rabenold 1987). From the data available in the study area I consider the lappet-faced vultures were not roosting communally in order to acquire information about food, but it might enable the birds to form a network in the sky and thus search effectively for food over a large areas. Most birds started foraging singly or in pairs and they moved in different directions enabling them to cover the area cooperatively. Prior and Weatherhead (1991) suggested that food patches must persist for at least two days for roosts to function as information centers since most roosting birds only travel to and from the roost once each day. In the study area the majority of lappet-faced vultures roost near the carcass in the first day to start feeding at the first light of the second day. This is especially true at carcasses placed inside the reserve, as most of these carcasses were placed between 500m and 10km from the roost site, and birds descending to food would be seen easily by the other roosting vultures.

(II) Brown-necked raven

There may be several reasons why the brown-necked raven was most often the first to arrive at a carcass. Firstly, the species is more common in the area than any other scavenging species (Jennings 1986; Newton and Newton 1993), Secondly, this species breeds solitarily and related species are known to occupy large territories (Goodwin 1976; Knight and Call 1980; Marzluff and Heinrich 1991; Heinrich *et al.* 1994). According to Bossema and Benus (1985), ravens probably form lasting pair bonds and once established in a territory they occupy it for life. In all the sites where carcasses were placed there was a territorial pair of raven occupying the area, and they usually arrived at the carcasses first. Finally, the ability of ravens to use flapping rather than gliding flight may allow them to start foraging early in the morning before the thermals form, upon which gliding birds such as vultures rely. In agricultural areas in Africa carcasses were also located most often by crows and ravens (Mundy *et al.* 1992).

There may be various reasons why the number of ravens at carcasses inside the reserve varied with the time of day while numbers at carcasses outside the reserve did not. Firstly, this could be due to the different numbers of ravens inside and outside the reserve, secondly, it could be due to the difference in the size of territories and the home ranges, or it could be related to the availability of food in the two areas. Newton (1979) suggested that the home range size varies depending on the food supply available to a raptor.

(III) Eagles

As a result of hunting and overgrazing in Saudi Arabia the majority of wild prey species which eagles could feed on during migration have been depleted or driven to extinction in some areas (Child and Grainger 1990). As a result, the eagles instead take advantage of carrion available in the area. The number of eagles feeding at the rubbish dump was constant through the day. This does not necessarily mean that the same birds remained through the day because new birds may take the opportunity to forage when a satiated bird leaves the patch (Krebs and Davies 1981; Perrins and Birkhead 1983). The number of eagles attending a carcass varied with the time of day, and declined as the food become depleted.

(IV) Mammalian carnivores

Mammalian carnivores e.g. foxes, cats and feral dogs, have alternative sources of food. Rueppell's fox *Vulpes rueppellii* feeds on insects, whereas the red fox *Vulpes vulpes arabica* preys more on small mammals (Olfermann 1994). The carcass experiments showed that foxes will feed from a carcass only during the dry season (July and August), when there was a decline in the plant productivity in the reserve, (Combreau and Rambaud 1994), and a corresponding decline in insects and small mammals (Combreau and Rambaud 1994; Olfermann 1993). Feral cats and dogs were observed more often near settlements feeding from garbage dumps, although they spent a very short time feeding. These animals are subject to hunting; two dogs were shot just 200m from me, near a main road in the study area. Though on the whole they are unmolested.

These observations of the various scavenging species are consistent with the suggestion that scavenging ecology varies between areas (Mundy *et al.* 1992). Atwell (1963) found that the numbers of each scavenging species varied with the number of ungulates and their mortality rates. In the study area, I have found evidence that in the study area the raven was the first species arrived the carcass; the frequency of attendance of different species varied; and the way numbers of each species changed through time varied.

5.4.3 Feeding behaviour

The bill structures of the smaller scavenging birds such as ravens, eagles and Egyptian vultures, are not adapted for tearing the skin, even though they succeed sometimes. These small scavenging birds have alternative food sources, and need unspecialised beaks even though carrion may be important as part of their diet for certain periods of the year. By contrast, the lappet-faced vulture concentrates on carrion and has a deep powerful beak with a strong hook at the tip adapted for tearing skin and feeding on the meat of mammals (Houston 1979; Mundy *et al.* 1992). This species is clearly the major scavenger on carcasses in the study area. Its ability to open the skin of large carcasses also provides feeding sites for the smaller scavenger species.

Table 5.1 The first species locating and feeding from the carcasses (n=24)

Species	First arrival	First feeding
Raven	17	20
Lappet-faced vulture	0	0
Eagles	1	1
Egyptian vulture	1	1
Mammalian scavengers (foxes and cats)	5	2

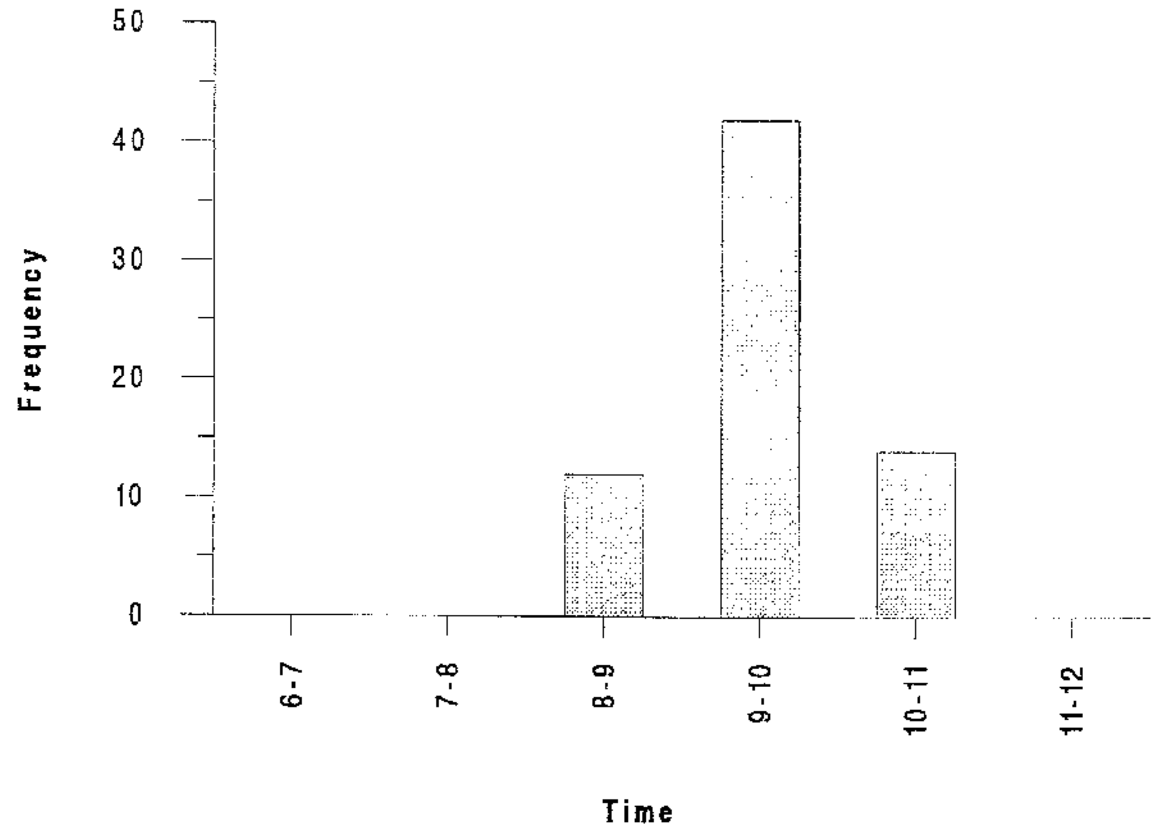


Figure 5.1 The timing of departure from roost site in the lappet-faced vultures (n= 78 birds during nine observation days).

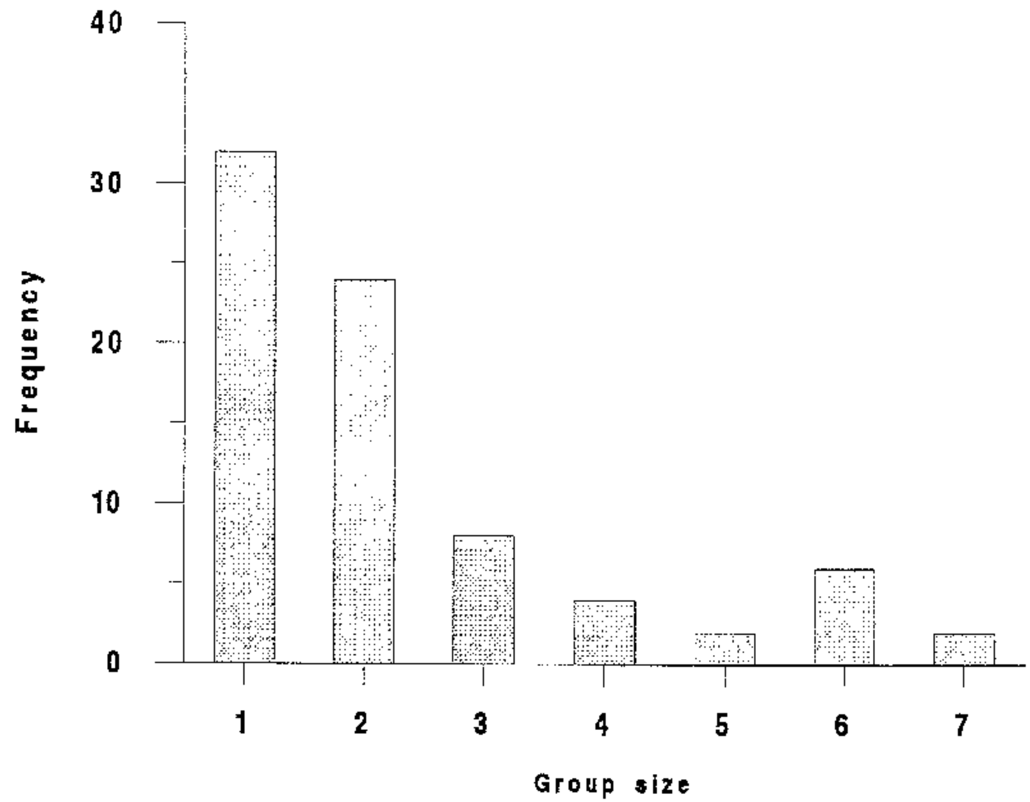


Figure 5.2 The group size of the lappet-faced vultures when leaving the roost site.

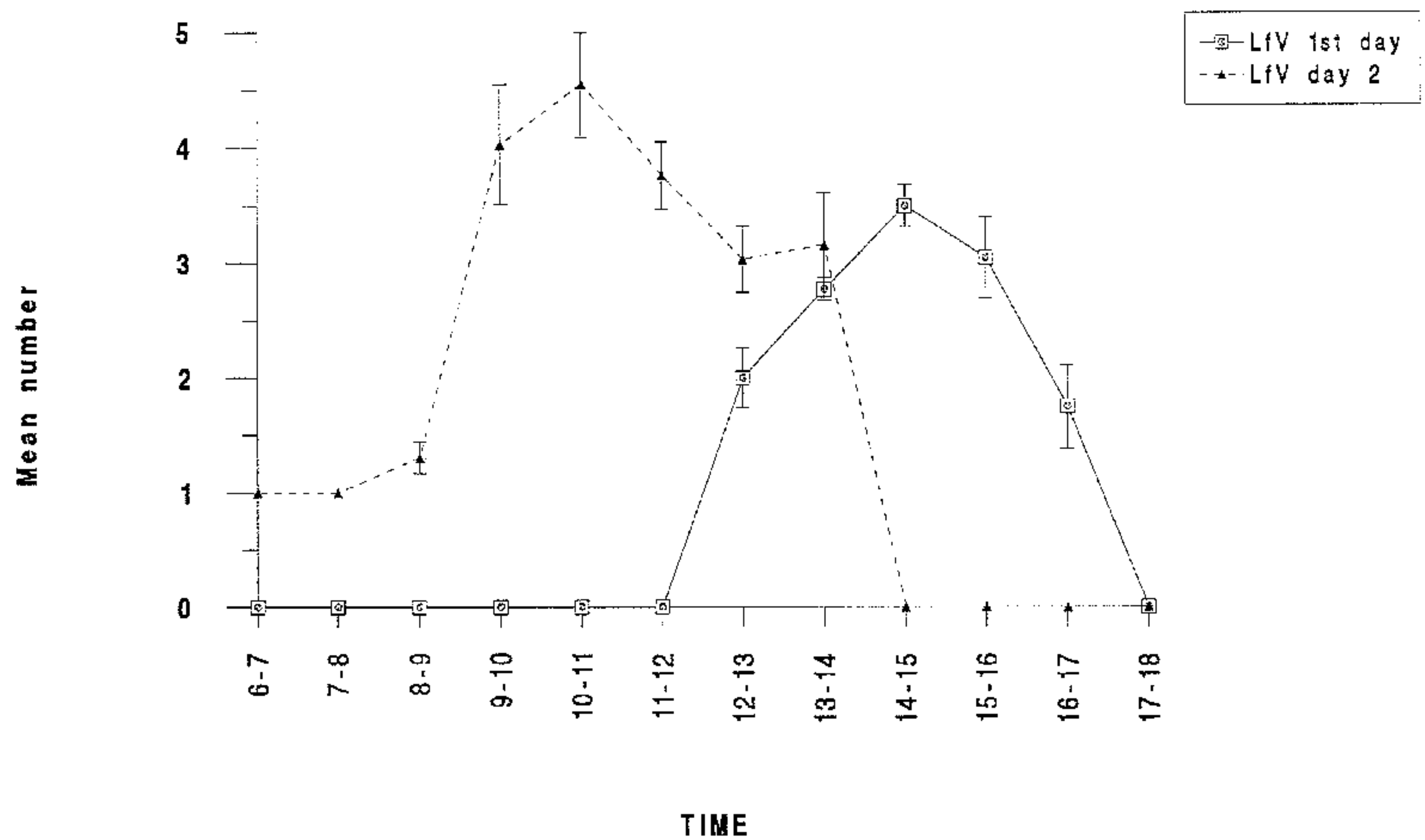


Figure 5.3 The mean number of lappet-faced vultures attending at the carcasses placed outside the reserve (bars represent the standard errors)

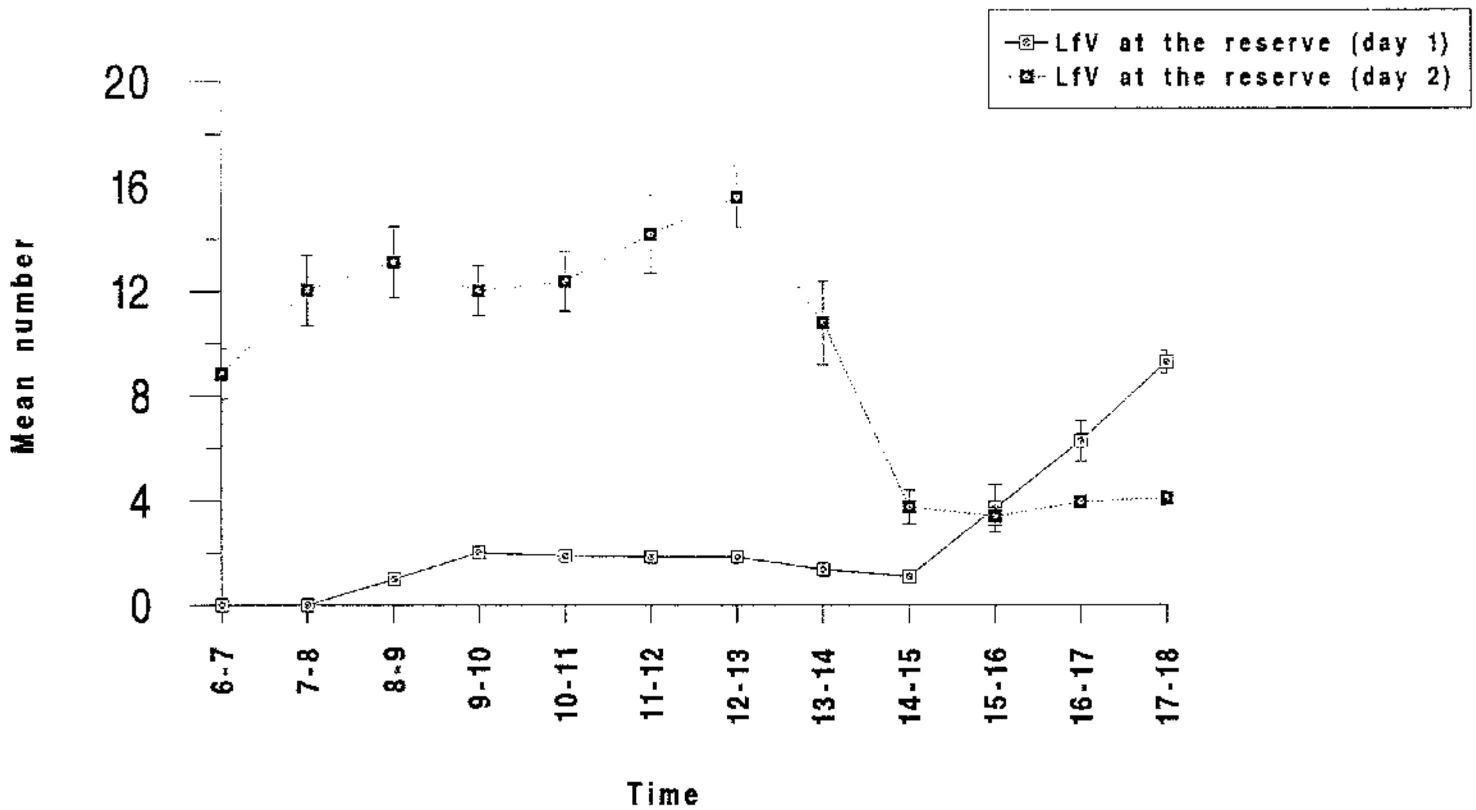


Figure 5.4 The mean number of lappet-faced vultures present at the carcasses placed inside the reserve (bars represent the standard errors)

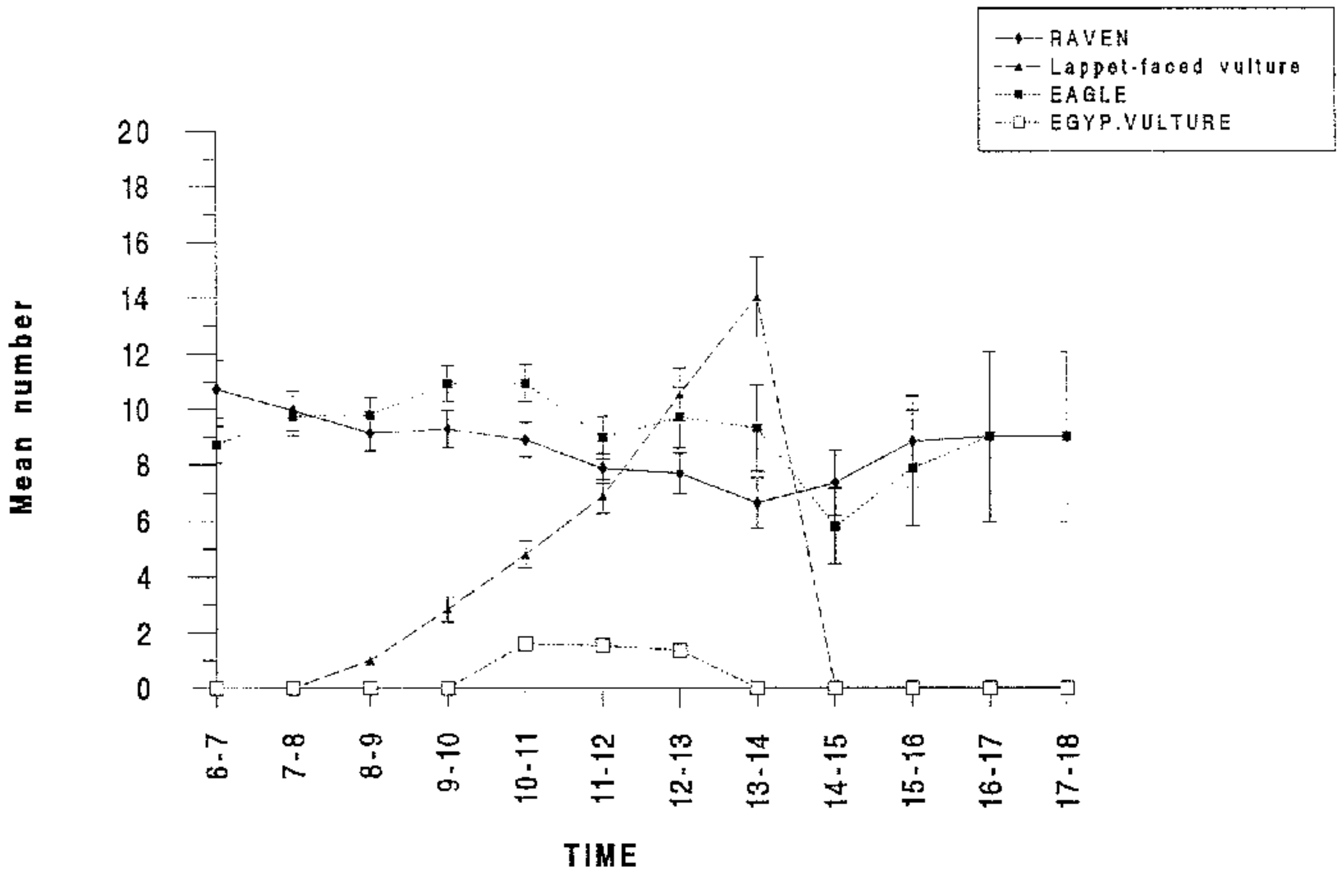


Figure 5.5 The mean number of scavenging birds at the permanent food supply (bars indicate the standard errors)

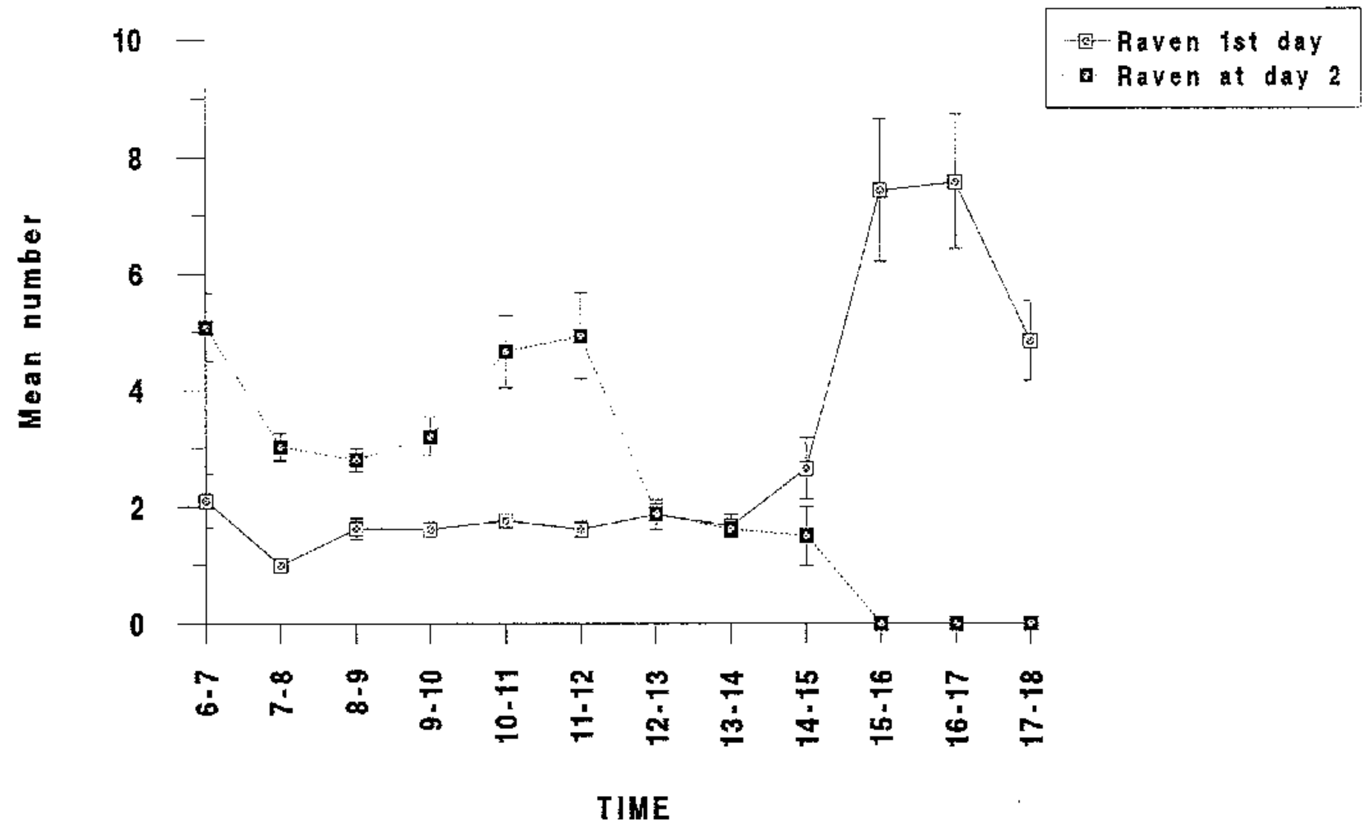


Figure 5.6 The average number of brown-necked ravens present at carcasses placed outside the reserve (bars represent the standard errors)

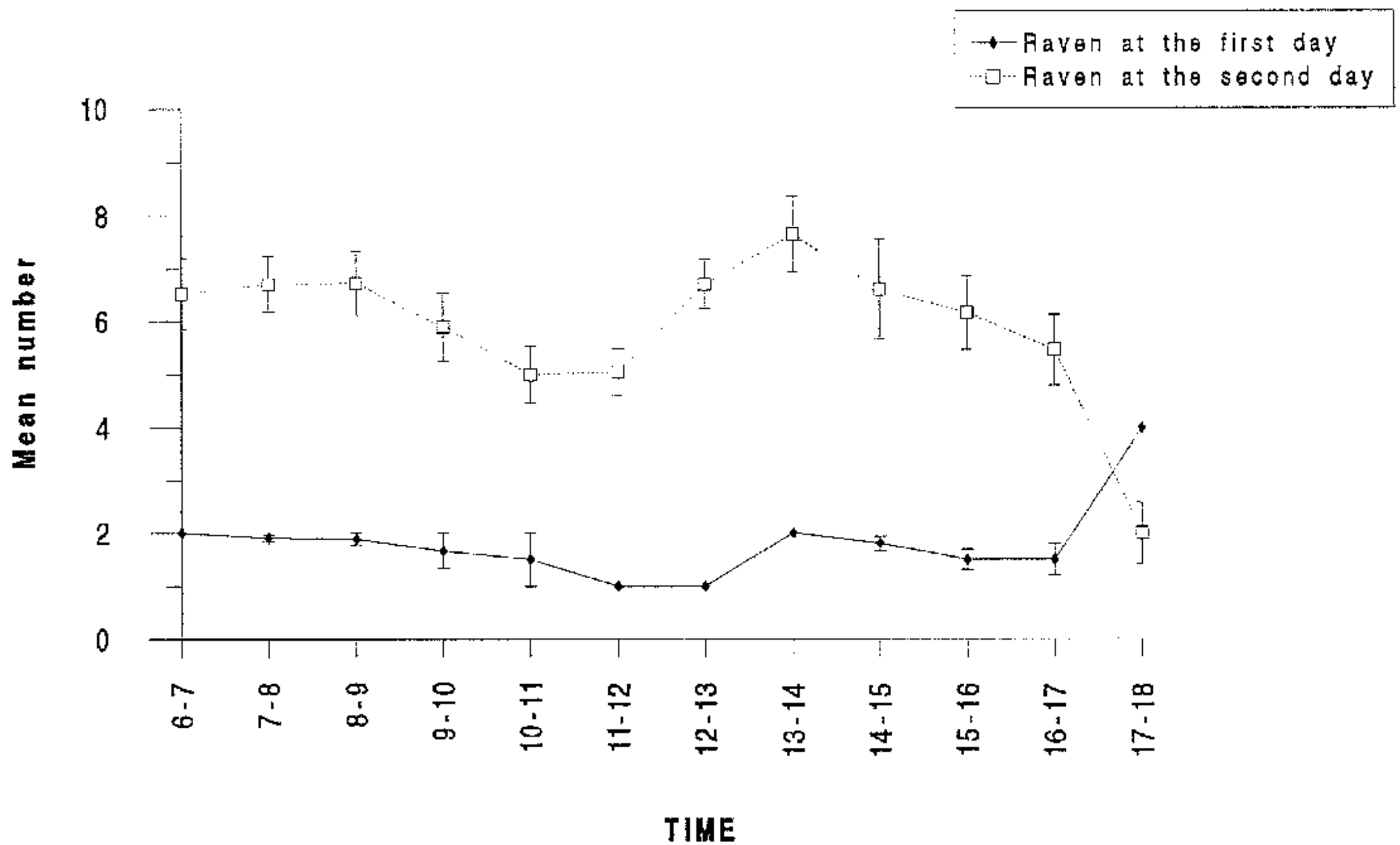


Figure 5.7 The average number of brown-necked ravens present at carcasses placed inside the reserve (bars indicate the standard errors)

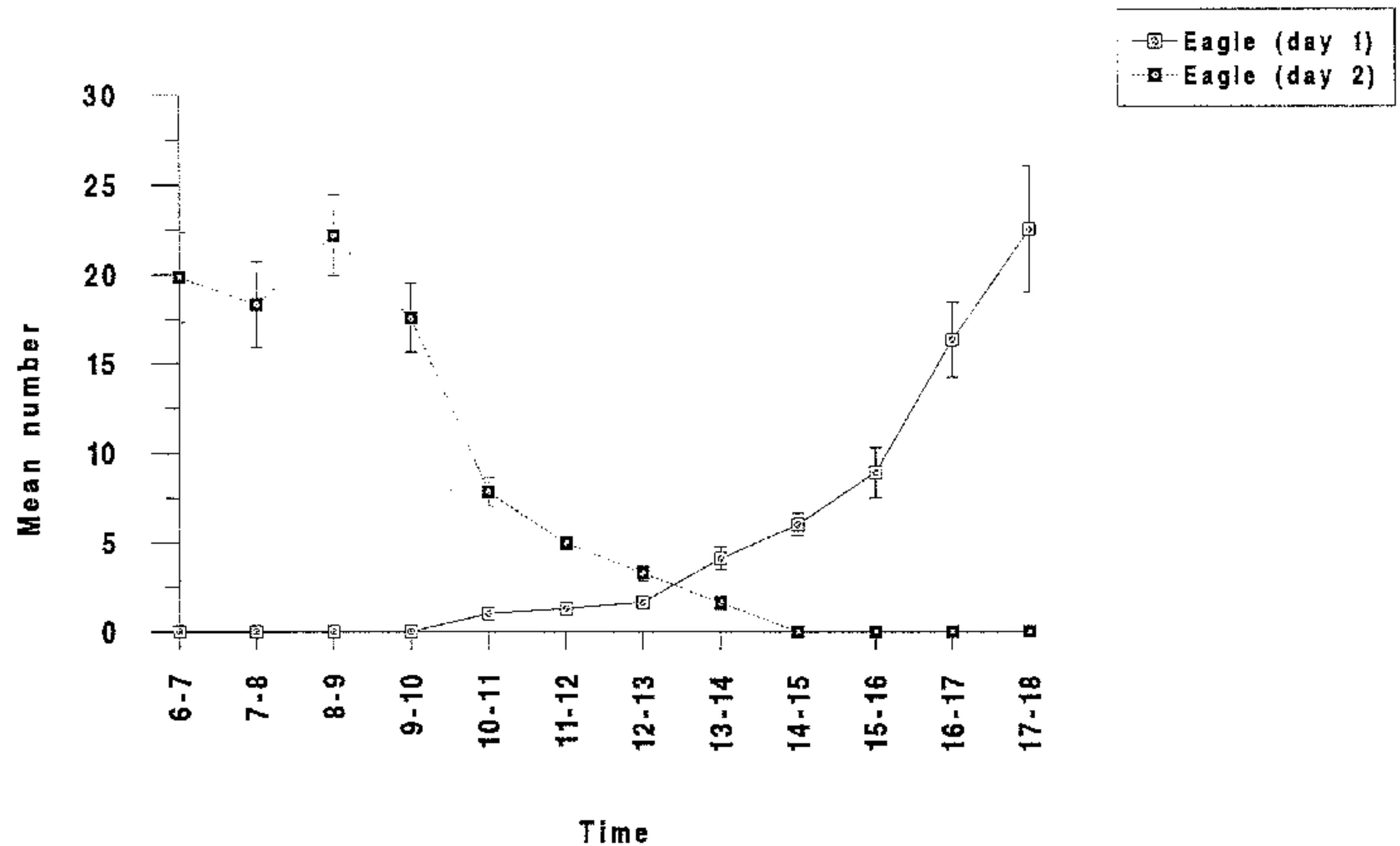


Figure 5.8 The mean number of eagles present at carcasses placed outside the reserve (bars represent the standard errors)

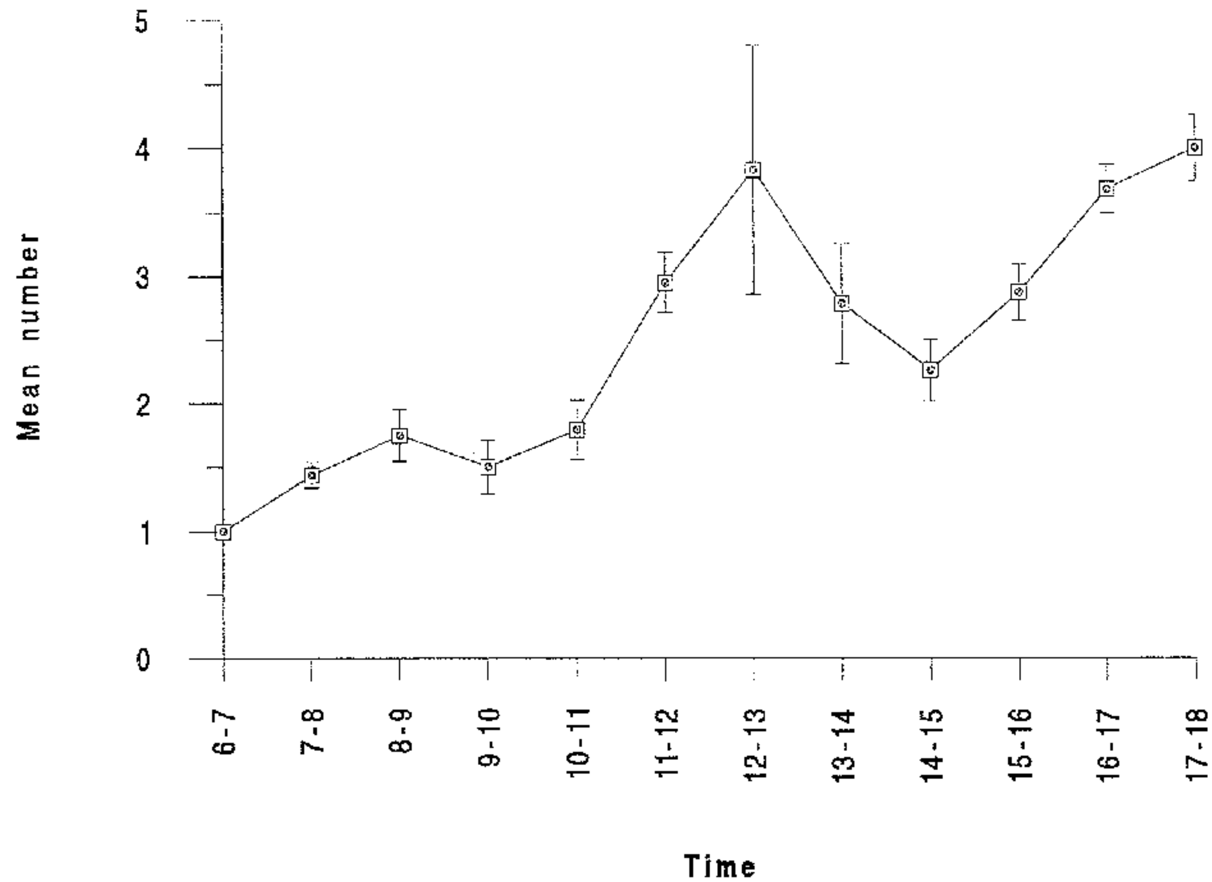


Figure 5.9 The mean number of eagles attending carcasses inside the reserve on the second day (bars represent the standard errors)

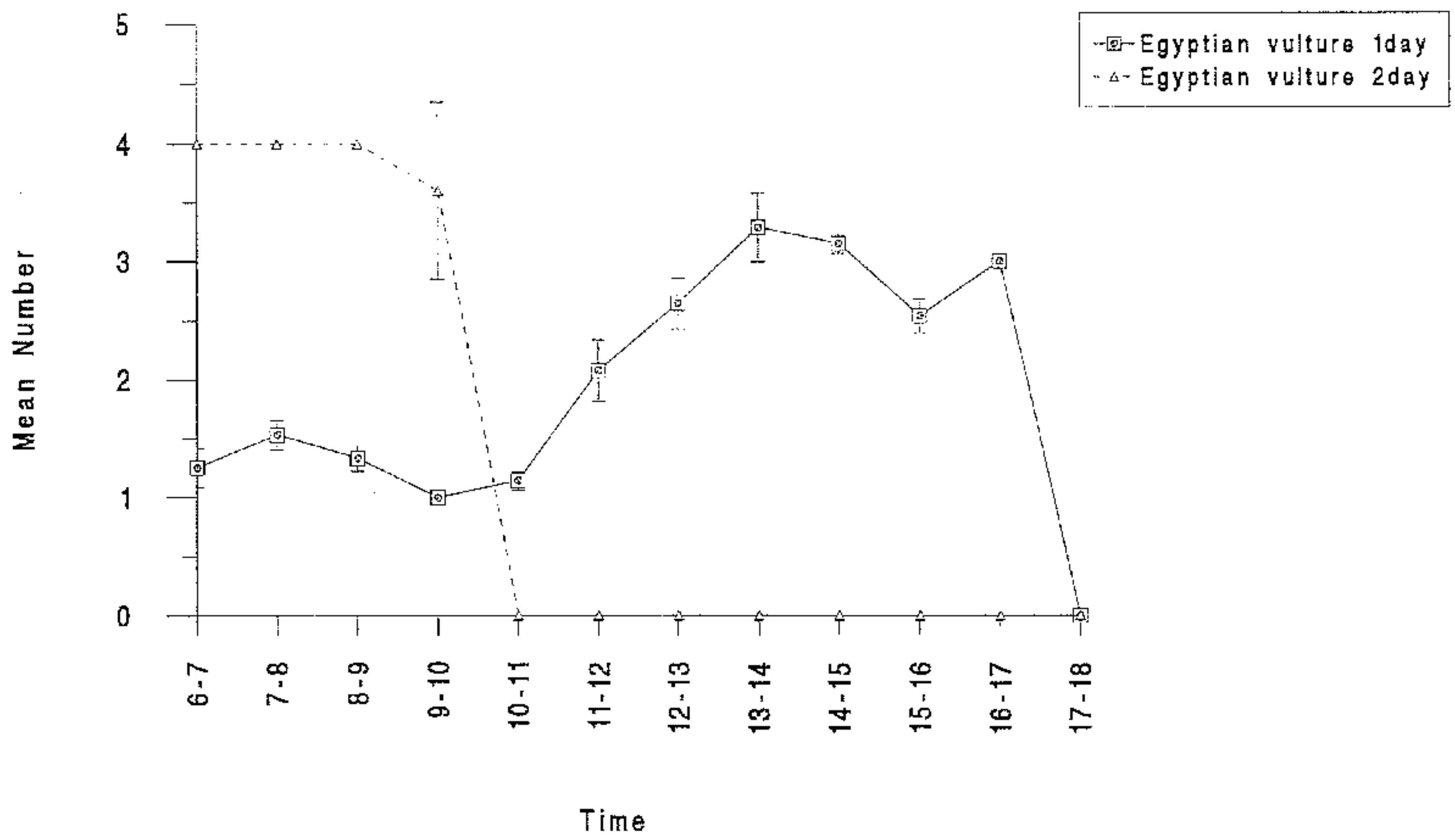


Figure 5.10 The mean number of Egyptian vultures attending carcasses outside the reserve (bars represent the standard errors)

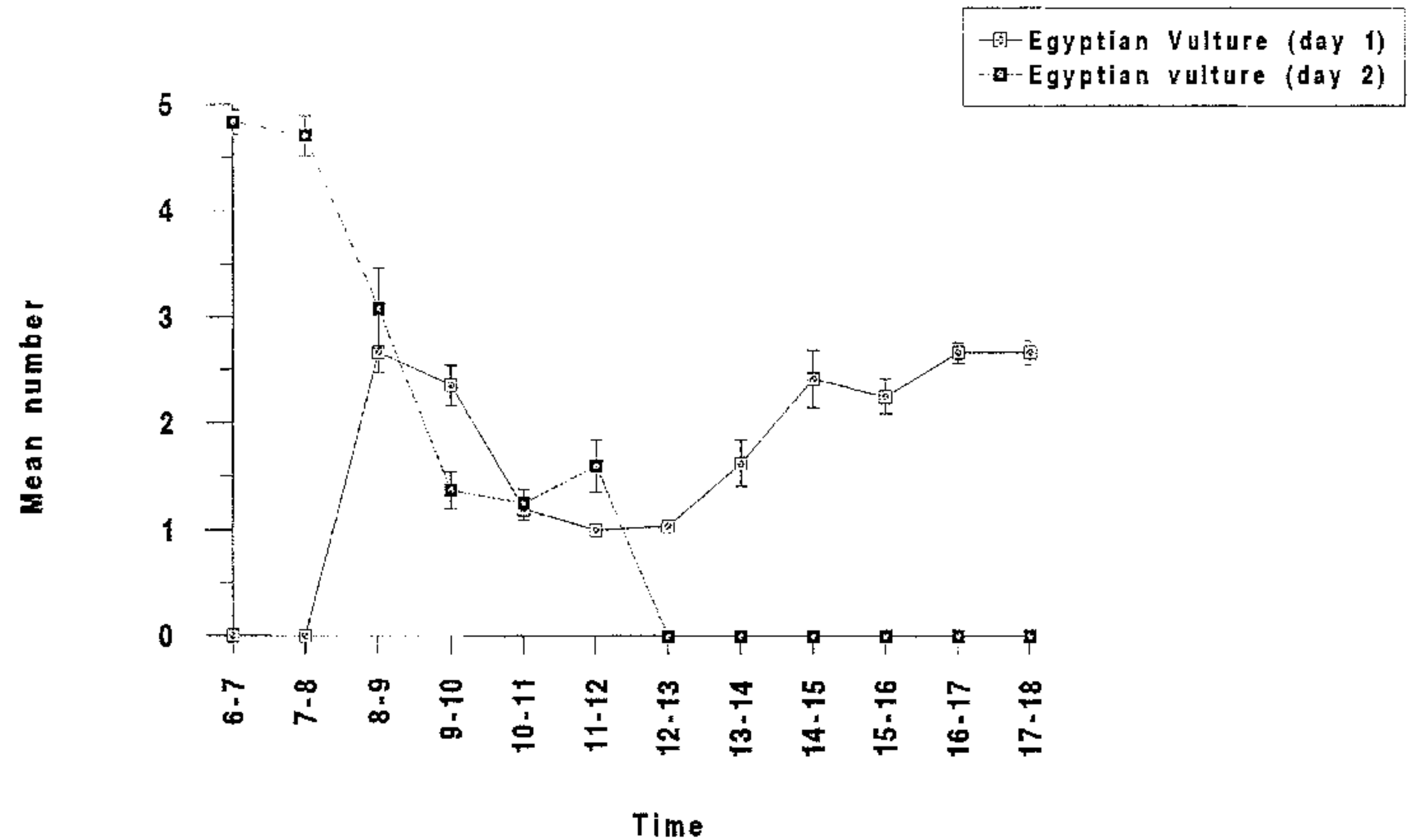


Figure 5.11 The mean number of Egyptian vultures present at carcasses placed inside the reserve (bars represent the standard errors)

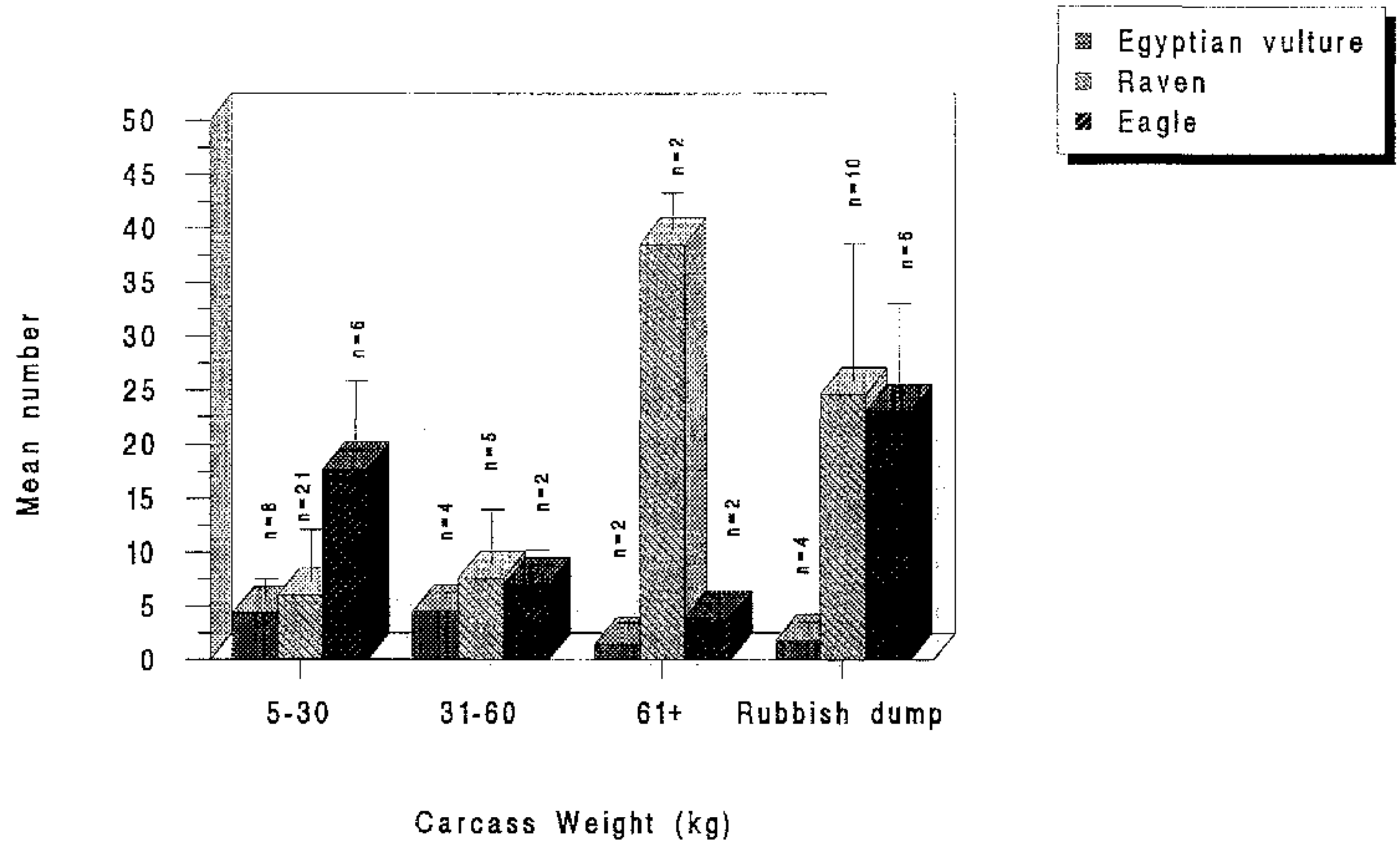


Figure 5.12 The maximum mean number of each species of avian scavenger attending carcasses of different weights (bars represent the standard deviation)

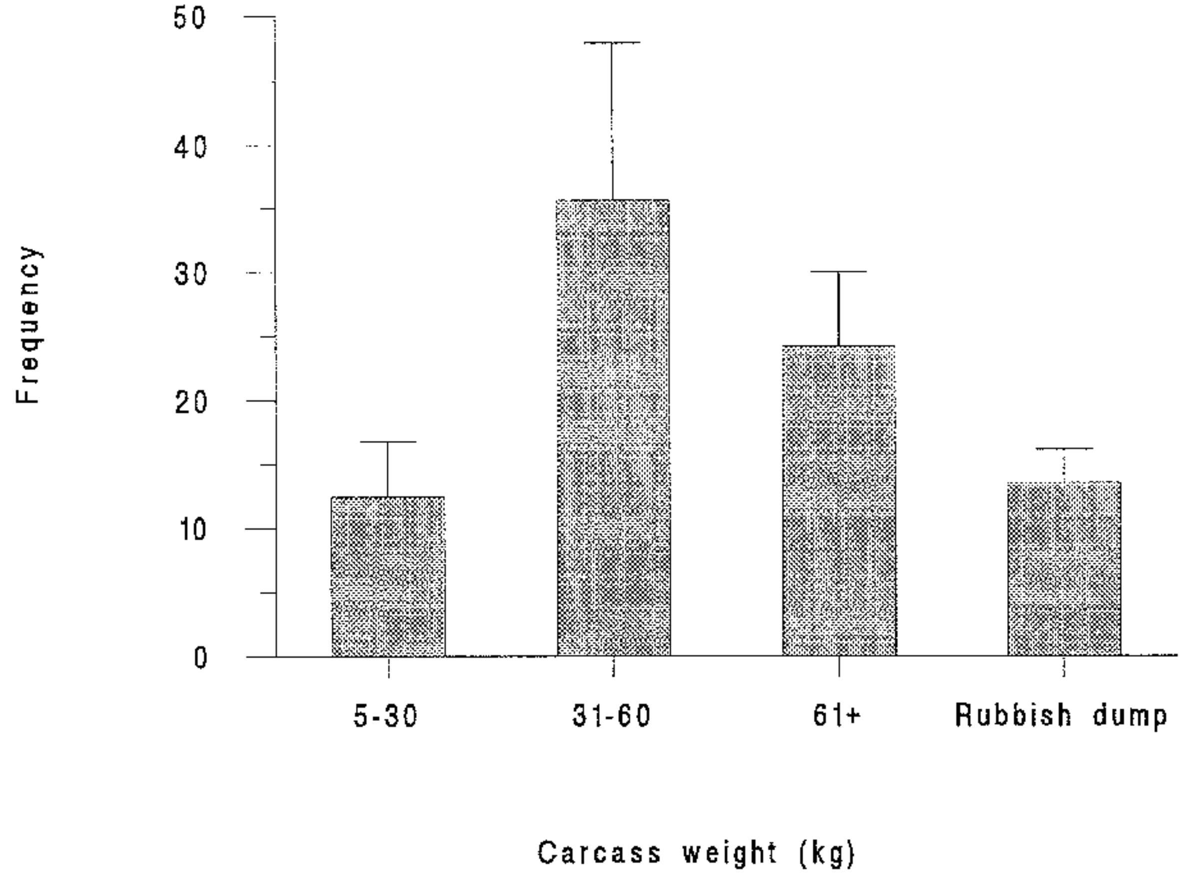


Figure 5.13 The average maximum mean number of lappet-faced vultures attending carcaases of different weights (bars indicate the standard error).

Chapter 6. Competitive interactions between scavenging species

6.1 Introduction

The potential for competitive interactions between animals increases greatly where mixed species flocks feed on patchily distributed food resources, and there are many avian examples of this amongst waders and gulls (Goss-Custard 1980; Monaghan 1980). Many field studies of closely related species living in the same area have shown differentiation in feeding habits between species at least during periods of food shortage (Lack 1954; 1971; Kerbs and Davies 1981; Perrins and Birkhead 1983). In the case of vultures, studies on ecological separation of African vultures showed that there was considerable specialization among the avian scavengers to avoid competition over food (Kruuk 1967; Pennycuick 1972; Houston 1976a; 1980; Mundy *et al.* 1992).

The study of the East African vultures by Kruuk (1967) showed that ecological differences were based on arrival times at the carcass, aggression, beak size, and body size. Lack (1971) suggested that whenever vultures are sympatric, competition for available resources is likely to be intensified, and differences in behaviour, morphology, or both may be expected. Houston (1976a) showed further ecological differences based on habitat preferences and flying capabilities. Hertel (1994) studied the diversity in size and feeding morphology within past and present vulture assemblages, and suggested that competition is an important determination of vulture feeding morphology.

In this chapter I will discuss the competitive interaction between the scavenging species at the vulture study area, and this will include an estimation of the amount of food each group (insects, mammals and birds) probably utilized from the carcasses, and how they reduced competition among the avian scavengers. The importance of the lappet-faced vulture is considered in terms of its role in the guild of scavenging animals in the desert ecosystem.

6.2 Methods

6.2.1 The amount of food utilized from the carcasses by different types of scavenging animal.

Observations were made at the 24 carcasses placed at the random sites, at permanent rubbish-tip food sources, and at carcasses located during the ground surveys. At these observations, all scavenger species attending and feeding were recorded and the amount of food each group had taken were roughly estimated through weighing the carcasses before and after they had fed. Carcasses were weighed using a baby scale and bathroom balance at the start of observations and again at the end, the relative amount of meat eaten by each feeding bird was then estimated from the observations of feeding.

In the ground survey census the carcasses located in the area were checked monthly to note if the carcass had been utilized, and from the carcasses shape and weight I estimated the amount of food utilized by all scavenging species between my visits. Furthermore, three carcasses (2 chickens and 1 small goat) were placed in a wire fox trap, to study the effect of insect scavenging species on carrion, and to identify the insect species in the study area. These traps were used as exclusion cages to prevent any interference from scavenging birds and mammals.

6.2.2 The dominance hierarchy between the scavenging species and among the scavenging birds.

Observations on the dominance hierarchy between the scavenging species was made through recording the maximum number of each species attending the carcass, and their intraspecific and interspecific behaviour were observed through recording the number of aggression attacks between and within the different species. In addition, a correlation coefficient was made between the changes in the number of species with time to see if the arrival of one species had an effect on the number of the other species.

6.2.3 The important of lappet-faced vultures as carrion feeders in the desert ecosystem

The importance of lappet-faced vultures among the scavenging birds in utilizing the carcasses was investigated under the following criteria, which have been mentioned by different authors (Kruuk 1967; Lack 1971; Houston 1976a; Hertel 1994). (I) the relationship between morphology and feeding methods, (II) the abundance of the species in the area, (III) the aggression of the species at feeding. These factors all influence the food consumption by the vulture population.

Firstly, the link between morphology and the feeding methods used by each species involves differences in body size, weight & height, wing span, and beak strength in each species (Kruuk 1967; Houston 1976a). Data on these was taken from Cramp and Simmon (1980) and Mundy *et al.* (1992). The amount of food each species could remove was estimated. Methods of feeding were observed at the carcasses, together with records of the parts of the carcasses on which each species fed. Data on the relative abundance of each avian scavenger species was taken from the previous chapter, and data on aggressive interaction is presented in this chapter.

6.3 Results

6.3.1 The amount of food removed from the carcasses by different groups of scavenging animals.

From my monthly transect counts I have data on the natural carcasses and how rapidly they were consumed, based on re-visiting each carcass at least every 15 days. Figure 6.1 shows the percentage of food utilized by all the scavenging species out of the total biomass of carcasses available in different seasons at the study area. This is based on the monitoring of 158 carcasses of different species (See Table 3.13), and the 24 carcasses which were observed for the first three days. Figure 6.1 shows that when the amount of food available was low such as in Summer and Autumn 93 the carcasses were utilized entirely. There was significantly less food utilized by these scavenging species in the seasons when more carcasses were available. Figure 6.2 shows that there was significant different in the amount of food consumeded by the scavenging species in different seasons (ANOVA, $F_{5,16}$= 7.62, P<0.005). The total amount of meat removed from the carcasses was an average of 1029 kg, SD $\pm$ 661 per day. The total amount of food which was utilized by the scavenging species was only 35% of the total carcass weight present in the study area during the whole study period. There was an increase in the amount of food utilized by all scavenger species from 1993 to 1995 which was probably due to an increase in the number of scavengers, attracted by the large amount of food in the area.

Regarding the insects, 11 species out of 6 families were collected from the experiments at the carcasses, (see chapter 2). The observations at the carcasses which were placed in the fox trap showed that maggots were present on the second day in the chicken carrion when the carcass was still wet. But on the third day dead maggots were observed at all of the carcasses, which probably resulted from the high temperature in the area. None of these experimental carcasses were consumed by insects, and all eventually dried out.

Mammalian scavengers were recorded feeding at only three carcasses out of the 24 which were watched continuously for three days. These animals left tracks in sand around the carcass, and fed during the night. The mean amount of food removed by foxes and cats from these carcasses was 2433 g $\pm$ 1790. At the Zalm city rubbish dump, feral dogs were only seen four times during the day. In general the amount of food these scavenging species removed was estimated as about 4.4% of the total percentage of biomass utilized by scavenging species, or 1-5% of the total food available to scavengers (Table 6.1).

All bird species combined were estimated to have been responsible for consuming about 30.6% of all the food taken by scavengers. By weighing the carcasses before and after the lappet-faced vulture eating the average amount of food consumed by an individual was 1040g $\pm$671. The proportion taken by each species will be considered later. The remaining 65% of food was utilized by insects and subject to general slow breakdown by microorganisms. At the sheep and goat carcasses maggots and beetles were observed at the carcasses for the first two weeks. Ants were also seen at carcasses and they were observed sucking from the carcass moisture, but they also fed on the maggots as they were seen carrying away some maggots as has been reported for ants *Camponotus sp* and *Ectatomma sp* at forest sites in the New World (Houston 1987a). After about three days any uneaten tissues on sheep or goat carcasses became very dry and probably over a period of several months were eventually consumed by insects and microorganisms. However, more data is needed to determine the effect of these bacteria and insects on old, dehydrated carrion in this ecosystem.

The figures in Table 6.1 are only rough estimates, because it is difficult to determine accurately how much food each species actually ate. Observations often had to be made some distance from the carcass to avioid disturbance, and heat haze often made accurate observations difficult. In addition, carcasses rapidly lost weight through dehydration, and so carcass weights are only an approximation of the weight actually eaten. However, it is clear that bird and mammal scavengers combined only consumed about one third of the total food available. Most of this was taken by bird scavengers, and mammals were comparatively unimportant. The remaining food was broken down by bacteria and insect activity, often over a long period of time when the carcass had dried out and reached a condition which made it unpalatable or inaccessible to bird and mammal scavengers (Table 6.2).

6.3.2 The dominance hierarchy between scavenging species and among scavenging birds.

The feral dog was the only mammalian species which was seen feeding at the carcasses (Photograph 6.1). The other species of carnivores are nocturnal feeders, and they arrived only at night. Tracks of foxes and cats were found five time at the sand near the carcasses, however they only fed twice (Table 5.1). Therefore, competition between the native mammalian and bird species was reduced as they used different times for feeding. Additionally, feral dogs were observed feeding on four occasions at the Zalm area where food was permanently available. On all occasions all the avian scavengers were observed to move away as soon as dogs arrived, and there is no doubt that dogs are dominant over all avian scavengers. However, these animals are becoming a target for persecution from the shepherds and farmers as they claim that these animals attack their livestock. Two dogs were shot in front of my car in December 1993, and the shooter was then congratulated by local people as they considered he had done them a favour.

Table 6.3 shows the percentage of interactions between the bird species. The lappet-faced vulture was usually the most aggressive against its own species. Other species of avian scavengers often moved aside from carcasses when the dominant lappet-faced vultures approached to avoid conflict. Although the brown-necked ravens were often the first species to arrive at carcasses, they also gathered in large numbers at Zalm area during Summer and Autumn. They showed high levels of intraspecific aggression. In groups they would also try to dominate the feeding area, by chasing all other larger birds such as the lappet-faced vulture by pulling their tails and jumping on their backs. However, this mainly involved young ravens and they probably do it for play rather than defending the food source. There is an excess of food at the site, and ravens rarely take advantage of a food item after it has been abandoned by the bird that they attacked. This area holds large numbers of immature ravens, rather than territorial adults.

Ravens also sometimes attack small birds which come to feed from the insects around the carcasses. Fifteen brown-necked ravens were observed at the Zalm site chasing and hunting a hoopoe lark. At carcasses placed at random sites I have seen the local territorial ravens behave similarly. However, on most occasions the ravens lost fights with other larger species (Table 6.3).

Table 6.3 also shows that most of the aggression attacks made by scavenging species were directed towards members of the same species. The eagles were the only group to show strong aggression attacks against the lappet-faced vulture. The figures 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, in the previous chapter showed that the competition between the scavenging birds was reduced through species attending the carcasses at different times. In Table 6.4 I show the species which was actively feeding and dominating the carcass at different times of the day. The highest mean number of each species feeding from the carcass were observed at different time of the day. This shows that the smaller species feed mainly in the morning and the evening, whereas feeding for the lappet-faced vulture was concentrated at the mid-day.

Species might further avoid competition by leaving a carcass when more dominant species arrive. However, there was no correlation between changes in the numbers of each species at a food source. There was no correlation between the changes in the numbers of lappet-faced vultures and eagles (r_{s2} =-0.056, P>0.5) (Figure 6.3), nor raven X eagle (r_{s2} =-0.038, P>0.5) and raven X lappet-faced vulture (r_{s2}=-0.038", P>0.5), (Figures 6.4 & 6.5). Each species may have preferred feeding times, which avoid competition with other species, but there is no evidence that the arrival of dominant species has any influence on the others birds present at carcasses.

6.3.3 The importance of the lappet-faced vulture as a scavenger in this desert ecosystem

(1) Morphology

The body size of the avian scavengers in the study area ranged in weight from 500 g to 8000g, (Table 6.5). The amount of food which could be eaten by the lappet-faced vulture was estimated from weighing carcasses as described in the methods, and I found that this was approximately 13% of their body weight. If we assumed that other scavenging birds were able to utilize the same percentage it suggests the food consumption figures given in table (6.5). The lappet-faced vulture obviously can consume more than all the other scavenging birds because of its greater size (Table 6.5). Furthermore, the body size plays a major role in competition between the species, and it has been shown among vulture species that smaller birds move aside when the larger species approach the food patch (Wallace and Temple 1987).

Kruuk's (1967) studies on the East African vultures suggested that the six common species in that area could be separated into three pairs according to their bill strength, structure and feeding behaviour. The smaller species which tend to feed on smaller scraps around the carcasses and pecking at orifices (eyes, mouth, rectum), include the Egyptian vulture and the raven (Table 6.6). The second group contained the eagles and the griffon vultures which tend to feed primarily by pulling the soft muscles and viscera off their prey. The third group contained the lappet-faced vulture, which feeds primarily on the hides, tougher parts of a carcass such as tendons and bones of smaller ungulates, but can also feed on muscle and softer tissues. Thus, the lappet-faced vulture can probably feed from a wider range of parts of the carcass than any other species. In a desert environment, where dehydration can cause soft tissue to become hard and leathery, the strength and tearing ability of the lappet-faced vulture is probably of particular benefit.

(2) Status

The avian scavengers could be divided into three groups according to their seasonal presence and their use of the study area (Table 6.7). Firstly, the resident species, which are present all the year around in the area. Secondly, the species which use the area for feeding only but which leave the area for breeding; these species such as Egyptian and griffon vultures were observed mostly in Summer and Autumn. Finally, the winter visitors or the migratory species include the eagles and cinereorus vultures, (very rare and only observed once at Zalm area).

The number of species attending the carcasses will also play a role in terms of total food consumption. Out of 42 counts made of the total number of birds seen at carcasses which had been placed or found at the study area Egyptian vulture was poorly represented with a maximum number of five birds at the carcasses (Figure 6.6). The eagles did attend and feed in high numbers, but they were only present in the study area for a short period in year. It is clear that the ravens and lappet-faced vultures were the most frequent birds found feeding from the carcasses.

6.4 Discussion

The extinction of wild ungulates in the study area and the increase of domestic ungulates demonstrated in chapter 3 has had a detrimental effect on the native ground vegetation. Many previously undisturbed areas have become accessible to hunters due to the construction of new roads, and the availability of 4-wheel drive vehicles. This has resulted in the decline of wild ungulates such as gazelles and Arabian oryx.

Additionally, large carnivores, which used to prey on wild ungulates, have started to feed on the increasing domestic herds, leading to a negative attitude of the local people towards these animals. Predators such as wolf and hyena are now absent from most areas in Saudi Arabia (Child and Grainger 1990). Although there were other mammalian scavengers in the area, such as the foxes, they have other alternative food supplies and they mainly feed on insects and small mammals (Olfermann 1993; Olfermann 1994). The other feral mammals occur only near the small towns and villages where they feed from the garbage dumps. It was difficult to estimate the amount of scavenging carried out by mammals, but they were not responsible for removing substantial amounts from the provided carcasses. Further studies are needed to determine the actual amount of food these mammalian carnivores obtain by scavenging. By contrast studies in the Serengeti showed that mammalian carnivores obtained 5 to 10 percent of their food from scavenging (Schaller 1972; Kruuk 1972).

The avian scavengers are more successful than the mammalian scavengers in utilizing these carcasses. Birds have many advantages in searching for food from the air, because they can cover large areas, and by watching other birds they can collaborate to find food. Pennycuick (1975) estimated the horizontal speed of a vulture in steep dive can reach 70km/h while the running speed of a hyena is about 40 km/h, so vultures can cover large areas with little energy while mammalian runners use considerably more energy to reach food (Schmidt- Nielson 1972; Pennycuick 1975).

Houston's (1976a) studies in the Serengeti implied that vultures do not gain an advantage over mammalian scavengers just because they get to the carcasses first. Their advantage is that they find carcasses that the mammalian scavengers often never reach at all. In the study area the mammalian carnivores are nocturnal and they feed chiefly at night, therefore, competition at the food source was reduced between this group and the scavenging birds, but it was also found that mammalian scavengers failed to locate most of the sources of food provided.

The decline in mammalian carnivores, and the large amount of livestock carrion now available has given benefits to avian scavengers. especially the lappet-faced vulture, which is clearly the most important species in utilizing this source of food. The competition between the scavenging species was reduced because the different species used different times to attend the carcasses.

The heat and high soil temperatures, which could reach 69°C in Summer, probably play a major role in controlling the number of insects at the carcasses. This could have an effect on the amount of food these insects utilized from the carcasses. However, in this study there was insufficient time to consider in any detail the factors which influence insects at carrion. There is obviously a need for more detailed work to understand the role of the invertebrate scavenging communities in this desert ecosystem.

Larger species of birds may be better able to drive away competitors at a feeding site, and moreover, they can survive for longer periods between meals than smaller birds (Kruuk 1967; Lack 1971; Wallace and Temple 1987). They also require less energy per day per unit weight than do smaller birds (Konig 1983). Moreover, Pennycuick (1972) has shown that a high wing loading increases flight speed in straight gliding flight at the cost of only a slight deterioration in soaring performance in weak thermals. These factors all make it advantageous for a scavenging bird to be of large body size.

The strong beak enables the lappet-faced vulture to tear the skin of the carcasses whereas the other smaller species are unable to do this. Therefore, the smaller species rely on lappet-faced vultures to open the carcasses.

The ability of the lappet-faced vulture to utilize most parts of the carcasses (skin, soft and tough tissues and bones of the small ungulates) give this bird further advantages over the smaller species. Finally, the smaller scavenging species have other alternative source of food, whereas the lappet-faced vulture probably depends on carrion for feeding. Thus, we can conclude that the majority of food removed from the carcasses was done by the lappet-faced vulture, and this species is the major scavenger species. The amount of food available to the scavenging species in the study area was more than they could utilize, and there were large proportions of the carcasses which were uneaten by any of the large scavenger species.

Table 6.1 The percentage of food utilized by the three groups of scavengers in the study area, from a series of 182 carcasses monitored until all meat had consumed.

Invertebrates & Becteria	Bird scavengers	Mammals
65%	30.6%	4.4%

Table 6.2 The part of the carcass each group of scavenging species utilized.

Type	Insects & Bacteria	Mammals	Birds
Camel	Soft tissue. Skin & tough tisse. All ages from fresh to dehydrated	Soft tissues, Skin & tough tissues (first 10 days)	Soft tissues, Skin & tough tissues, (first week)
Sheep & Goat	-do-	Soft tissues	-do-

Table 6.3 Percentage frequency of interactions among avian scavengers at the carcass, (n = 14, number of aggressive attacks = 1850).

	L.f.v.	Raven	Eagles	Others*
Intraspecific	71.5	39.7	63.3	
Interspecific	28.5	60.3	36.7	
Interspecific Wins	70.9	25.8	64.8	
Interspecific Losses	29.1	74.2	35.2	
Overall proportion interactions	41.8	25.3	30.7	2.2

*Griffon vulture, black kite *Milvus migrans*, Egyptian vulture *Neophron percnopterus* and marsh harrier *Circus aeruginosus*

Table 6. 4 The mean number of species which was actively feeding and dominating the carcasses on different time of the day. From carcasses placed both inside and outside the reserve

Time	Species	(Out) 1st day	(In) 1st day	(Out) 2nd day	(In) 2nd day	(Out) 3rd day	(In) 3 rd day
6-7	Rav	0.6	2	2.3	4.6	0	2.1
	LfV	0	0	0	0.6	2.1	1.1
	E.V	0	0	0.9	2.3	3.7	0
	Eag.	0	0	7.9	0.8	1	2.6
7-8	Rav.	1	1.4	1.7	4.5	0	1.8
	LfV	0	0	0.1	1.6	2.2	0.2
	E.V	0	0	0.8	1.8	3.7	0
	Eag	0	0	6.1	0.3	0.5	2
8-9	Rav.	1	0.7	1.6	3.9	0	0.7
	LfV	0	0	0.3	2.4	1.3	0.2
	E.V	0	1.4	0.4	1.1	3.6	0
	Eag.	0	0	5.8	0.7	0	0.9
9-10	Rav	1.3	0	2.1	3.3	0	5.3
	LfV	0	0	0.4	3.3	1.5	0.3
	E.V	0	1.1	0.2	0.7	2.8	0
	Eag.	0	0	3.5	0.7	0	0
10-11	Rav	1.53	0	3.3	3.2	0	5.3
	LfV	0	0	1.5	4.2	1	0
	E.V	0	0.6	0.2	0.6	1.2	0
	Eag.	0	0	1.3	0.8	0	0
11-12	Rav	1.1	0	3.2	3.2	0	0
	LfV	0	0.2	1.8	4.9	0	0
	E.V	0	0.9	0.9	0	0	2.7
	Eag.	0	0	0.3	1.2	0	0
12-13	Rav	0.5	0	1.1	3.7	0	0
	LfV	0	0.3	2.1	7.7	0	11.5
	E.V	0	1	1.8	0	0	2.7
	Eag	0.3	0	0.2	1.4	0	0
13-14	Rav	0.1	0.8	1	3.8	0	0
	LfV	0.6	0.2	2.2	5.3	0	11.5
	E.V	0	1.3	2.7	0	0	0
	Eag.	0.3	0	0.3	2	0	0
14-15	Rav	1	0.8	1.5	4.1	0	0
	LfV	1.6	0	0	2.5	0	0
	E.V	0	1.9	2.8	0	0	0
	Eag.	1.4	0	0	1.9	0	0
15-16	Rav	2.72	0.4	0	4.2	0	0
	LfV	1.5	0	0	2.1	0	0
	E.V	0	1	1.9	0	0	0
	Eag.	4.4	0	0	2.4	0	0
6-17	Rav	2.4	0	0	2.7	0	0
	LfV	0.3	0	0	2.1	0	0
	E.V	0	0.1	0	0	0	0
	Eag.	7.7	0	0	2.5	0	0
17-18	Rav	1.8	1	0	1.3	0	0
	LfV	0	0	0	2.1	0	0
	E.V	0	0.1	0	0	0	0
	Eag.	8.6	0	0	2.2	0	0

Eagle (Eag.), Egyptian vulture (E.V), Lappet-faced vulture (LfV) and Raven (Rav.)

Table 6.5 Estimation of relative size, weight and the amount of food the avian scavenging species in the area could consume at one feeding period.

Species	Body length* (cm)	Weight* (g)	Maximum amount of food consumed (g)
Raven	45	500	65
Eagles	88	3000	390
Egyptian Vulture	68	2500	325
Lappet-faced vulture	115	8000	1040

* Based on Cramp and Simmons (1980), Mundy *et al.* (1992), and Newton pers. comm.

Table 6.6 The methods of feeding and differences in the beak function between the four common scavenging birds species in the study area (From Kruuk 1967).

Species	Methods of feeding	Beak functions
Ravens	Pecking at orifices (eyes, mouth, rectum), and eating insects on or around the carcasses	Pecking
Egyptian vulture	Pecking at orifices (eyes, mouth, rectum), eating meat, viscera and pecking scraps on bones.	Pecking
Eagles	Pecking at orifices (eyes, mouth, rectum), eating meat, viscera, and pecking scraps on bones.	Pulling
Lappet-faced vulture	Tearing off skin and tough tissues, eating meat, skin, and bones	Tearing

Table 6.7 The period when different species were present in the study area (personal observations)

Species	Period of their occurrence	Group
Ravens	All the year	Resident
Eagles	Late August to early March	Winter visitor
Egyptian vulture & Griffon vulture	All the year	Feeding
Lappet-faced vulture	All the year	Resident

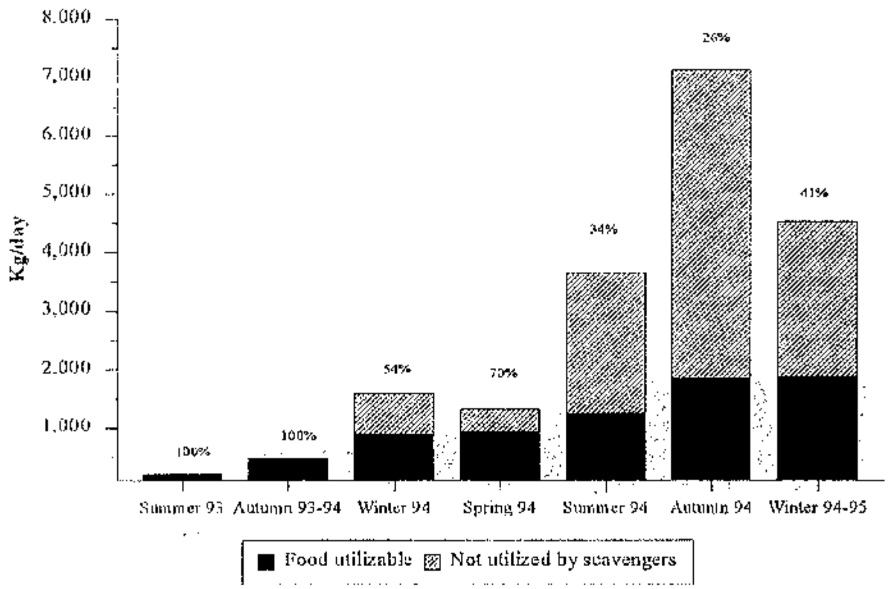


Figure 6.1 Biomass of carcasses available, and the proportion (%) utilized by scavenging species

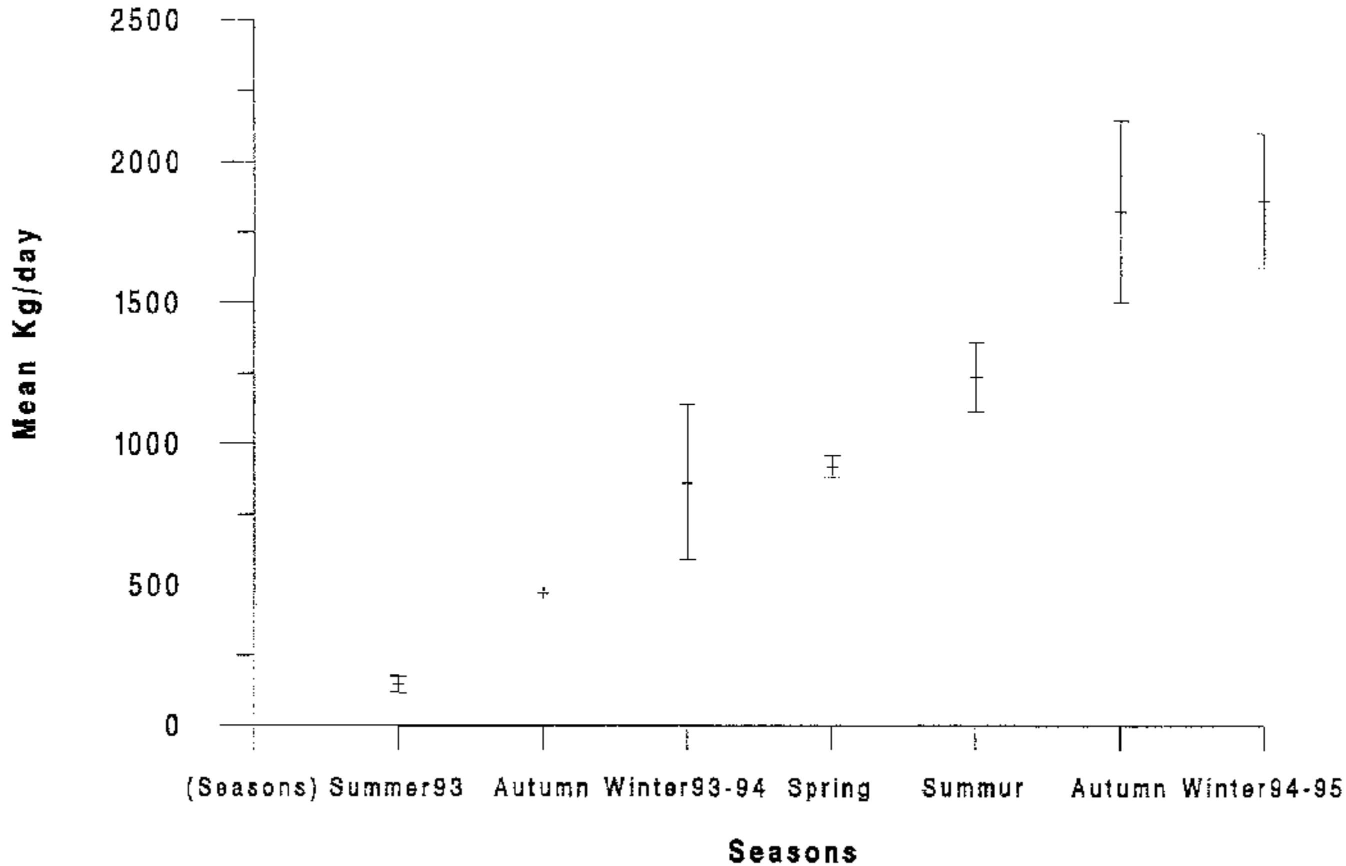


Figure 6.2 The mean biomass consumeded by all the scavenging species in different seasons (bars represent the standard errors)

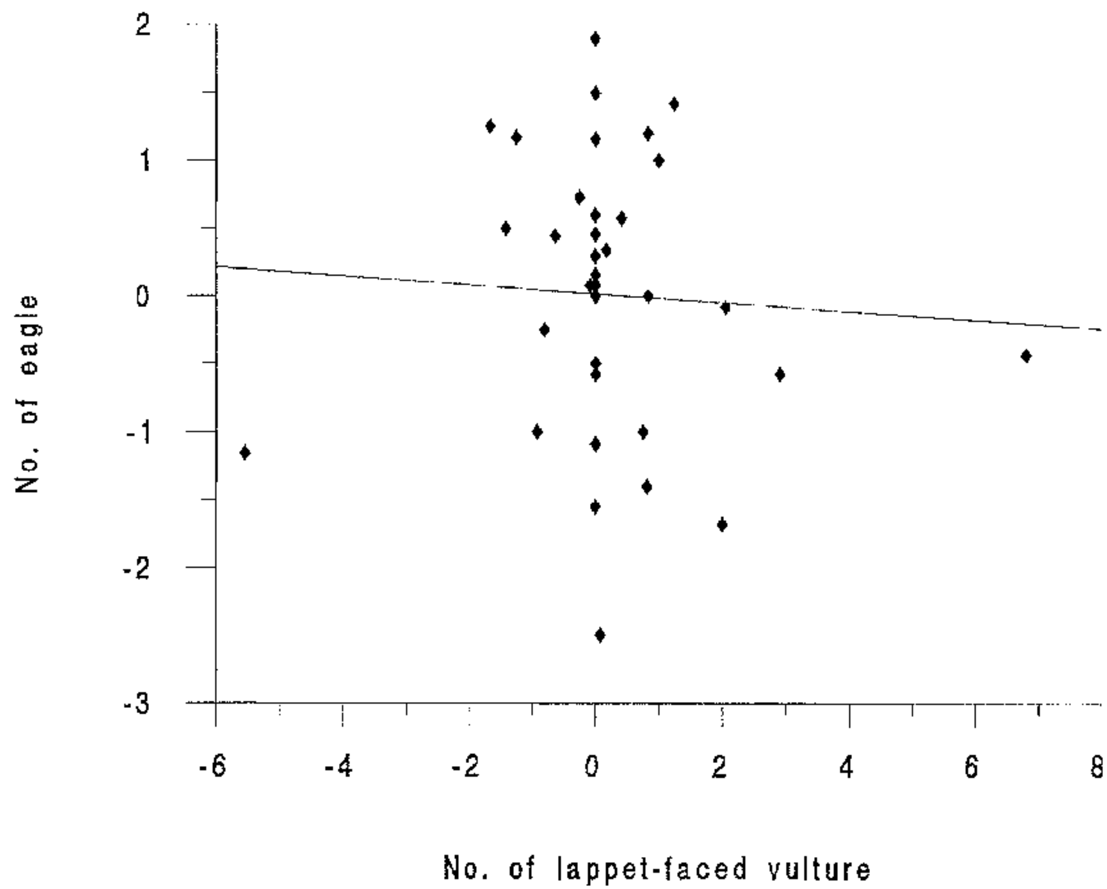


Figure 6.3 The relationship between the changes in the numbers of lappet-faced vultures and eagles at the food site.

$y = 0.02072 - 0.03282x \quad r^2 = 0.00317$

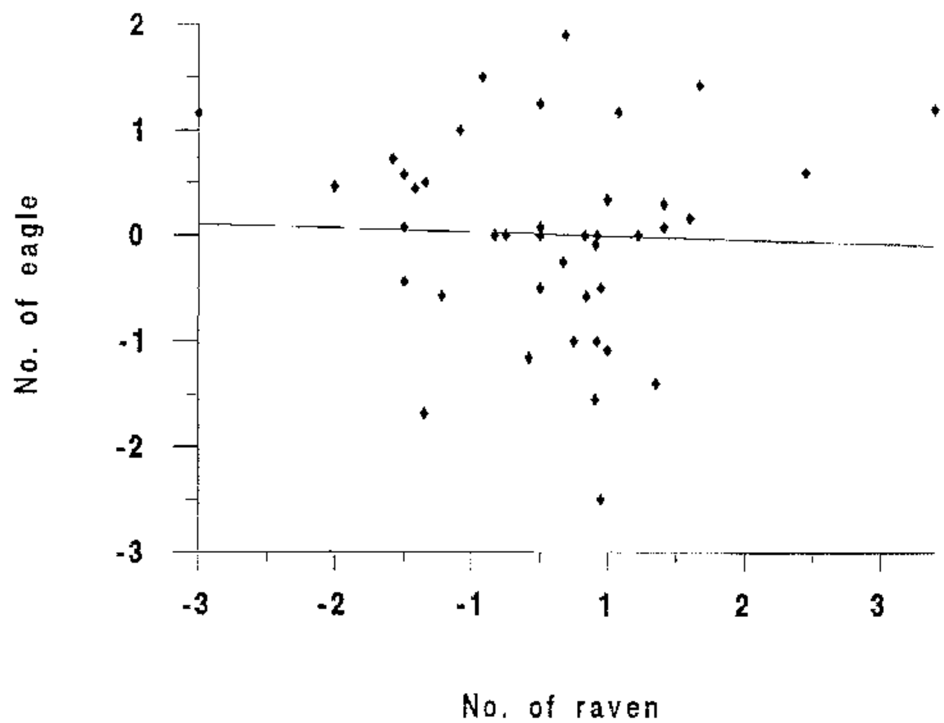


Figure 6.4 The relationship between the changes in the numbers of ravens and eagles at a food site.

$(y = 0.01765 - 0.03806x \quad r^2 = 0.00144)$

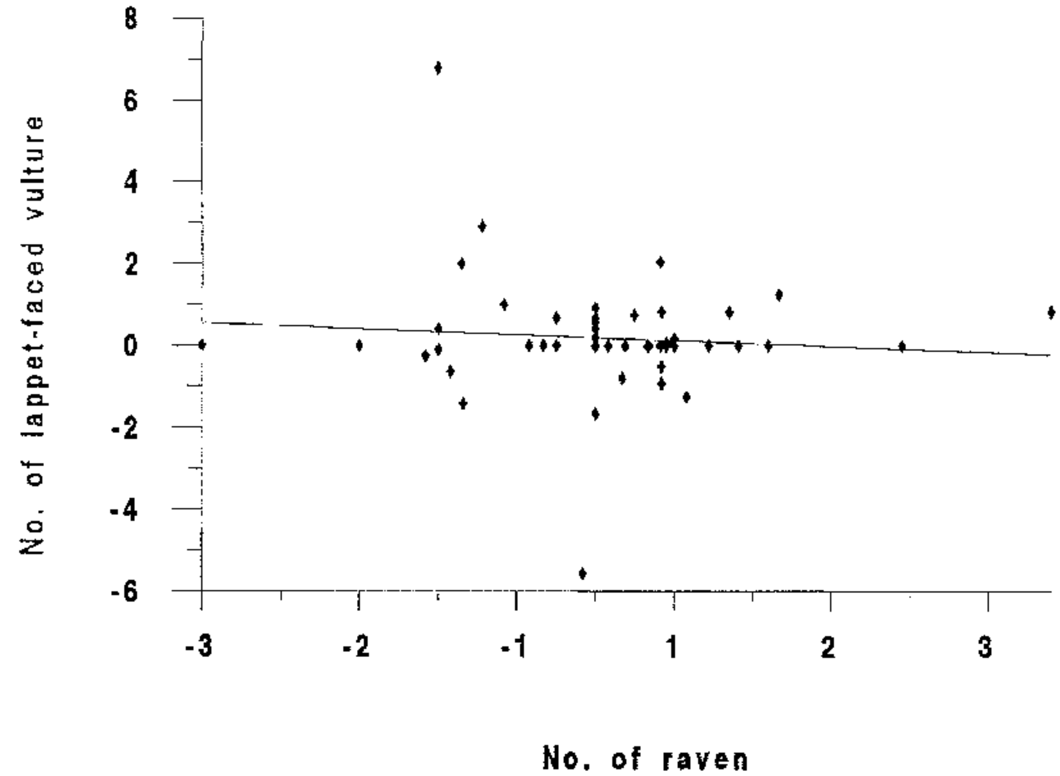


Figure 6.5 The relationship between changes in the numbers of ravens and Lappet-faced vultures at a food site.

(y = 0.20333 - 0.14353x r^2 = 0.00690)

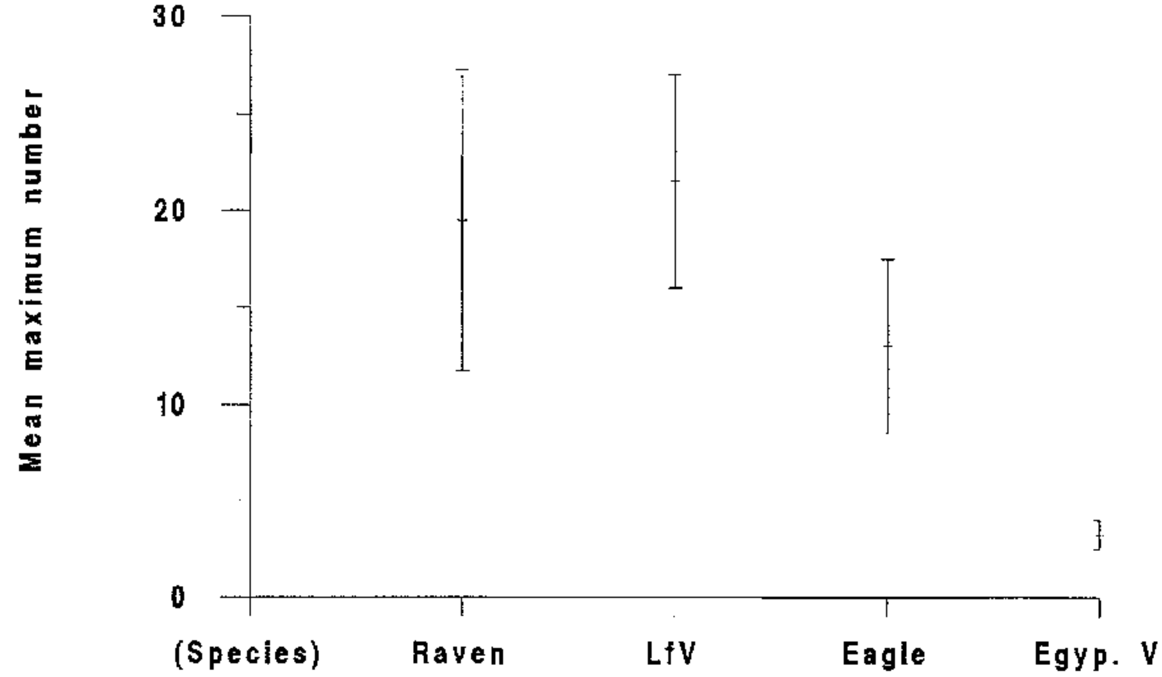
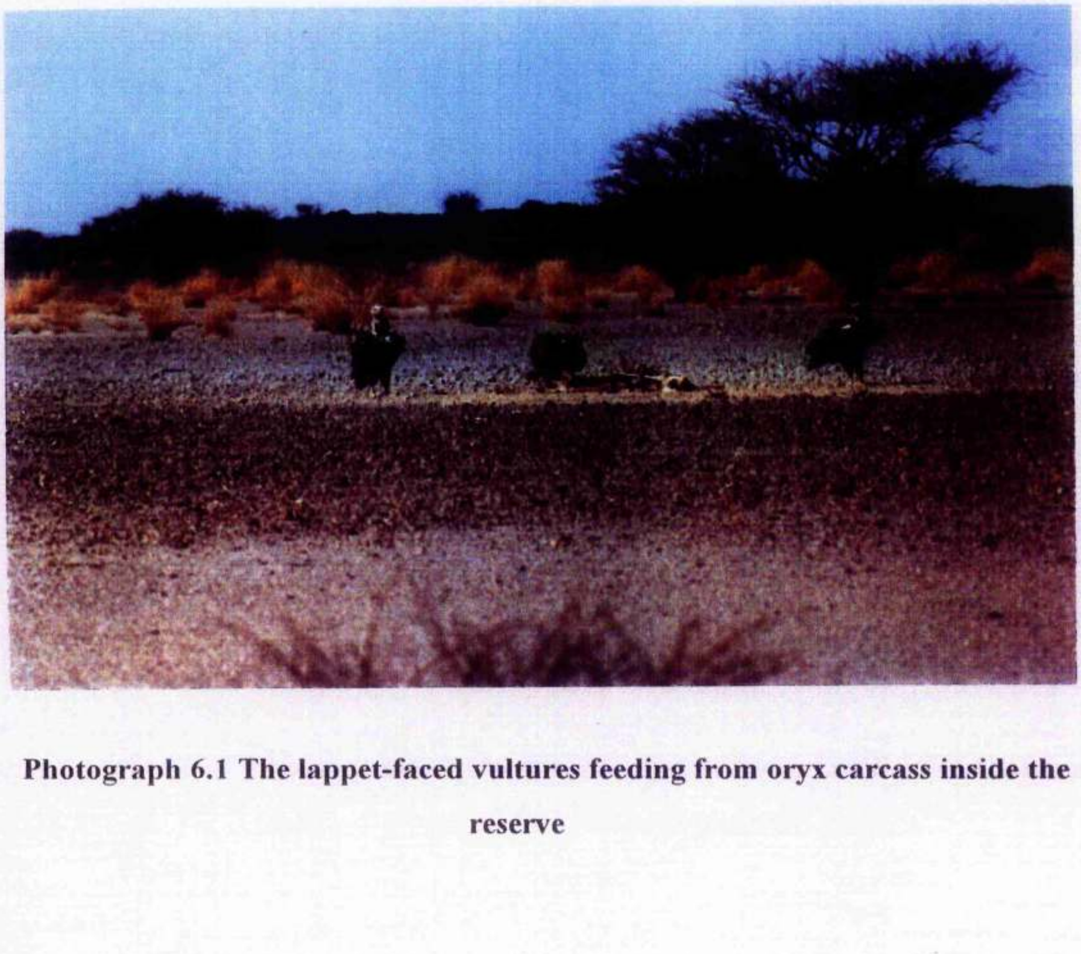


Figure 6.6 The mean number of each species of scavenging bird attending the carcasses in the study area, n=42 (bars represents the standard errors)



Photograph 6.1 The lappet-faced vultures feeding from oryx carcass inside the reserve

Photograph 6.2 The wild carnivores were a target of persecution from the local people.

Photograph 6. 3 The red fox (top), feral dogs feeding from carcass near settlement (bottom).

Chapter 7. Parental investment in breeding

7.1 Introduction

The breeding of large birds of prey such as vultures poses several interesting questions, especially concerning the significance of their low reproductive potential (Amadon 1964; 1980). All species of vulture take several years to reach sexual maturity and have a low reproductive rate once breeding age is reached (Houston 1980; Mundy *et al.* 1992)

The lappet-faced vulture is the only Afrotropical vulture species present in the Middle East (Archer and Godmen 1937; Brown *et al.* 1982; Newton and Newton in Press). The clutch is usually one egg, the colour is off-white or cream, and the incubation period is between 54-56 days (Newton and Newton in press; Mundy *et al* 1992). Little detailed work has been done on the breeding biology of this species in Saudi Arabia (Jennings and Fryer 1984; Newton and Shobrak 1993). In a standard treatise on Arabian birds the lappet-faced vulture has been mentioned only twice (Meinertzhagen 1954). The status of this species in the Arabian Peninsula has been reviewed by Jennings and Fryer (1984) and Newton and Shobrak (1993). It has been declining in other areas in Africa and Israel (Leshem 1984; Mundy *et al.* 1992), and the number of breeding birds in Saudi Arabia is estimated at only 1000 breeding pairs (Newton and Shobrak 1993).

A part of the National Commission for Wildlife Conservation and Development (NCWCD) strategy is to protect the endangered species in Saudi Arabia and other species which have a conservation value in the area (Child and Geranger 1990; Smith 1994). In 1989 when the NCWCD established a fenced area of 2321 km^2 for the future reintroduction of some endangered birds and ungulates in the country, a number of bird species were attracted to this undisturbed area. One of these species was the lappet-faced vulture, whose numbers started to increase. In 1991, 100 birds were counted, (Weigeldt and Schultz 1992). Because of the conservation value of the species the NCWCD started in 1992 a long term programme to monitor the vulture population and study their breeding biology (Newton and Shobrak 1993; Shobrak *et al.* 1994; Shobrak *et al.* 1995). Data on the details of breeding success of these birds is being published elsewhere (Newton and Newton in Press), and this chapter concentrates on the investment made by adult lappet-faced vultures in the breeding season. This has implications for the conservation management of the species, for it determines how long adult birds must remain resident at the nest site and the extent to which a breeding attempt reduces the time that they have available for foraging each day. The study was made with the following aims;

- to determine the timing of the breeding season, choice of nest sites, period in which copulation occurs, and the time spent incubating by the two sexes.
- to determine the length of time spent guarding the chick by the adults, and the length of the post-fledging dependence period.
- to obtain data on chick feeding frequency and the food requirements of the chick.
- to obtain data on the importance of shading the chick from direct sunlight.
- to obtain data on the activity pattern of the nestling.

7.2 Methods

To determine the parental investment in breeding, two nests in 1992, three nests in 1993, and three nests in 1994 were observed several times during the breeding season for a full day from dawn to dusk. A total of 564 hours were spent over a 47 day period. Five of these days were spent watching nests while adults were incubating, covering the early, middle and late incubation periods. No observations were made at night, but it is known that vultures do not fly after dark and so no nest changeovers would have occured during darkness. The observations were made using the car as a hide, which was parked 70-150 m away from the nests, and activity was monitored using a telescope, and binoculars.

7.2.1 The timing of the breeding season, copulation, and time spent incubating by the two sexes

Nest sites were located in three ways, during the ground surveys, aerial surveys, and from information received by the other researchers and rangers in the reserve. Most of the measurements of the heights of the nests in the reserve were made by the field supervisor: Dr. Stephen Newton. Nests outside the reserve were measured by myself. The ground surveys for nests were carried out while carrying out other field work to count the livestock and check some camps around the reserve, as well as during the radio tracking. The aerial surveys were made during the livestock counts which are described in chapter 3. The whole of the study area was covered during the aerial surveys, and it is unlikely that any nest sites would have gone undetected.

7.2.2 Guarding the nestling and the post-fledging dependence period

The presence of the adults in the nest or guarding the chick was recorded during 39 days of observations at eight nests with chicks of different ages. All the chicks were marked with a metal ring (Saudi Arabian rings) carrying a number and the address of the National Commission for Wildlife Conservation and Development, Riyadh, and plastic rings on the other leg engraved with a large letter. 11 nestlings in 1993 were also fitted with a wing-tag coded with numbers, with which the bird could be identified while standing or flying when the leg rings were hidden from view.

Five chicks in 1994 were fitted with radio transmitters shortly before fledging, and in this way the position of the chick with respect to the nest could be checked from a distance without disturbing the fledging nestling. The nests were visited 1-2 times a week after the chicks had fledged. Aerial surveys under also made in single-engine STOL aircraft, (Maule M6) to track the radio-tagged juveniles in and outside the reserve. 19 flying hours were made over the nest areas from July 1994 to September 1995 to determine the post-fledging period. In addition, a total of 131 visits were made during the study period to nests other than those receiving intensive study in the reserve to record the presence of the chick and activity of the adults in the nest. Visits were made both on the ground and by aerial surveys.

7.2.3 Chick feeding and energy requirements

The investment made by adults in feeding the chicks was studied by counting the number of trips each pair made to bring food to the nestling during the nest observations, and the time spent foraging between leaving the nest and returning. The number of occasions on which the chick was fed was recorded, and whether the nestling fed from its parents bill directly or from food which was regurgitated by the adults onto the nest. The energy requirments were estimated using the formula for existance metabolism made by Kendeigh (1970), in which he used published information on the energy requirements in captivity of 18 species to correlate this with body weight and found that for non passerines:

$$\text{Log } M = -0.2673 + 0.7545 \text{ Log } W \pm 0.063$$

The weight of the nestlings were taken from growth curves (body-mass versus age) of the lappet-faced vultures nesting in Mahazat as-Sayd reserve made by Newton and Newton (in Press), and Microsoft Excel was used for the calculations. This estimate is not present the actual energy requirements of the nestlings as it shown in Houston's (1976b) studies on the griffon vultures that the food requirements in the breeding seasons can be increase up to 3 or 4 times greater than when area not breeding. The food intake was estimated by using the assumption of Houston (1971) in which he assumed that 100 gram of tissues from a carcass had a calorific value of about 125 kcals. The digestive efficiency of lappet-faced vultures was estimated as 81% of the total food intake. This percentage is the mean value from studies on the absorptive efficiency in the whitebacked vulture (82%, Kendeigh 1970), the Rüppells griffon vulture "83%" (Houston 1971; Houston 1988), and a range of Falconiformes which varied between 75-82%, (Barton and Houston 1993).

7.2. 3 The importance of shading the chick from direct sunlight

The importance of shading to the chick was considered by recording the time which the adult spent shading the chick and the methods they used in shading. The direction of the adult and the chick at the nest (if they were facing or not facing the sun) was recorded every five minutes, and a total of 4747 records were made over 311 hours of observations.

The posture position of the bird also plays a major role in protecting the chick from the heat. Studies on vultures have shown that the bare skin areas in the head, chest, and legs are important in heat regulation (Larochelle *et al.* 1982; Arad *et al.* 1989; Bahat 1995). Therefore, observations at the nest were made to record the chicks' posture. Five categories were recorded, the wing position (normal, slightly down, completely down, one wing spread or both wings spread); head position (up, down, hunched or resting on the back); body position (standing, sitting or crouched).

7.2.5 The activity pattern of the nestling.

The activity pattern in the nest with chicks of different ages were recorded using two types of observations; scanning samples and the focal animal watches. For the scanning samples the activity of adults in the nest was observed every five minutes, when seven categories were recorded such as preening, feeding, interacting, maintaining the nest, sleeping, watching, and flying. Some of these behavioural categories were divided into sub-categories such as preening (wing, tail, belly, neck and back), feeding and interactions (the same species or other species). The second type of observation was the continuous observation for the first five minutes at ten minute intervals, using a stop watch (Casio). These observations were conducted at three nests in 1993.

7.3 Results

7.3.1 The nesting time and sites, copulation, and the time spent incubating by the two sexes

(I) The nesting time and sites

Out of the eight nests which were intensively observed, nest building had started in all of them in late November. During 1991-1992 and 1994-1995 breeding seasons the majority of birds built a new nest within 100-1000m of the previous nest. However, one pair in 1994-1995 used a nest built in 1991-1992. The early stages of nest building were not observed, because I was in Glasgow in the Autumn of 1992/93, however, the majority of eggs were laid in December and early January. The laying dates, incubation and fledging periods, and the nestling growth rate have already been discussed by Newton and Shobrak (1993) and Newton and Newton (in Press). During the three years of the study 23 chicks were fledged out of 33 eggs laid. Therefore, the overall breeding success was 69% during the three years of studies (Table 7.1)

The nesting sites could be divided into core nesting areas and isolated single nest trees. Two core areas were found in the reserve, the eastern core area which contained the largest number of nests on *Maerua crassifolia* trees (30 nests within $40km^2$), with an average height of 4.6 m (SD $\pm$ 0.87). All the nests which were used for intensive observations were from this area. The second core nesting area was also in the reserve, at the southern end, in which eight nests were found in *Acacia tortilis* trees within an area of $5km^2$, with an average height for nests of 3.7m (SD $\pm$ 0.52). Nine isolated nests were found, of which four were active. Three were found in *Acacia tortilis* trees inside the reserve, two on *Maerua crassifolia* outside the reserve, and one on *Acacia raddiata* outside the reserve(height = 5.1 m). The nests have a bulky structure, and are often visible from a considreable distance on the *Maerua* trees, but those in *Acacia* sp. were well hidden in the canopy of the tree. Details of nest size and construction have been given by Newton and Shobrak (1993) and Newton and Newton (in press)

Nests were located both inside and outside the reserve, but the majority of active nests were found inside the reserve (map 7.1). Outside the reserve, only one active nest was observed in the 1993 breeding season with a chick more than 40-50 days old. In January and February 1994 no active nests were found outside the reserve, and the 1993 nest site had been abandoned. I visited on the ground 5 of the nests outside the reserve and large stones were found in all of them, which were probably thrown by shepherds.

In general, all nests were located in open areas with large trees. However, these trees are mostly found in the main wadis and depressions where water stayed for longer periods. These conditions also encourage a good ground cover of vegetation, which attracts the local shepherds as grazing for their livestock. Lappet-faced vultures were therefore attracted to nest in the areas which had the highest density of shepherds and livestock flocks. Questioning of the shepherds found that most of them considered that vultures might attack their livestock, and did not encourage their use of nests near to camps. Apart from direct persecution to drive birds away, there is also unintended disturbance. All shepherds that I interviewed said that they used the largest trees in the area for shade for themselves and their livestock, and were heavily dependent on this shelter. The largest trees that are most suitable for nesting by lappet-faced vultures are therefore likely to be areas of intense human disturbance which will discourage birds from using them.

(II) Copulation

I spent four days watching one nest shortly before egg laying and observed seven copulations, three on one day at the nest and twice a day on two other occassions also at the nest. On the fourth day the birds were standing 200m from the nest, and no copulations took place.

The copulation started after a head-turning display, during which the head and necks of the two birds droop vertically down, in which their bills are pointed to each other, and they then stretch them upwards and turn the head so that the bills pointed skyward. They then turn their heads and necks around their longitudinal axis. This display was observed also in the roost site and at the carcass. The average time of the copulation was 14.14 second (SD $\pm$ 4.22). However, no copulation was observed during the incubation period, also no rape or extra-pair copulations were seen. After copulation both birds fluffed and started to preen. As in other vulture species, courtship feeding was not observed in this species, (Mendelssohn and Leshem 1983; Mundy *et al.* 1992; Donazar *et al.* 1994).

(III) Time spent incubating by the two sexes.

I used the presence or absence of small feathers on the head, white feathers in the wings, and missing flight feathers to recognise individuals. The observations at one nest in two seasons showed that the female was slightly larger than the male. The female was present at the nest during incubation more than the male. Out of 544 observations at this one nest the female was present on the nest on 483 occasions, significantly more than the 61 observations of the male, ($X^2 = 326$, $P<0.001$). The pattern of incubation by the two pair members was not significantly different from their period of occupation of the nest, ($X^2 = 0.0229$, $P> 0.05$) that is, while the birds were on the nest they spent a similar proportion of time incubating and not incubating.

Out of five days observations the birds stood and stopped incubating for an average of 7.6 times per 12 hour observation day, (SD $\pm$ 1.95). The maximum time the birds spent not incubating was 12 minutes, with an average of 2.7 minutes, SD $\pm$2.3). During this period the bird was seen more than once flying to the ground and bringing back in its beak some *Panicum turgidum* grass, to furnish the nest.

7.3.2 Guarding the nestling and the Post fledging dependence period.

(I) Time spent guarding the nestling

For the whole of the period from when a chick has hatched until it is 55-60 days old, one of the adults stays with the chick on the nest day and night, and the other adult at night often roosts on a tree 20-150m away from the nest. The second bird roosting away from the nest is the first bird to leave the area in the morning. On several occassions when the second bird roosted away from the nest, it visited the nest around 9:00-11:00. But when it roosted near the nest it usually remained until 13:00-14:00 (Fig. 7.1) before flying away. Out of the four days of continuous observations I made during the stage of brooding small chicks, the bird which was brooding the chick overnight (called bird A) remained on the nest for 80% of the subsequent daylight hours. It was relieved for short periods in the day by its mate (bird B), but one was responsible for most of the brooding. From observations at one nest in only one year, the male seems to guard the chick for longer periods than the female. However, more data is needed to confirm this observation.

Bird (A) left the nest for foraging between 10:00-14:00. The average time it spent foraging was 193.2 minutes (SD $\pm$ 12, n = 11). Whenever bird A left to go foraging it was replaced by bird B until it returned. Bird B would then leave for foraging, and usually not return until the late afternoon. Bird B probably spent more time searching and locating the food patches, and it could give some information on food sites to the guarding bird (A) from the direction in which it returned to the nest. This could be the reason why the guarding bird (A) spent a short time in finding the food patches. Alternatively the guarding bird (A) may go to a known feeding area such as the garbage dump were food can be found most of the time.

When the chick is more than 55-68 days old it starts asking for food in an aggressive way, by pecking the adult's bill frequently. This probably forces its parents to roost at night on trees close to the nest and to leave the chick alone on the nest after sun-set; the parents returning to the nest in the early morning. This behaviour was seen at two nests in 1992 and 1994. When the chick was around 65-78 days old, both adults left the nest during the day to bring food for the chick and the time they spent at the nest was short, and restricted to the time needed for feeding the chick and resting; the average time the adults spend with the chick at the nest was 26.25 min (SD $\pm$17.02, n= 6). The adults were seen most of the time roosting together in one tree, but in two nests one in 1992, the other in 1994, the two birds were found roosting in two separate trees 100-200 m apart.

There was little risk of predation of the chicks in the nest because one of the parents was continuously present. However, during incubation and rearing the chicks the adult lappet-faced vultures were observed 18 times making aggressive attacks to chase ravens from the nest. At one nest in 1994 a raven was observed pecking at a 28 days old chick until one of the parents came and chased the raven. The ravens succeeded most of the time in stealing some pellets to use as nesting material. I found no evidence that mammalian predators were a serious risk to the birds. In 1993 a chick which was more than 90 days old fell from the nest and I found it in a very weak condition. Water and food were placed on the ground near the nest, to help it to recover. However, on the second day when I visited the site there were tracks of foxes in the area where the food had been placed, but the lappet-faced nestling was still near the tree unharmed. Large fledglings on the ground may, therefore, be able to defend themselves against foxes.

I saw the lappet-faced vultures defend the nest against other vultures (Egyptian vulture and lappet-faced vulture), on three occasions, one with an egg in the nest in which one of the parents was observed chasing another lappet-faced vulture soaring above the nest, the others with chicks more than 50 days old. I observed Egyptian vultures trying to steal food from the nest, but the adults chased it away. In 1992 an Egyptian vulture was seen eating lappet-faced vulture pellets in the nest as soon as the chick left the nest. I have also seen Egyptian vultures in the roost and near carcasses eating lappet-faced vulture pellets, and on two occasions were observed eating from the lappet-faced vulture's faeces. Ravens and the Egyptian vultures probably came to the nest mainly to steal food or nesting material. A chick around 70 days old was observed defending the nest from an adult lappet-faced vulture which was trying to steal food from the nest.

(II) The Post-fledging dependence period

I considered a bird to have fledged if it had left the nest site at least once. However, young birds make only short flights at first, and then return to the nest where they continue to be fed by the adults. It may be some time before the chick leaves the nest permanently. Table (7.2) shows that in the first month after fledging in July the chicks keep returning to be fed at the nest. Almost all the visits which were made to the different nests in the reserve found the fledging chicks to be in the nests. Only one radio-tagged juvenile which fledged in June 1994 was located away from the nest several times in the first month after fledging. In the second month (August) the chicks were still coming to the nest, but not as frequently as in the previous month. Fledging chicks were seen also roosting in trees near the nest site, and sometimes in the communal roost in the reserve away from the nest. In the third month (September), the juveniles left the nest for longer periods but some still returned to the nest or to the common roost site in the reserve. I have never seen fledged chicks being fed by their parents away from the nest site. One juvenile from 1994/95 was located dehydrated, 270 km from the nest in this month, and so some individuals may travel considerable distances by the third month after fledging. In the fourth month (October), the majority of birds started to disappear from the reserve for periods of more than a week. But two radio-tagged birds were seen at the nest site three times. The lappet-faced vulture therefore has a long period between first fledging and the time when the young bird is independent of its parents.

In the the fifth month (November) one nestling was seen twice early in the month in 1994 at the nest. After this period most of the fledging chicks had left the area. The breeding season is starting at this time. After November some the chicks were observed roosting in the communal roost area, but I never observed the chick return to the nest for food. In February 1995 one radio-tagged juvenile from 1994 was located at an active nest site which was in the same area as the nest from which it had fledged the previous year. However, no feeding of fledged nestlings was seen during the breeding season, and the adults at the nest were only seen feeding the nestling from that current season. Moreover, there were some juveniles resighted again in the reserve but not at the nest site. In conclusion, these observations suggest that the post-fledging dependence period for the lappet-faced vulture in Mahazat as-Sayd reserve is probably 4-5 months.

7.3.3 Chick feeding and energy requirements

(I) Chick feeding

The parents made several trips a day to bring food for the chick, ranging from 1-4, and the average number of trips did not increase with the age of the chicks, ($F_{3, 30}$ =2.44, P>0.05), (Fig.7.2). However, there were very significant differences between the number of these trips during the three years of observations. Figure 7.3 shows that far fewer trips were made in 1993 (ANOVA, $F_{2,38}$ =21.44, P<0.001). However, this difference in the feeding trips seems to have had no effect on the number of chicks fledged that year, as table 7.2 showed that the percentage of young fledging out of the total number of eggs laid in 1992/93 was more than the percentage in the previous year 1991/92 and the succeeding year, 1993/94 when the number of trips made by the parents had been greater.

After a feeding trip the adults regurgitated the food onto the edge of the nest. When the nestling is 0-30 days old, it can only eat small food items, and the adult tears small pieces off the meat and feeds them directly to the chick. When the chick has eaten sufficient food if there was any remaining it was eaten by the adult, who may regurgitate and feed the chick again later when it is needed. The chicks of more than 30 days old start feeding directly from the nest after the adults regurgitated the food. However, there were no significant differences between the number of feeds that chicks of different ages received from their parents (Fig. 7.4), ($F_{3, 31}$ = 5.71, P>0.05); similarly, for chicks greater than 30 days old, the average numbers of times chicks fed directly from the nest was not significantly different between chicks of different ages ($F_{2, 28}$ = 8.36, P>0.05), (Fig. 7.5). The adult sometimes brings water to the nestling; this was observed once in 1992. On the arrival of the adult to the nest the chick went into a begging attitude in which it stood with its head below the level of its body, and slightly tilted, so as to enable it to see the adult, and then started to peck at the adult beak until the adult regurgitated fluid.

(II) Energy requirements

On one occasion I weighed the food in the nest soon after the adult regurgitated. This was in a nest where the chick was 137 days old (already fledged). The weight of this food was 219 g of fresh meat and skin of goats. Table (7.3) shows the energy requirements using the formula of Kendeigh (1970) for existance metabolism "Log M = - 0.2673 + 0.7545 Log W $\pm$ 0.063" by the lappet-faced nestling, and estimates of the amount of food the birds required. As the food requirements during breeding greater 3 to 4 times than non breeding (Houston 1976b), therefore the total amount of food the lappet-faced vulture nestling needs from the day it hatches to fledging is approximately 141 kg. And as the fledging chicks stayed in the nest for around a further four months the total amount of food each nestling needed to obtain from the parents could probably reach 300 kg per nestling.

7.3.4 The importance of shading the chick from direct sunlight.

(I) Chick shading

Three types of chick shading were observed at the nest, with shade provided by the adult, the chick's own body, and the nest structure. The adult shading could be divided into three methods, normal brooding, body shade in which the adult stood between the chick and the sun, and wing shade in which the adult extended the wings for a short time to protect the chick from the direct sunlight. When the chick is 0-30 days, it needs to be in the shade most of the time, and the adults shade it by brooding, body shade, and wing shade. On the nest the parents moved young chicks of 0-22 days into their shade. As soon as the chick is old enough to stand on its feet, it starts to move itself into the adult's shade. However, as the chick grows, the time spent by the adults in shading decreases, and the chick starts to shade itself by not facing the sun and by putting the head down to keep it in the shade of its body, (Figure 7.6). By this age the covert and flight feathers are growing strongly, and chicks position themselves so that bare areas of skin are in the shade, and direct sunlight only strikes heavily feathered parts of the body. Nest shading happened on two nests in 1993 when the wind blew the nest so that it was no longer horizontal; thus the chick could stay in the shade for part of the day. This is probably an unusual event, and in most nests the central depression is too shallow to allow much shade from the nest rim.

The average time that adults shaded the chick by spanning the wing was 94.42 seconds (SD $\pm$ 64.28, n= 29). They were observed shading the chicks in this way only when they were less than 90 days old. However, statistically there was no significant difference in the time spent by the adults in shading the chicks with chick age during the first three months of rearing, (Figure 7.7). Shading with open wings was recorded most frequently between 14:00-15:00 (Figure 7.8), when the solar radiation was most intense.

(II) Posture position

As an adaptation to the high temperatures, the adult lappet-faced vultures kept their bare skin areas away from the direct sunlight. During the nest observations I recorded the direction the bird was facing with reference to the sun direction, and also the postures of the head, wings and body.

While brooding or when the adults were standing over the chick the adults positioned themselves so that they were not facing the sun and birds changed their position according to changes in the sun direction Out of 1011 observations at the nest the adults were on 80% of occasions facing in the opposite direction from the sun. The percentage in which the nestling was facing the opposite direction to the sun was 94%, (n= 3736).

Posture of chicks was also strongly influenced by sun position even though they were mostly shaded by the adults. Figure 7.9 shows that the nestlings keep their heads down, especially in the mid-day when the temperatures were more than 40C°, and the head was recorded in the down position significantly more frequently than in the up position in the three age groups of chicks above 30 days old ($X^2 = 240.117$, df= 2, $P<0.001$). Figure 7.10 shows that chicks adopted significantly different wing postures at different time of the day ($X^2 = 19.365$, df = 2, $P<0.001$). The reason for these changes in posture are not clear, but the various methods of holding the wing away from the body may allow air to pass to the bare skin area under the wing and assist in cooling. The body posture of the chick changed with age (table 7.4), and as chicks get older they spend more time standing and less time sitting. Standing may improve air flow under the chick and assist in thermoregulation.

7.3.5 The activity pattern of the chicks in the nest.

Between hatching and about 30 days of age the chicks are brooded almost continuously by the adults, and their activity could not be observed. Observations on activity pattern were therefore confined to three groups of ages, (31-60, 61-90, and > 91 days).

(I) The scanning observations

In the scanning observations there were no significant differences in the type of behaviour shown by chicks of different ages at different times of the day, with the exception of vigilance behaviour, which was most frequently shown by chicks between 61-90. This is probably because at this age adults start to leave the nestling in the nest alone, (Preening, $X^2= 2.805$, Df=4, $P>0.05$; Flying, $X^2= 2.239$, df= 4, $P>0.05$; Feeding, $X^2= 0.642$, df=4, $P>0.05$; Interaction, $X^2= 5.911$, df= 4, $P>0.05$; Sleeping, $X^2= 4.721$, df= 4, $P<0.05$, and vigilance, $X^2= 19.528$, df=4, $P<0.01$). Figure 7.11 shows that for the majority of time the chicks at the nest were sleeping.

Chicks of all ages spent more time preeing the wings than any other part of the body (Fig. 7.12). There were slight differences in the parts of the body preened by the chick as it grew. Other birds seemed to spend more time preeing the under parts of the body, perhaps to keep the feathers open and permit cerculation of air to the skin to assist with cooling. However, the samples sizes were too small for statistical analysis of data. The nestlings older than 91 days practised flying by jumping and flapping the wings frequently, the average time spent in jumping flying was 40.5 seconds per session, (SD $\pm$ 14.84). The nestling mainly interacted with its parents when asking for food, but two chicks older than 91 days were observed attacking house sparrows *Passer domesticus* which had built their nest under the lappet-faced vultures nest. This behaviour seemed to be play rather than aggression. There were other bird species breeding under the lappet-faced vulture nests and no aggressive behaviour was observed against them. Arabian babbler *Turdoides squaiceps*, great grey shrike *Lanius excubitor*, palm dove and the brown-necked raven, all built their nests under the lappet-faced vultures, probably for protection, shade, nesting material and availability of insect food. The pellets of lappet-faced vultures attracted some insects to lay their eggs, and other birds could find maggots for their nestlings. Ravens seem to use this resource especially. I also observed the reaction of birds to low-flying air force Jets above the nest. The nestling immediately lay down in the nest. On one occasion the adult was guarding the chick, and the sudden arrival of the jet caused the chick to lay down, and the adult stood facing the direction of the jet and showed the aggressive behaviour. Presumably this is the behaviour they show to large avian predators such as eagles.

(II) The continuous observations

As in the scanning observations, the chicks in the continuous observations spent most of the time sleeping showing and vigilance behaviour. Table 7.5 shows the activity pattern of birds more than 60 days olds at different times of day. Birds spent significantly more time sleeping than in vigilance behaviour at all times of the day, and similar results were obtained from to the scanning observations (X^2= 14.144, df=2, P<0.001)

7.4 Discussion

7.4.1 Breeding season, copulation behaviour and time spent incubating by the two sexes

(I) The nesting time and sites

The egg laying of the lappet-faced vulture in the study area started in late December and early January (Newton and Shobrak 1993; Newton and Newton in Press). These data are comparable with observations from other areas in the Arabian Peninsula, such as Oman and United Arabs Emarrits (UAE) (Gallagher 1982; Jenning and Fryer 1984; Leshem 1984), within other parts of Saudi Arabia (Jennings and Fryer 1984), and the northern population in Israel (Leshem 1984). Several factors probably influence the timing of breeding and favour the winter season for egg laying. Firstly, it will minimise the thermal stress on both the egg and the incubating adults. Daylight in winter is shorter than other seasons, which will reduce the time exposed to direct sunlight, and in addition thermal radiation is less intense in winter which will reduce the heat stress on the sitting birds.

A second factor could be the food availability, and it is known for some bird species that birds start laying as soon as sufficient food becomes available (Perrins 1970; Lack 1971; Perrins and Birkhead 1983); and this has been suggested for the sparrow hawk *Accipitor nisus* (Newton 1979). In the study area, the calving of camels occurs in the winter, which may in the past have resulted in marked seasonal abundance of food at this time. However, under present conditions there is no evidence that food availability is influencing the time of laying.

A third factor could be that the breeding season is timed so that the period when chicks require a large amount of food coincides with a period of food abundance. In March and April there are many spiny-tailed lizards which can provide the nestlings with calcium. But during the pellet analysis the number of pellets containing spiny-tailed lizards was very low (see chapter 4). Most lambs are born in the spring (Badri, Pers. comm.), which may provide the nestlings with a good food supply and the calcium needed for growth. However, during the period of study the level of mortality among domestic animals varied considerably from one year to the next. Present food conditions are probably not at all similar to the natural pattern of food availability from wild ungulates, under which the timing of the breeding season evolved.

The number of breeding birds in the reserve has increased and birds have started to nest in areas where they have not been observed before (Salem, pers. comm.). The reserve provides an undisturbed place for lappet-faced vultures to breed and most of the suitable nesting trees outside the reserve are surrounded by fences for over-nighting the domestic herds. Only six nests were located outside the reserve, of which only one was active in 1993 and even this had large stones at the nest and between the branches; Jennings and Feyer (1984) reported that local shepherds try to destroy eggs by throwing stones into the nest. In Israel lappet-faced vultures also suffered from disturbance at the nest sites because of the new settlements and military activity near the birds nesting ground. (Bruun *et al.* 1981; Mandelssohne and Leshem 1983). The secure area in the reserve, together with abundant food supplies, are probably the main factors responsible for the higher percentage of survival of the young compared with the African sub-species. Pennycuick's (1976) studies in Serengiti, Tanzania showed that the chick survival rate was 43%. In Zimbabwe the survival rate among the chicks was 55% (Anthony 1976).

In general, disturbance of the nesting sites is one of the major reasons for the decline of raptors (Newton 1979; Mendelssohn and Leshem 1983; Mundy *et al.* 1992). In the study area outside the reserve there were enough trees to support breeding by lappet-faced vultures, but the high number of camps which used these trees and the areas around them must have increased the disturbance pressure on the breeding birds. Unfortunately, the large size of the lappet-faced vulture and the long breeding season have a negative effect in the altitude of the local people, because they think that this bird will attack their livestock. There is clearly a need for good publicity among local people of the need to conserve this species and to emphasise that it poses no threat to farming interests.

(II) Copulation

The long copulatory periods in birds of prey have been already discussed by Cade (1960), Brown (1966), Newton (1979), Lampkin (1983), Møller (1985), Birkhead and Lessells (1988), Aguilera and Alvarez (1989), Westneat *et al.* (1990) and Donazar *et al.* (1994). In this study the average duration of the copulation was similer to that of African lappet-faced vultures (Mundy 1982; Mundy *et al.* 1992). In contrast, some other species of vultures, such as the white-headed, have the copulation lasting for 25-35 seconds, but there does not appear to be any display before or after the copulation, whereas in the lappet-faced vulture the head-turning display was observed several times before each copulation. As in the lappet-faced vulture, the white-backed griffon vulture copulates several times each day at the nest (Houston 1976b; Mundy 1982; Mundy *et al.* 1992).

Several casual observations of individually identifiable birds have shown that extra-pair copulations are frequent in birds of prey (Rivoire and Hüé 1947; Willoughby and Cade 1964; Green 1979; Walter 1979; Mundy 1982; McCrary and Bloom 1984; Poole 1985; Birdhead *et al.* 1987; Møller 1987; Nergo *et al.* 1992; Donazar *et al.* 1994; Koga and Shiraishi 1994). During the observations no extra-pair copulations were observed and all the copulations were seen at the nest sites. Before the egg is laid the pair leave together when they go foraging, and this may be to enable the male to guard the female and prevent extra-pair copulation. It has been shown in other species that the presence of the mate while foraging probably reduces the likelihood of extra-pair copulation (Møller 1987; Birkhead and Møller 1992).

(III) Time incubating by the two sexes.

Differences between the sexes in their parental care have been detected in many bird species. (Brown *et al.* 1978; Davies 1985; Houston and Davies 1985;

Montevecchiand and Porter 1980; Pierotti 1981; Quinn 1990; Malacarne *et al.* 1992; Whittingham and Robertson 1994). Moreover, Mundy *et al.* (1992) showed that the female bearded vulture *Gypaetus barbatus* does all the incubating or the majority of it. This study showed that there was a difference in parental care between the sexes in the lappet-faced vultures. Antony (1976) obtained similar observations when he watched one lappet-faced vulture nest in Africa for 32 hours over a four days period, and during this time only one change-over occurred and one bird incubated non-stop for at least 75 hours. These observations are, however, based on only a few individuals and further work is needed to know if they are typical of this species.

These differences between the sexes could be caused by several factors. Firstly, lappet-faced vultures, like the other species of vultures, have a long breeding season, low reproductive rate, and it takes them several years to reach sexual maturity (Houston 1980; Mundy *et al.* 1992). According to the strict definition of parental investment by Trivers (1972) "any investment by the parent in an individual offspring that increases the offspring's chances of survival at the cost of the parent's ability to invest in other offspring" it follows that within species there can be potential conflict of interest between sexes. The differences in parental contribution in the incubation and chick feeding could be due to variation in the investment made by the two sexes.

Loss of interest by one member of a pair will probably force the other member to work harder than previously. This has been observed in other species of birds (Kluijver 1950; Alatolo *et al.* 1982; Greenlaw and Post 1985; Lefelaar and Robertson 1986; Sasvári 1986; Lyon *et al.* 1987; Wright and Cuthill 1989; Hinsley and Ferns 1994). Similarly, in species which live co-operatively, such as the crowned babbler *Pomatostomus temporalis*, and dunnocks *Prunella modularis*, the parents may work less hard if others do more (Brown *et al.* 1978; Davis 1985; Houston and Davies 1985).

A second factor could be sexual dimorphism. During the observations of copulation and incubation the large birds seemed to be the females and the male appeared slightly smaller. Mendelssonh and Leshem (1983), also reported a similar difference in size between the male and female. Females because of their larger size, may be able to withstand longer incubation periods.

In this study the male did most of the foraging, while the female spent most time incubating and a very short time in foraging. It could be that the male was finding the food patches and informing the female in the nest about the location of these patches so that she could find the food quickly. In addition the difference in the body size may enhance defence of the offspring against predators and the larger female may be better able to defend the nest, (Storer 1966; Reynolds 1972; Snyder and Wiley 1976; Andesson and Norberg 1981).

Thirdly, the difference also could be related to the age and experience of parents. This has been observed in the pallid swift *Apus pallidus* (Malacarne *at el.* 1992) Also the three years of observations on the California condor *Gymnogyps californianus* in captivity showed that the female was incubating more than the male in the first and the second year, but in the third year there was no significant different between the two sexes in the time of incubating (Harvey *et al.* 1994). These differences were related to age and the experience of the individual. In general the interest of each sex in making parental contribution to the incubation and chick feeding are probably due to individual variation, sexual dimorphism, and experience. However, further studies are needed to determine the morphological differences between the sexes in the breeding birds, and their parental investment and foraging methods.

7.4.2 Guarding the chick and the Post-fledging dependence period.

Mundy's 1982 studies on the lappet-faced vulture in Africa showed that " brooding and guarding the chick occurred up to 50 days with almost none after day 60. In contrast the brooding and guarding of the lappet-faced vulture chicks in my study area exceeded 75 days, although some nestlings were seen alone in the nest for short periods at 55 days. No observations of predation by mammals or birds were recorded, even though Ratal *Mellivora capensis* occur in the reserve and are though to be able to remove White-backed vulture nestlings from thorn trees in southern Africa

(Marlow 1983) a species which nests in very similar situations to lappet-faced vultures. Foxes in the reserve were, however, the main predators of inexperience houbara bustard released in the reserve (Combreau and Ramband 1994).

Parental care extends beyond the nestling period in a wide variety of birds (Ashmole and Tovar 1968; Burger 1981; Diamond 1975; Feare 1975; Nelson 1976; Skutch 1976; Bradley *et al.* 1989) including raptors (Brown and Amadon 1968; Newton 1979; Sherrod 1983; Mundy *et al.* 1992). The post fledging dependence periods have been observed for the Crowned eagles *Stephanoetus coronatus* (11,5 months; Brown 1966) Harpy eagles *Harpia harpuja* (10 months; Fowler and Cope 1954) , the California Condor *Gymnogyps californiamus* (7 months; Koford 1953), and Black vultures *Coragys atratus* feed the chicks even away from the nest up to six months after leaving the nest (Jackson 1975).

In the Old World vultures the post-fledging dependence period has been observed only in the lappet-faced vultures and cape vultures (Mundy and Cook 1975; Anthony 1976; Pennycuick 1976; Robertson 1985; Mundy *et al.* 1992). The post-fledging dependence period in the lappet-faced vultures in the reserve was probably four months. In Israel the young birds were recorded staying with their parents until October, which is a similar period. In contrast the post-fledged dependence in the African lappet-faced vulture could last up to six months(Mundy 1982). This shorter post-fledging dependence period in the lappet-faced vulture in the study area may be associated with their dispersal, which will be discussed in the next chapter.

7.4.3 Chick feeding

The lappet-faced vulture in Saudi Arabia depends mostly on livestock for their diet (Shobrak *et al.* 1995). This kind of food is unpredictable in term of quantity and time. The study showed that the number of trips made by the adults was less in 1993. This could be due to the large number of breeding birds that year, which gave better opportunities to find food sites by watching the behaviour of other birds. However, the ground census which was made to determine the food availability (see chapter 3) showed that in summer 1993 the food available for the scavenging species was less than in the summer 1994. There was still an abundance of food for scavengers and the percentage of food which was utilised by the scavenging species in summer was more than the other seasons (see chapter 6). The birds may also have had to go greater distances to locate food.

7.4.4 The important of shading from direct sunlight to the chick.

Birds have many different ranges of thermal neutral zones, which differ according to their geographical distribution and physiological adaptation (Coope 1977; Atkinson *et al.* 1987; Jeffree and Jeffree 1994; Bahat 1995). However, the exact time at which the chicks start to thermoregulate depends on their growth rate and the length of nesting period (Duinn 1975). Some birds, particular the sea-ducks, are well able to respond metabolically to changes in ambient temperatures within a few hours of hatching (Koskimies and Lathi 1964), gulls can do so with 1-2 days (Hall 1979), while galliforms take a few days (Freeman and Vinace 1974).

Studies on vultures have shown that at low temperature the birds avoided as much as possible the exposure of bare skin areas (e.g. head and neck, bare skin areas on the chest, unfeathered areas in the centre of the back and the legs) to reduce heat dissipation. In high ambient temperatures, the griffon vultures tend to stretch their head and neck, and extend their wings or at least hold them folded, but away from the body to radiate heat (Bahat 1995).

Similar postural behaviour has been observed in the New World vultures in studies by Larochelle *et al.* (1982) on the black vulture, and Arad *at el.* (1989) in Turkey vultures. In this study the lappet-faced vulture chick was not left unshaded until its dorsal covering of feathers was well developed, and it was able to thermoregulate well for itself. (Mundy *et. al.* 1992). As in other vulture species the lappet-faced vulture chicks and adults in the nest avoided exposing the head, chest and the legs to the direct sunlight for most of the day. In the study area the heat load provided by solar radiation could reach 1000 Watts/m^2 (See chapter 2), and behavioural mechanisms to reduce heat stress will be important for reducing energy expenditure and survival of both adults and chicks.

7.4.5 The activity pattern of the chick at the nest.

Similar to most birds of prey the lappet-faced vulture chicks in the nest minimise activity (Newton 1979), and spend most of the time sleeping. This probably minimises the use of energy, which the chick reserves for growing. Behavioural changes observed during chick growth were largly associated with the development of flight skills in older chicks, and an increased tendecy to stand in older chicks.

The breeding success of birds within the protected area of the reserve was high and compares farourably with that of other large birds of prey (Newton 1979). We can conclude that, given suitable breeding areas, the lappet-faced vultures have a satisfactory breeding preformance. However, the birds probably face considerable disturbance if they attempt to nest in areas with a high human density, and this may effectively limit their breeding distribution.

Table 7.1 The number of eggs laid and the percentage of the nestlings which fledged

Year	No. of eggs laid	No. fledged	Known to have died shortly after fledging	Survival rate
1991/92	6	4	0	66.67
1992/93	15	11	1	73.33
1993/94	12	8	3	66.67
Total	33	23	4	69%

Table 7.2 The percentage of fledged chicks observed at the nests after fledging, (the Post-fledging dependence period). All years combined.

Period after fledging	No. of visits	No. of nests visited	Percentage of chicks recorded at the nest
1st month (July)	18	16	96
2nd month, (August)	21	15	72
3rd month (September)	21	11	43.7
4th month (October)	8	5	15
5th month ((November)	6	5	6.67
6th month (December)	7	8	0
More than 6 month, January to July	50	10	0.2 (one radio-tagged juvenile from 94 recorded on one occasoin in the nest area)
Total	131	70	

Table 7.3 The estimated food and energy requirements of chicks of the lappet-faced vulture, derived from Kendeigh (1970).

Age (days)	Weight of chick (g)*	Kcals/day	Food intake (g)	Food digested (g)
10	600	68.13475	55	45
20	1400	129.1241	103	83
30	2500	199.9859	160	130
40	4350	303.7342	243	197
50	5200	347.5186	278	225
60	6000	387.1405	310	251
70	6600	416.0059	333	270
80	7400	453.5121	362	293
90	7900	476.4454	381	309
100	7200	444.2331	355	288
110	7100	439.5699	352	285
120	7000	434.8906	348	282

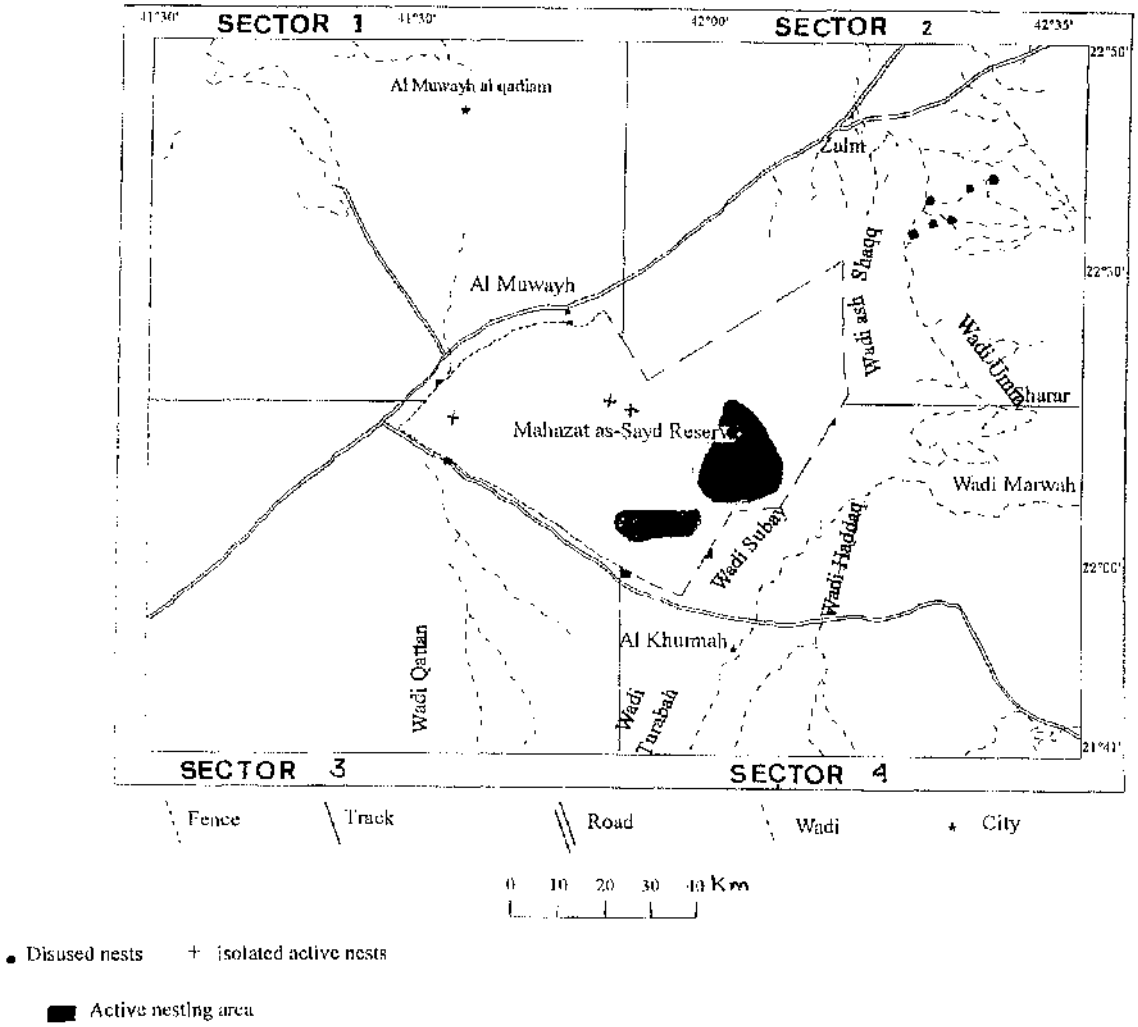
* The weight of the chicks is based on Newton and Newton (in press) measurements of chicks at Mahazat as-Syad reserve in Saudi Arabia.

Table 7.4 The type of body posture adopted by chicks at different ages (n=39 days)

Age in days	Body posture		
	Standing	Sitting	Crouched
0-30	4	67	29
31-60	6.5	59	34.5
61-90	32	31.5	36
>91	59	20	21

Table 7.5 The time (in seconds) spent in different activity during a total 353 minutes continuous observations of three chicks of different age above 60 days (in 1993)

	Time of day (hours)		
Behaviour	**6-10**	**10-14**	**14-18**
Preen	580	533	216
Feed	144	4	77
Interact	1	1	77
Nest Maintainance	1	4	1
Sleep	3318	4104	3888
Vigilance	2956	2376	2809
Fly	6	74	3



Map 7.1 The lappet-faced vulture nests at the study area.

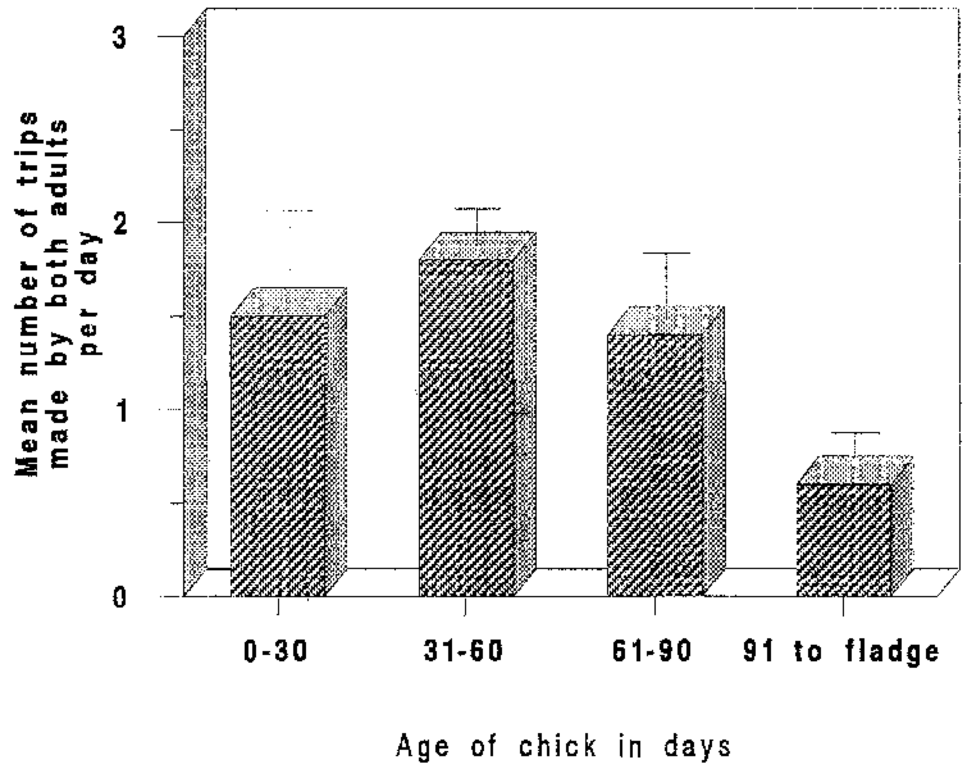


Figure 7.2 The mean number of trips made by the adults to bring food for the chicks at different ages, (bars represnts the standard error), n=39.

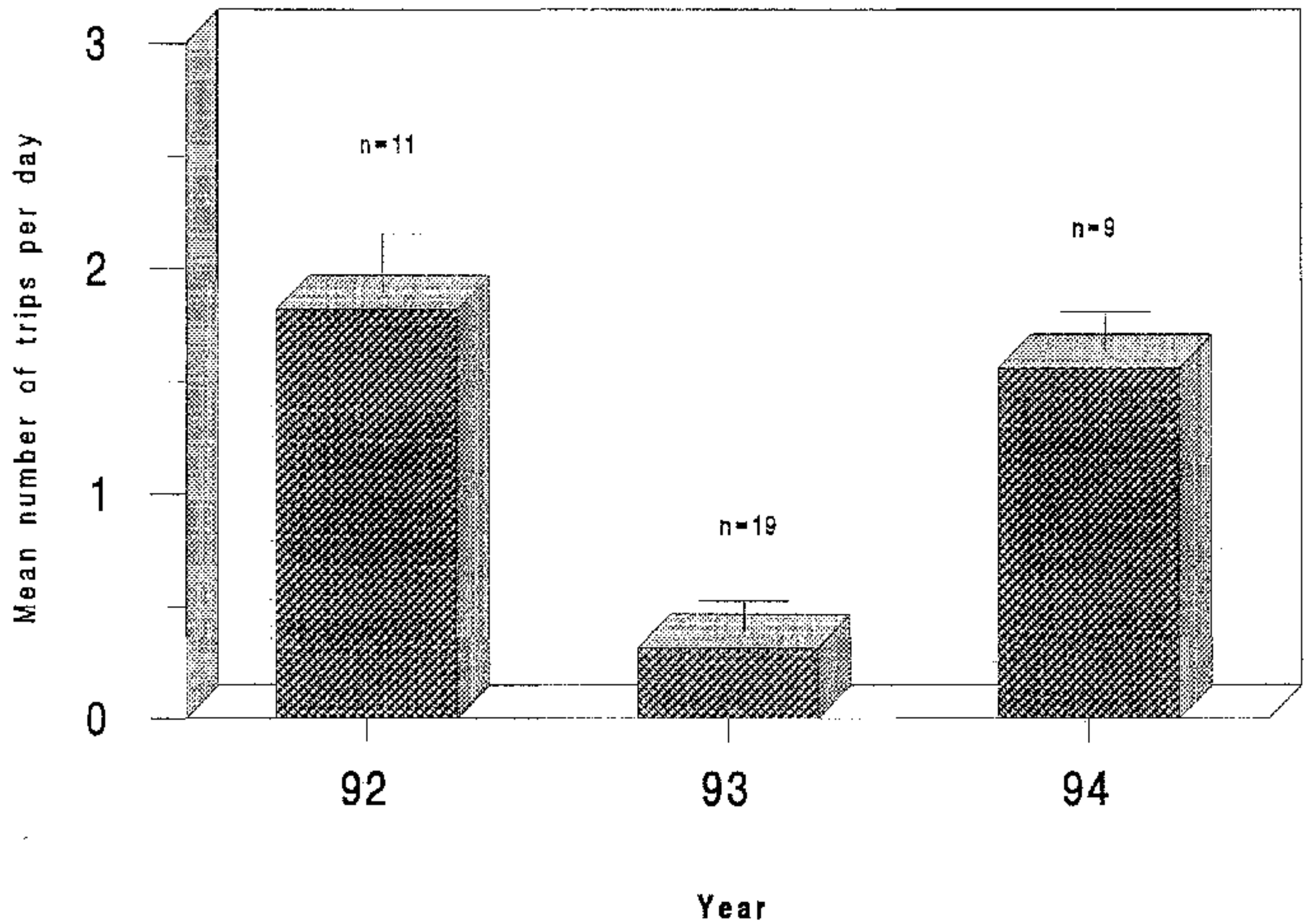


Figure 7.3 The mean number of trips made by adults in three different years, (bars represents the standard error).

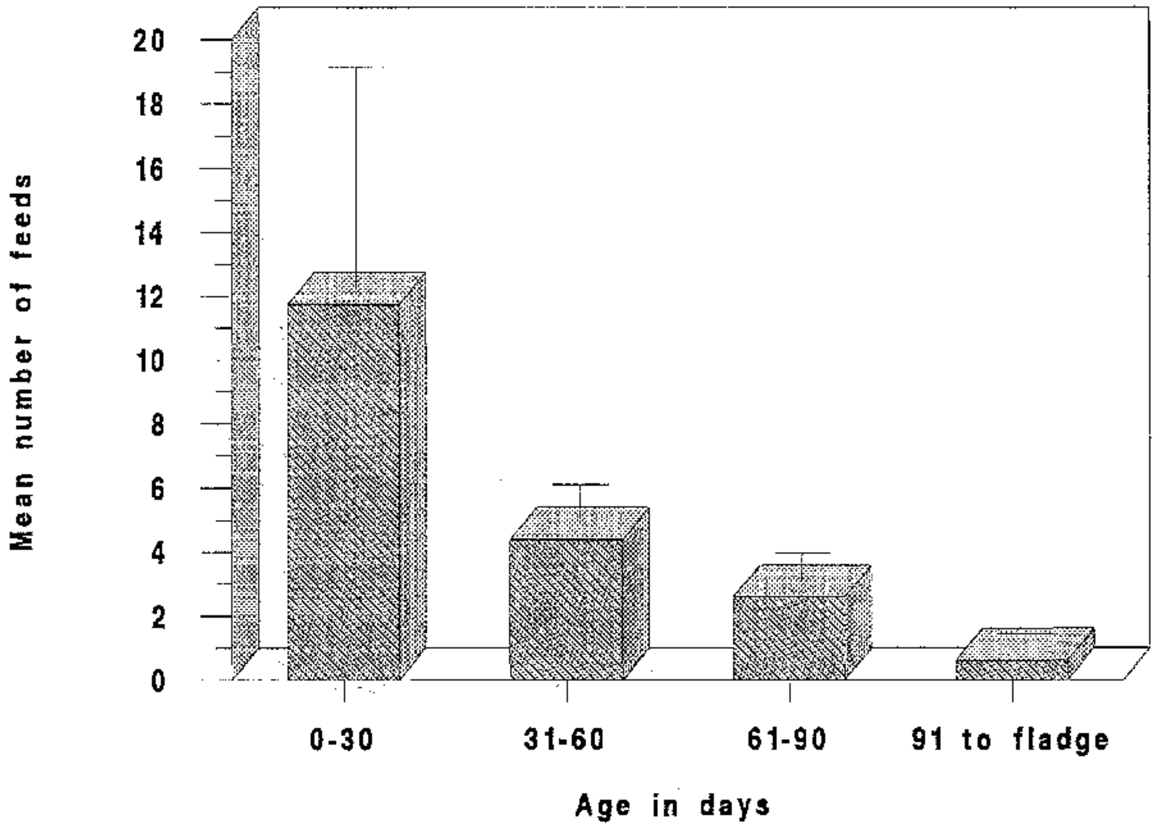


Figure 7.4 The mean number of times chicks were fed directly by adults at different ages, (bars represents standard error), n= 39.

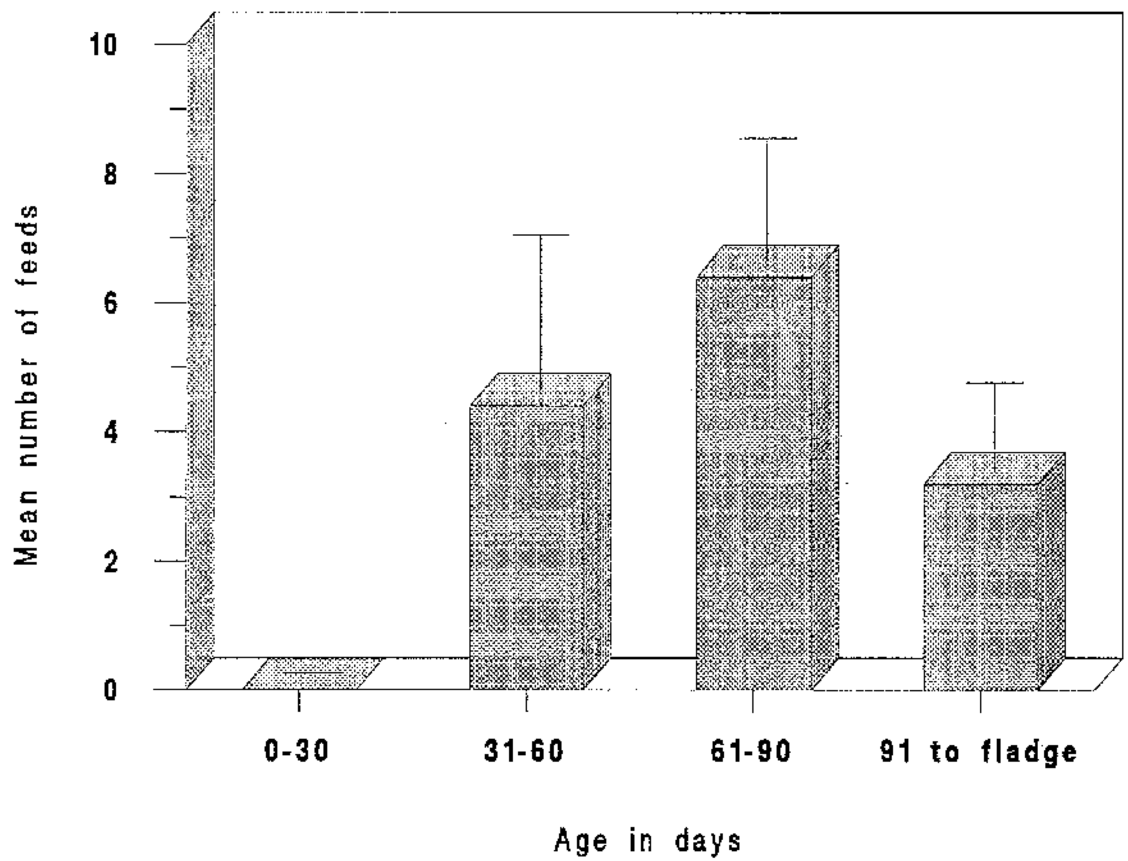


Figure 7.5 The mean number of times chicks fed from food regurgitated in the nest by adults at different ages, (bars represents the standard error), n= 39.

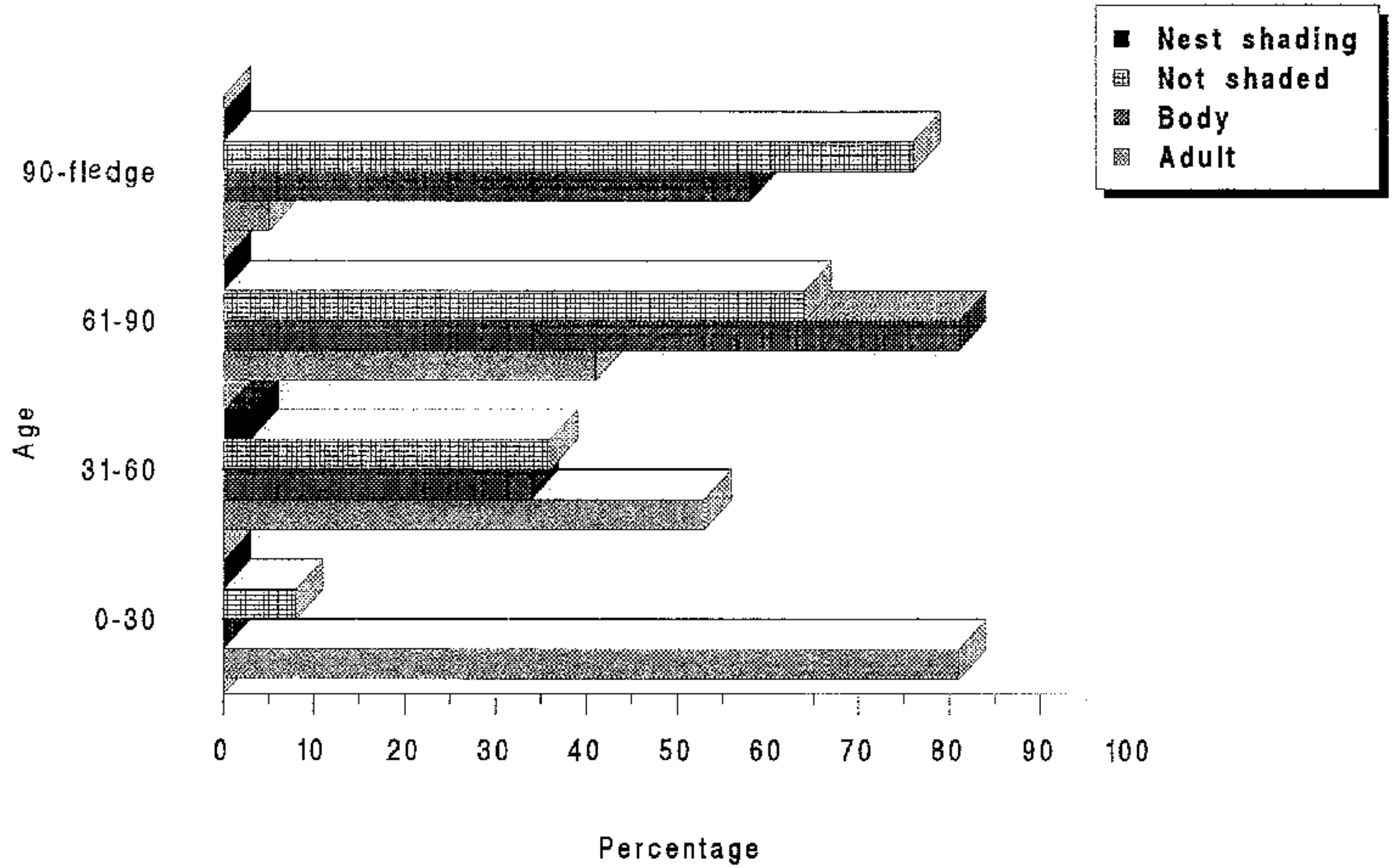


Figure 7.6 percentage of time spent in the shade by chicks of different ages

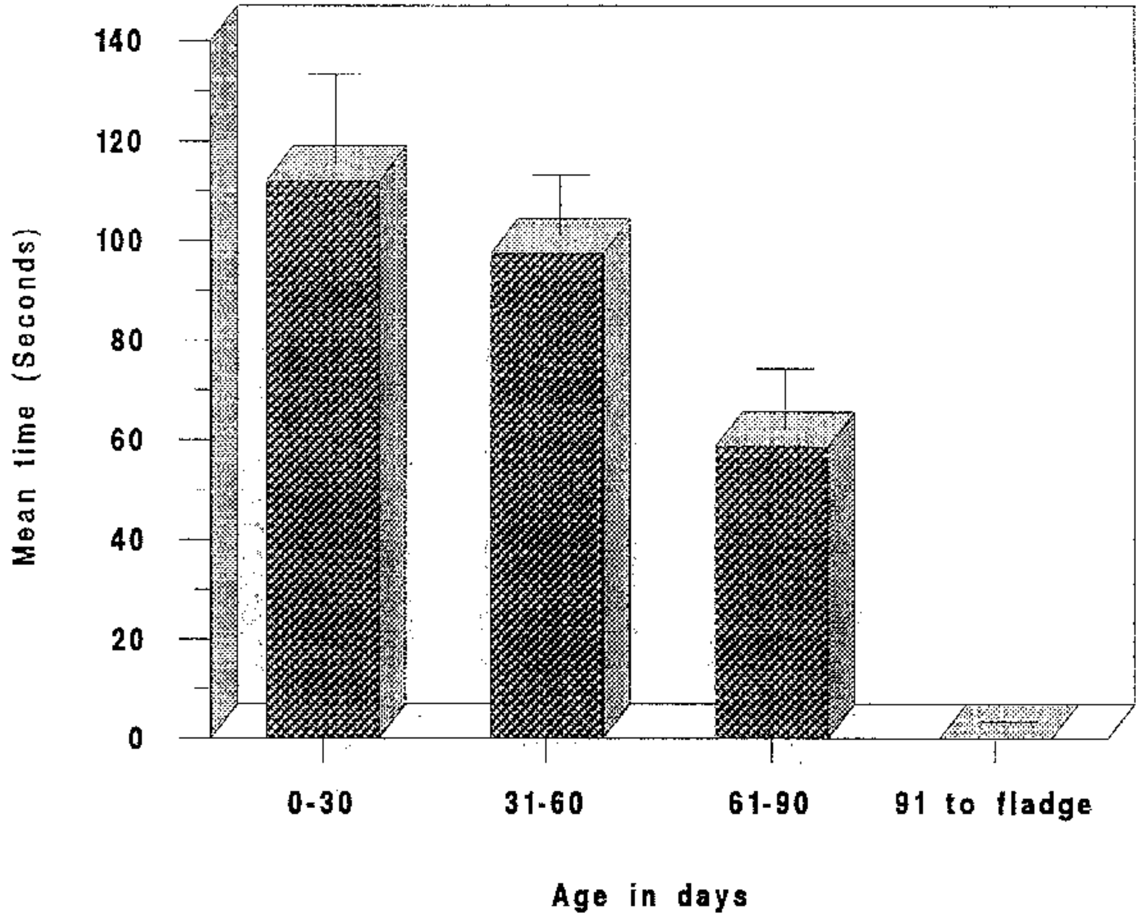


Figure 7.7 The mean duration of time that adults shaded the chicks by wing shading at different ages, (bars represents the standard error).

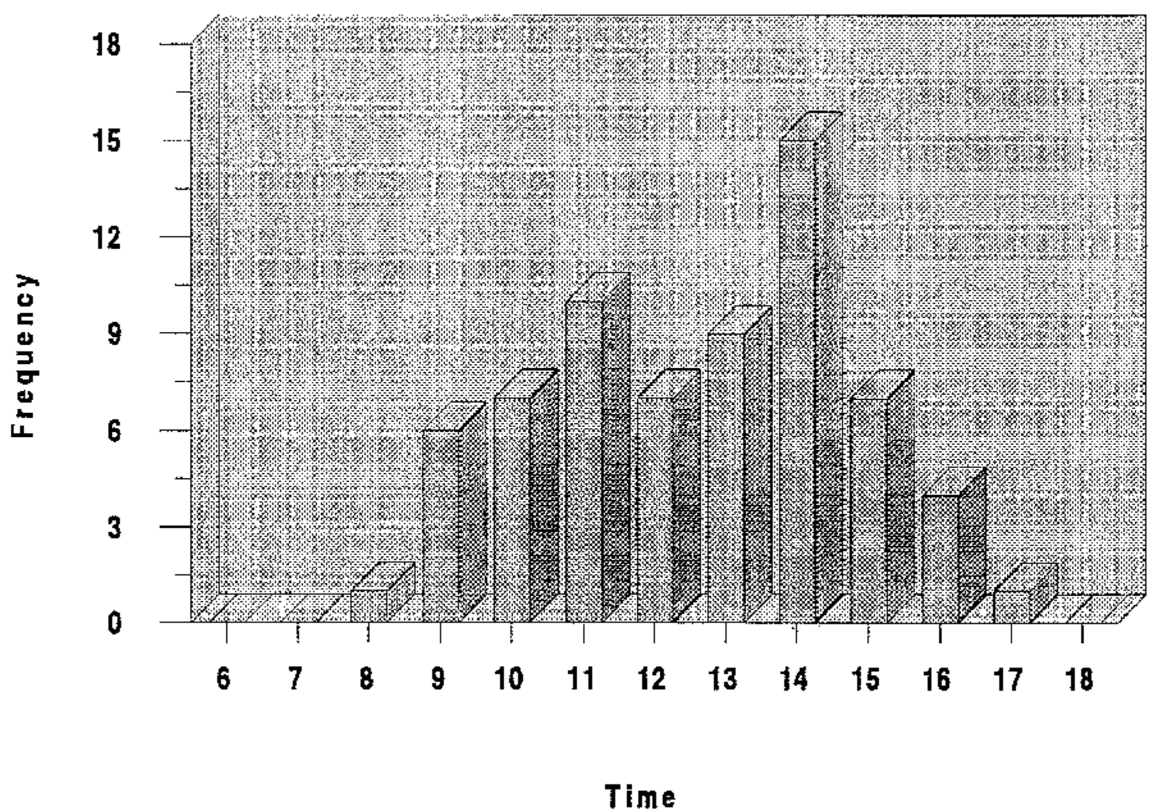


Figure 7.8 The frequency at different times of day with which adult birds were seen shading the chick by opening their wings (n=39 days).

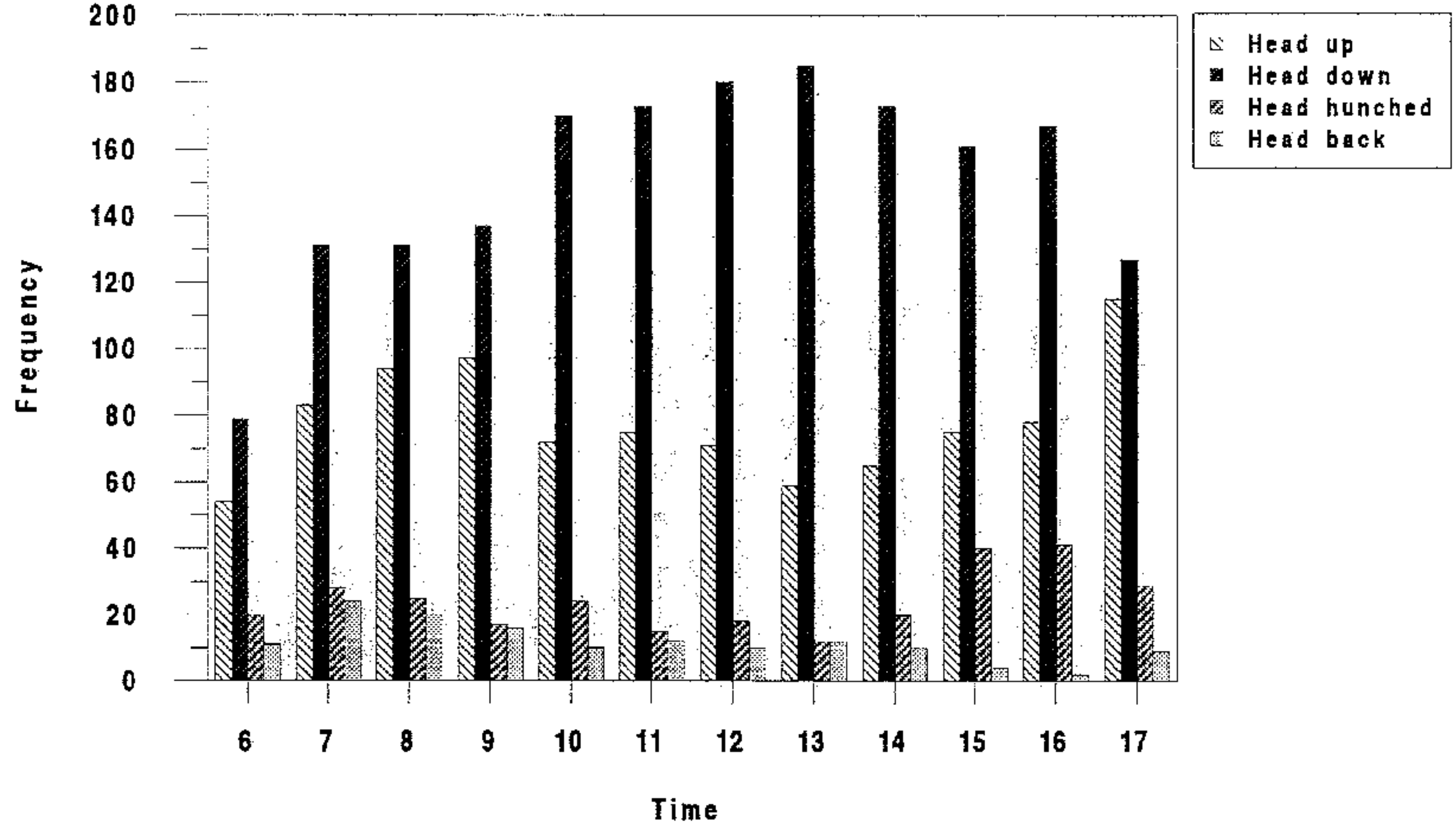


Figure 7.9 The frequency of different head positions for the chicks at different times of the day, number of observations was 3181, number of nests 8.

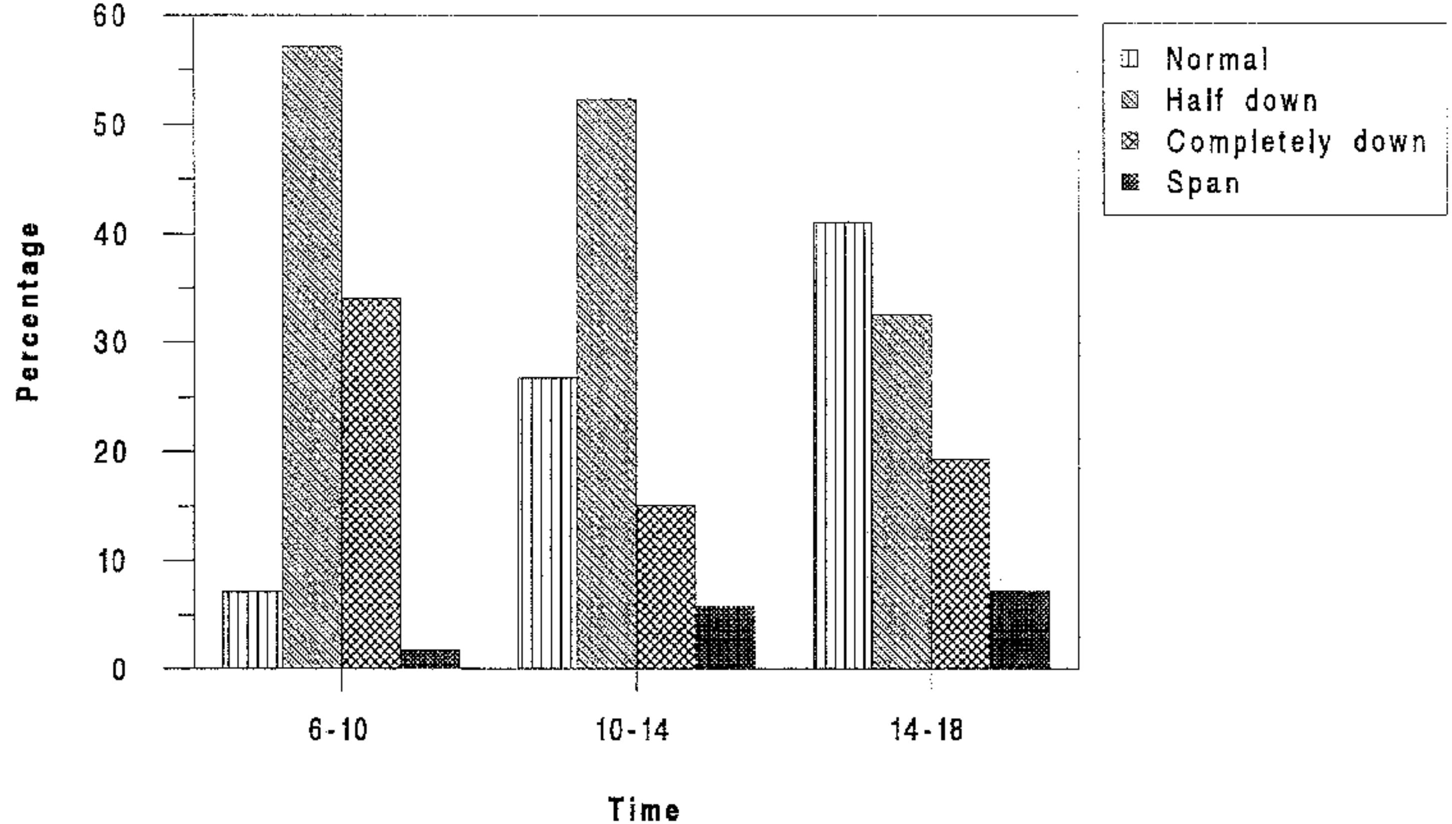


Figure 7.10 The percentage of different wing posture adopted lappet-faced vultures nestlings at different times of day.

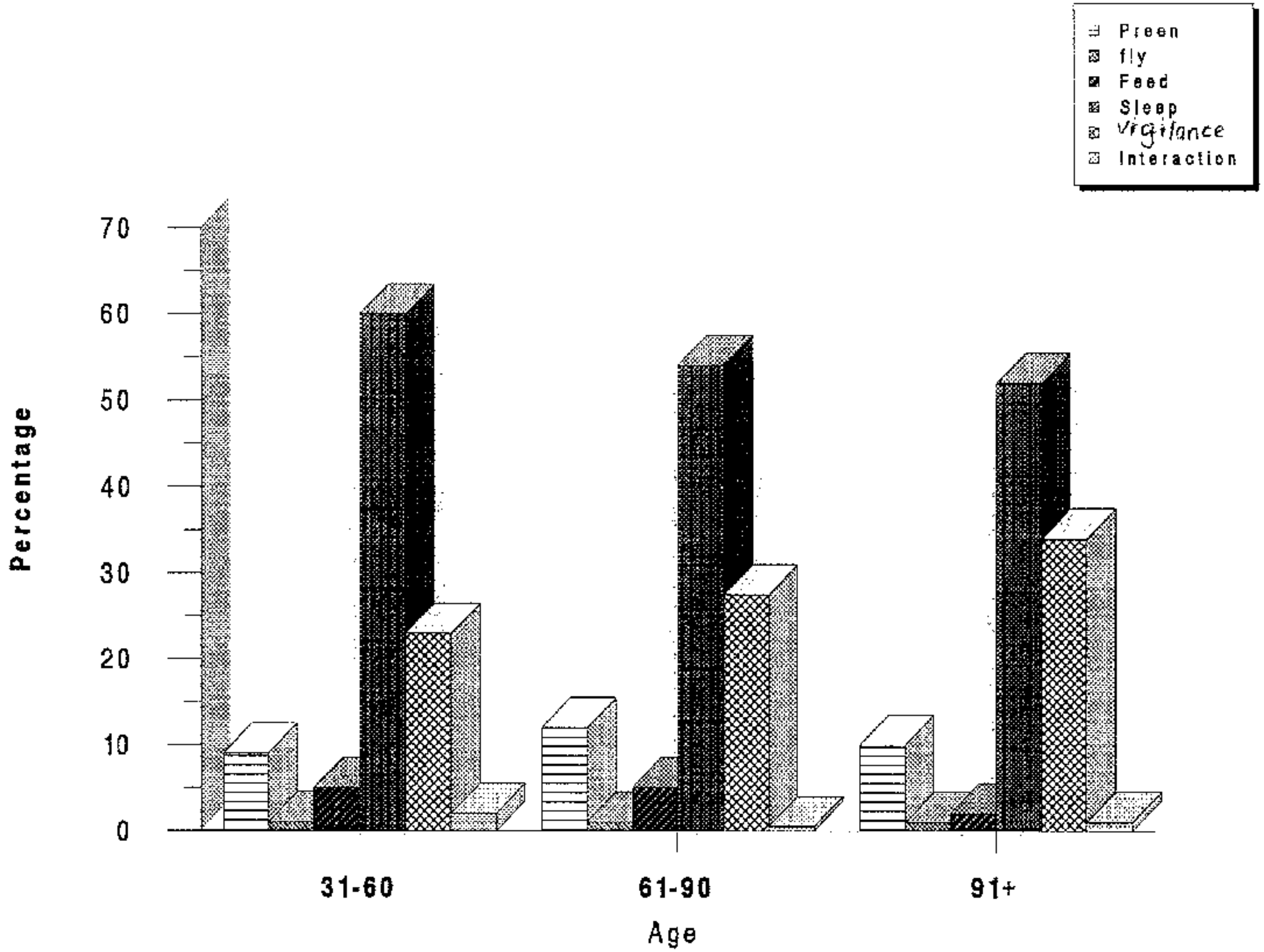


Figure 7.11 The activity pattern of the lappet-faced vulture nestlings at differents ages at the nest, (Scanning observations)

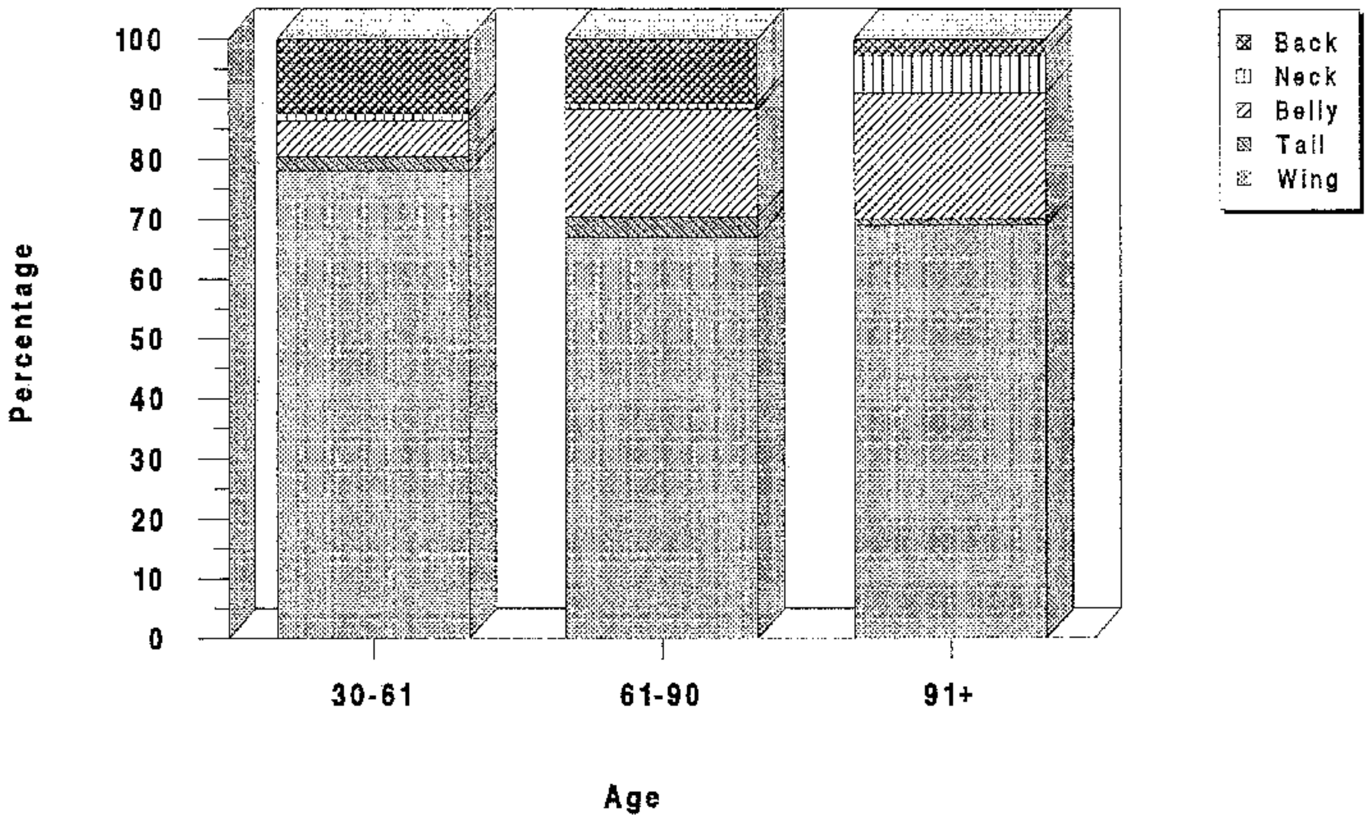
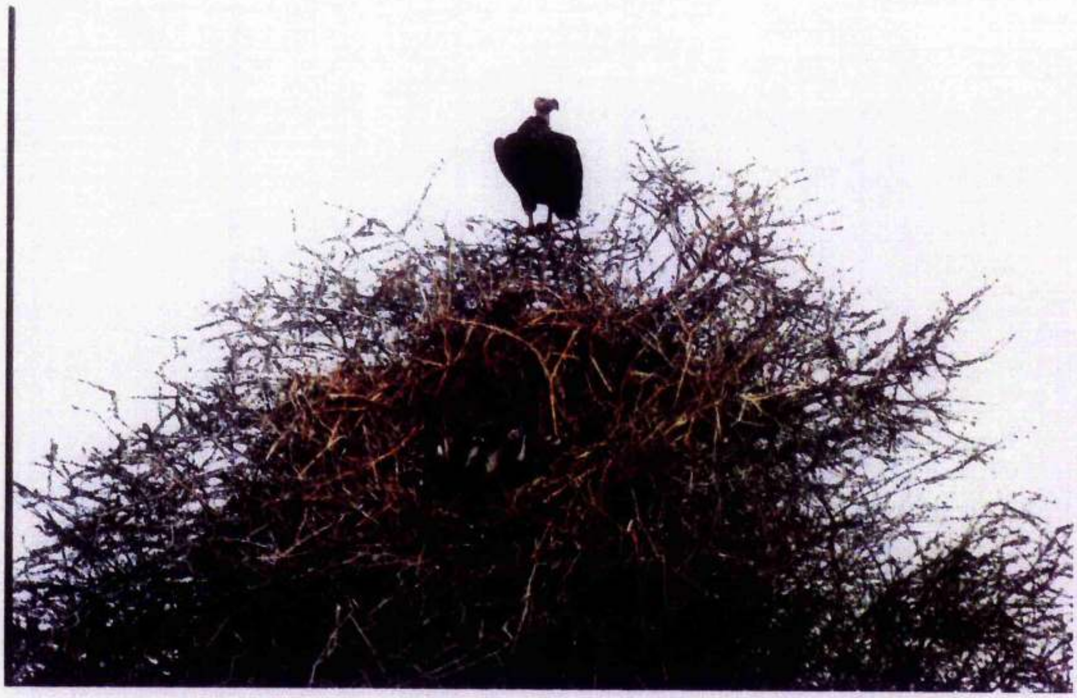


Figure 7.12 The percentage of time spent preening of different parts of the body in chicks at different ages

Photograph 7.1 Lappet-faced vulture chick 0-30days old.



Photograph 7.2 Adult lappet-faced vulture guarding s nestling 30-60 days old.

Photograph 7.3 Chick aged more than 90 days practising flying

Chapter 8. Movements

8.1 Introduction

The development of radiotelemetry techniques has had an important influence on the direction of wildlife research. This technique allows detailed ecological and management studies of movement, behaviour, habitat use, survival, and productivity of individuals. Valuable information can be obtained in a relatively short time by using this technique (Samuel and Fuller 1994), although for practical reasons this is often limited to detailed study of only a few individuals. The birds of prey are particularly well suited for radio-tracking studies because of their extensive home ranges. Most speceis are also large enough to carry telemetry devices with long battery life. Kenward (1980) provided a review of radio monitoring of birds of prey and included information on recent applications of radio tracking in various countries. Very little radio-tracking has been done on vultures. I am aware only of studies on Rüppell's griffon vultures in East Africa (Pennycuick 1983), on Cape vultures in South Africa (Boshoff *et al.* 1984), bearded vultures in Natal province (Brown 1988), Turkey vultures from the New World (Kirk 1988), and recently the European griffon vultures in Israel (Bahat 1995). In recent years satellite telemetry has been developed, which gives a limited number of location positions each day but which can be cost effective for wide ranging species, and in remote areas (Craighead and Craighead 1987; Fancy *et al.* 1988). During the last decade, Argos PTT transmitters have been successfully used to monitor long distance flights of swans, petrels, albatrosses, storks, eagles and griffon vultures (Berthold *et al.* 1992; Fuller *et al.* 1984; Higuchi *et al.* 1991; Jouventin and Weierskirch 1990; Nowak *et al.* 1990; Strikwerda *et al.* 1986; Griesinger *et al.* 1992; Bahat 1995).

Few studies on movements have been made on the lappet-faced vulture. Observations of marked birds in Africa have shown that they do wander far, one bird having been resighted 700 km away within its first year (Mundy *et al.* 1992). If the birds move such large distances in Saudi Arabia it will be important to answer questions such as: where do the fledgling lappet-faced vultures go?. Do immature birds occupy different areas from breeding birds, and do breeding birds move away from the nesting area after breeding.

In this chapter I will investigate the movements of adult, fledgling and immature lappet-faced vultures in the study area, using counts of the number of birds present in the reserve and radio and satellite telemetry. As well as giving some information on seasonal movements, telemetry was used to consider the survival rate of young birds in the period after leaving the nest. Dead birds are extremely rarely found and it was hoped that the use of transmitters would allow the causes of fledgling mortality to be identified.

8.2 Methods

8.2.1 Seasonal abundance of the lappet-faced vultures in the reserve

To obtain data on the seasonal abundance of the lappet-faced vulture in the study area, a total count was made of all the birds at the common roost sites in the reserve. The counts were made between 1 and 5 times a month, starting in March 1993 and continued for two years. The results were compared with earlier census counts at the reserve, which were started in Autumn 1990 by Weight and Schulz (1991), and continued for three years using the same technique by Newton and Shobrak (1993) and Newton and Newton (in press).

8.2.2 Resightings of marked birds

All the chicks in the reserve which hatched between 1992-1995 were marked at the nest a few days before their fledging date. Two types of marking were used. Plastic leg rings with large engraved letters which could be read using binoculars were fitted on chicks hatched between 1992-1993 (Photograph 8.1). The second marking technique was the use of plastic wing tags with a large number painted on the surface, and these were fitted to all birds hatched between 1993-95 (Photograh 8.2). This wing tag appeared to be more efficient than the leg rings, because it was easy to identify from a distance without disturbing the bird. The leg rings could only be read at short distance. Also if the bird was standing on a tree, which most of the time they do, the rings were often obscurred by branches.

8.2.3 Movements of Radio tagged juveniles

The radio-transmitter equipment was manufactured by the AVM Instrument Company, Livermore, California, USA, were H-Model / patagial, tags with a total mass of 48-54 g, and life expectancy of 18 months. The transmitters were fitted on the wings of eight chicks at the nest, just a few days before they fledged (Photograph 8.3). The location and the movements were monitored by a TR-4 receiver, RH-1 headphones, and Adcock antenna (H-type) (Ra-2AK 164/166 Mhz), all supplied by Telonics, Mesa, Arizona, USA.

I used both ground and aerial tracking. The ground tracking was more efficient in the early stage after fledging when birds only moved short distances. This tracking was carried out 1-2 days a week, between July 1994 and January 1995. Birds were tracked until visual identification or a very strong signal could be recevied. As the birds moved away from the reserve, ground tracking become more difficult, and I used aerial transects based on Kenward's method (1987) to cover large areas around the reserve. The total area covered by this method was more than 212,000 km^2. The aerial tracking surveys were undertaken in a single-engine STOL aircraft, (Maule M6), using two H-type antenna fitted in the aircraft wings, and the signals were picked up by manual receiver 10-Khz, with a detachable automatic scanning module from Telonics. The aerial surveys were made twice a month started in late August 1994 to February 1996. An Additional survey was made during September 1996.

The locations of the birds were determined by GPS equipment (Global Positioning System), which was fixed in the car and the plane. The actual co-ordinates were transferred to a Universal Transverse Mercator (UTM) system using a program written by Dodge *et al.* (1986) to convert latitude-longitude co-ordinates from the GPS navigators to UTM, which was available at the GIS department in the National Wildlife Research Centre. The maps for the radio-tagged birds shown here were made by the UTM co-ordinates as 50 grid of X= 66.25, and 50 grid of Y= 47.8. The Freelance graphic package were used to draw these maps.

8.2.4 Movements of birds fitted with Satellite transmitters

(I) Capture

Two lappet-faced vultures both immature but more than three years old were captured at Mahazat as-Sayd reserve. The capture technique takes advantage of the large body size of the birds and their dependence on thermals to help them to fly. Birds were caught by chasing after them in the early morning with two people in a car, one driving and the other watching the bird's direction. A bird was selected which was roosting alone, to avoid disturbing large numbers of birds at a communal roost. Driving the bird into the air, and following it closely while it was airborne, forced it to fly long distances, and as there were no thermals at this time of the day, the birds were forced to use flapping flight. This kind of flight is costly to such a large bird and lappet-faced vultures are not capable of flying long distances by flapping. When the bird becomes exhausted it would land, and the observer could sometimes catch it before it flew again. The first bird was caught on 25 January 1995, the second bird on 12 February 1995.

(II) Tracking equipment

A 95 g Platform Transmitter Terminals (PTT) module "100" based on the Argos-Tiros satellite system was used to track the birds. The total weight which had been but onto the bird was approximately 155-160g, included the rings, wing-tags, satellite and conventional transmitters, which is 1.5 to 2.5% of the body weight. The satellite transmitters were manufactured by Microwave Telemetry Inc., Columbia, Maryland, USA, and operate on an Ultra high frequency of 401.650 MHz. They were programmed to transmit for 20 hours every week (20 hours on -148 hours off), starting from 04:00 GMT time (07:00 Saudi Arabian time) and were adjusted to every 65 second of transmission. The period of transmitting was 75 weeks. The model PPT 100 is designed to monitor the temperature, battery voltages, altitude, and activity as well as providing location data. These parameters are transmitted during each transmission. However, in this chapter only the location and altitude data will be discussed.

The location classes used here were the standard classes (0,1,2,3) in which location accuracy is estimated $\pm$150 to 3000m under the new system of Argos. The non-standard classes (A, B) were not used in this study as their accuracy is not estimated. The transmitters were fitted as back-packs and secured by a Teflon ribbon double-loop (Photograph 8.4). A 45 g conventional VHF transmitter and plastic wingtag with letter code were also attached to the wing. The transmissions of PTT No 23628 was started 25/1/1995, but stopped in September for unknown reasons and so for this transmitter data is presented from 25/1/1995 to 28/8/1995. The PTT No. 23629 was started 12/2/1995, unfortunately the transmissions stopped after four months in 31/5/95 for three months before it started again in early September. The reason for this is also unknown.

8.2.5 Home range

The home range area was measured using the PC software package SEAS (Spatial Ecology Analysis System) developed by John Cary, Department of Wildlife Ecology, in University of Wisconsin, U. S. A. The convex polygon was used in the data analysis, based on ellipse and harmonic mean distances as proposed by Dixon and Chapman (1980). The home ranges for the radio-tagged fledgings were made during the six months period after leaving the nest. As all the birds moved away from the area after this period, it was not possible to track them farther. However, the reserve was checked by the plane every month to record the return of any of these birds to the study area. The home range for the birds with satellite transmitters was calculated for the period of transmitting, which for one unit (PPT No. 23629) started in 12/2/1995 and stopped transmitting at the end of May (31/5/1995). The home range for the second bird (PTT No. 23628) was calculated for almost seven months (25/1/1995 to 31/8/1995).

8.2.6 Mortality

Birds found dead in the study area were given post-mortem examination whenever possible by the veterinarian at the National Wildlife Research Centre in Taif, Saudi Arabia. A liver sample from a fresh juvenile lappet-faced vulture was analysed for pesticides and heavy metals at the Institute of Terrestrial Ecology, UK. The chemicals which were checked in the samples were organochlorines, Mercury, pp-DDE (derived from insecticide DDT), HEOD (from the insecticides aldrin and dieldrin), and PCBs (industrial polychlorinated biphenyl's).

8.3 Results

8.3.1 Seasonal abundance of lappet-faced vultures in the reserve

The results showed that the number of lappet-faced vultures roosting in Mahazat as-Sayd reserve fluctuated seasonally. In 1993 there was a highly significant difference in the number of birds counted each month (ANOVA $F_{7,23}$= 16.25, P<0.001), (Figure 8.1). Similar significant differences were found in 1994 (ANOVA, $F_{10,27}$ = 11.45, P<0.001), (Figure 8.2). The figures showed that minimum numbers of birds were observed in the spring between March and April, with numbers rising through the summer to reach the highest counts in September. Similar seasonal results were obtained in the 100km^2 census made in the reserve during the previous three years of study (Weigeldt and Schulz 1992; Newton and Shobrak 1993 Newton and Newton in press).

8.3.2 Resightings of marked birds

In this study I defined a nestling which has successfully left the nest once as having fledged, based on Campbell and Lack (1985). All of the sighting of marked fledglings were at carcasses where the birds came to feed. Out of 15 chicks fledged and marked in 1992/93, four individuals were located again in the reserve. Some of these birds were seen more than once (Table 8.1). These four individuals were resighted significantly more frequently than would be expected if all marked birds had had an equal probability of being seen again (X^2= 3.97, P<0.01). This implies that not all of the marked individuals were remaining in the area and available for resighting: the others having presumably left the area or died. It is known from other studies in birds of prey that juvenile mortality is much higher than that of adults (Newton 1979; 1980; Mundy *et al.* 1992).

8.3.3 Movements of Radio tagged juveniles

The chicks after fledging started to fly small distances of 100 to 200m, then return to the nest. Gradually as the chick gets older the distances they travel increase (Figure 8.3). Birds moved siqnificantly greater distances as they increased in age (ANOVA, $F_{5, 150}$ = 62.65, P<0.01). The maximum distance recorded was 200 km from the nest in December. However, some birds probably move longer distances than this, and were undetected. One radio-tagged young fledged in late May 1995 and was found 300 km from the nest in its four month after fledging.

In the first three months after fledging the birds were mainly observed visiting an area with standing water and which is located 7 km to the east of the reserve, and then returning to the nest. At this age they usually roost in the nest overnight. Some time in the second and third month the birds start to roost away from the nest, but still come back to the nest to be fed by their parents. Figures 8.4, 8.5, 8.6, 8.7. and 8.8 shows the movements of five young lappet-faced vultures in the months after fledging. In the fourth month of fledging the chicks started to disperse, and could not be located within the study area. However some of them returned to roost in the reserve after this period, and two birds were observed in the reserve at the roosting area 7-8 months after fledging.

Figures 8.4 to 8.8 show that the birds started to move mainly to the south, south east and east of the reserve, and the majority of this area was in sector 4 of the whole study area. In this sector the density of livestock was higher than that of the other sectors (see chapter 3). Moreover, the only area where natural water pools could be found was in Wadi Subay in this sector (see chapter 2), which probably was very important to the birds, because they were visiting it regularly in the first three months after fledging. Many of the birds located at greater distances from the reserve were also located near large Wadi's where natural water could be found.

8.3.4 Movements of the birds fitted with Satellite transmitters

Figures 8.9 and 8.10 show the movements of the two birds with the PPT transmitters. The transmission from the PTT No. 23628 stopped in early September 1995, after the bird had covered a distance of 5071 km. The bird with PTT No. 23629 moved to the north of the reserve and stayed there for more than three months, covering an area of 1325 km before the transmission stopped at the end of May. But on the 7th of September the transmission started again. The bird this time moved more than 400km to the north west of where it was recorded in late May, at one of the protected areas in the north of the country where another breeding population of lappet-faced vultures occurs. A week later the same bird was again recorded in Mahazat as-Sayd reserve, having covered more than 900km, and it stayed there until early October 1995 when the last transmission was received.

Table (8.2) shows a comparison of the distance moved by the two birds during the same period of time. The bird with PPT No. 23628 moved almost twice the distance of the second bird with PTT No. 23629. Moreover, the first bird moved in a different direction, especially in May / June. The second bird with PTT No. 23629 seemed to be sedentary for some period of time, and the movements seemed to be mainly North-South-North, because the bird was recorded in the north and a week later back south at the reserve. Also the table shows the maximum speed recorded using SEAS PC software package between successive locations, and its seems that both birds had almost the same maximum speed. Out of 15 records when the birds were flying the maximum altitude recorded was 8825 feet (2675 m) from ground level made by the bird with PTT No. 23628.

8.3.5 Home range

(I) The radio-tagged fledging chicks

Table 8.3 shows the home range of the young lappet-faced vultures during the first six months after fledging. Some of these birds such as bird No. 90 were recorded only in the first three months after fledging (Figure 8.8). Other birds like No. 80 and No. 88 (Figure 8.6, 8.7) were located in all six months after fledging. These two birds were roosting 100 km south of the study area after they left the nest, therefore, it was possible to track them continuously and for longer periods. The others (No 74 and No. 78) were recorded during the first six months but during this time they disappeared for a month or more before they were recorded again (Figure 8.4,8.5). The factors which make the birds leave the area are difficult to determine. The home ranges shown in this table are probably not the actual home ranges used by the birds because it is known that sometimes they were out of the range of my searching.

(II) The immature birds fitted with satellite transmitters

The bird with PTT No. 23628 moved large distances, and the total home range for this bird calculated by SEAS during seven months from 25/1/1995 to 31/8/1995 was 92,881 km^2. However, the second bird with PTT No. 23629 spent more time in one area, and had a shorter period during which the transmitter was operating, and the home range recorded for this bird during the four months was 36,771 km^2.

8.3.6 Mortality

During the study period nine birds were found dead in the study area of which one was an adult, the rest being young birds just fledged. All of these birds were found dead in July and early August, which is the first and the second month after fledging. Three out of the eight young birds radio tagged in 1994 were found dead 100-200 m from the nest only a few weeks after fledging. Table 8.4 shows the probable cause of mortality. Two young were found trapped, one in the Mahazat as-Sayd fence, the other in a tree near the nest just 2 months after fledging. The two probably died from starvation.

The chemical analysis of the liver of the young lapped-faced vulture showed that the bird had not died from pesticide or mercury poisoning as the level of chemicals were very low. Post-mortem analysis showed that the bird probably died from starvation, which is the same probable cause of mortality for the three radio tagged birds. However, one of the radio tagged birds which fledged in late May 1995 was found on 17th September of the same year by local people, 300 km from the nest. The bird was still alive, but appeared thin, slightly dehydrated (<5%), displayed a general weakness, and had a body weight of only 4,800 g. The veterinary diagnosis report showed that the bird was suspected of suffering from pesticide poisoning (acetylcholinesterase inhibition). This bird was given the necessary medical treatment and stayed under observation for more than 28 days before it was released in the reserve. One nestling was found dead at the nest just 6-8 weeks after fledging but the cause was not known because the bird was partly scavenged. The cause of mortality of three of the birds seems to be as a result of road accidents. probably from being hit by a vehicle when feeding on a carcass at the roadside.

8.4 Discussion

8.4.1 Seasonal abundance of the lappet-faced vultures in the reserve

The results of this study show that the lappet-faced vultures probably have an annual cycle of abundance in the reserve. The factors driving this cycle are not clear. The peak of numbers seems to be in Autumn when the chicks have already fledged and are starting to spend more time away from the nesting area and to be more independent. Part of the increase in numbers is therefore caused by young birds bred in the reserve, but there are not sufficient young reared to account for the increase in numbers, and so there must also be immigration of birds into the area at this season. Non-breeding birds may be deterred from using the reserve earlier in the year because of the dominance of breeding adults during the period of chicks rearing, which is in early spring.

In the study area there was high food abundance throughout the year, therefore I presume that food availability probably is not the factor causing changes in the numbers in the reserve. In the black vulture seasonal differences in movements were found in the wet season caused by the level of livestock mortality (Kirk 1988). In the case of the lappet-faced vultures other factors could be leading to the seasonal abundance. One of these factors could be the climate because the weather in the north becomes cold in the winter, and the day length is also shorter. Birds probably move to the warmer areas to the south. It is known that the annual climatic cycles strongly influences the variance in favorability of given geographic choice of habitat, and the reproduction and movement patterns of many species of birds are annually periodic (Power 1989). However, more studies are needed to determine these factors.

8.4.2 Resightings of marked birds

Studies on the colonial cliff-nesting Cape vulture have shown that immature birds use the areas in the vicinity of the colonies which are not used by the adults (Mundy *et al.* 1992). Although the number of marked birds resighted was low, they were probably all in the area within 10-60 km from their nests, and in the same area as the adults. However, more data is needed from marked birds to understand the relationshep between breeding adults and fledged young. In vultures adults are dominant over juvenile birds, and adults may drive young birds away from breeding areas (Houston 1976b).

8.4.3 Movement of Radio tagged juveniles

The dispersion of foraging vultures over savannah habitats in Africa is partly related to food supply, which varies according to vegetation type and human-induced factors. Seasonal changes in food supply and the density of vultures also affect foraging movements (Houston 1976b; 1979; Mundy *et al.* 1992).

In the study area there was enough food available to meet the requirements of the lappet-faced vulture population. There was also little seasonal movement of livestock. The radio-tagged young birds were recorded most frequently in sector four where the concentration of livestock is higher than in the other sectors. Moreover, the availability of water and the high temperature at the fledging season probably explains the movements of radio-tagged birds to these drinking areas in the south and south east of the reserve. All the radio-tagged birds which moved away from the study area during the first six months of fledging were located near large wadis where permanent water was available. Juvenile griffon vultures in the post-fledging state have also been observed on migration or nomadism far away from their nesting grounds (Bahat 1995).

8.4.4 Movements of the birds fitted with Satellite transmitters

In this study the two birds showed different kinds of movements, but both of them left the reserve for long period, although one returned again to Mahazat as-Sayd in the Autumn. This could support the results of the counts of numbers of the lappet-faced vultures in the reserve, which shows that there was an annual cycle for the abundance of birds in the reserve. Moreover, it is known that there are breeding birds recorded at most of the areas where the birds were located, which suggests that there is contact between the different breeding populations of the lappet-faced vultures in Saudi Arabia. This contact is probably important in preserving the genetic diversity of the species.

8.4.5 Home range

The factors affecting the range area used by birds are highly variable and depend on species, sex, social status of individuals as well as habitat quality, food supply and ecological requirements at different time of the year (Krebs and Davies 1981; Perrins and Birkhead 1983; Houston 1976b; 1978; 1980; Kirk 1988; Mundy *et al.* 1992). Some scavenging species are thought to maintain largely exclusive ranges, such as the whiteheaded vulture and bateleur eagle (Kruuk 1967; Pennycuick 1972; Watson 1986; Mundy *et al.* 1992). While in *Gyps* vultures, home ranges overlap totally and all the species are to some extent colonial (Kruuk 1967; Pennycuick 1972; Houston 1976a; Mundy 1982; Boshoff *et al.* 1984; Mundy *et al.* 1992). No data is available for the foraging movements of breeding lappet-faced vultures, but in black vultures Parmalee and Parmalee (1967) showed that lifetime foraging ranges in eastern United States were 160-320 km, and Rabenold (1983) suggested that breeding birds concentrated their foraging movements within a radius of 20 km.

The results of the home range of the fledging birds and immature birds showed differences in the size of the area used by these birds. The factors which affect the size of the home range are difficult to determine. Disturbance in areas outside the reserve could have an effect on the home range of the species. One of the nursery areas which was located 80km to the south of the reserve was regularly used by two fledging birds for several months. But when a new camp was established in the area, no birds were seen in the area again.

8.4.6 Mortality

Much less is known about the mortality of raptors than other aspects of ecology (Newton 1979), as it accrues sparsely and unpredictably in space and time. The results showed that mortality in the lappet-faced vulture was high in the post-fledging period, especially in the first month after fledging. In this period the young learn foraging and to become independent from their parents, and in this period they are sometimes still fed by the adults. Furthermore, the long breeding season of almost one full year probably forces the parents to abandon the young when the next breeding season starts, which will have an effect on the fledgling nestling. It is notable that almost a half of all causes of mortality were due to human activity, either through accidents on the road or through birds becomming entangled in wire fences. Several other studies have shown that vultures are very susceptible to man-induced causes of mortality such as poisoning, electrocution in power lines, drowning in cattle troughs, shooting and other forms of direct persecution (Mendelssohn and Leshem 1983; Houston 1987c; Mundy *et al.* 1992; Piper 1993).

Table 8.1 The marked birds from 1992/93 resighted at the study area

Fledging Date	Resighting	No. of resighting	Behaviour
2/6/1992	5/4 and 22/9/1993	2	Sleeping, feeding at the reserve
13/7/1993	1,2,3,16/11/1994	4	feeding, at the reserve and Zalm area
30/8/1993	15,23/2/1994	2	feeding at Zalm area
July 1993	24,25/4/1994	2	feeding at the reserve

Table 8.2 The difference between the two birds fitted with PTT transmitters

Variable	Bird with PTT No. 23628	Bird with PTT No. 23629
Distance covered	5071 km (7 months)	1325 km (3.5 months)
Distance covered per month	724 km	361 km
Maximum distance moved per day	198 km	193 km
Maximum Altitude	8825 feet	5322 feet
Maximum Speed	47 km/h	45 km/h

Table 8.3 The home range of the radio tagged birds using SEAS PC softeware package

The bird ID, and frequency number	Fledging date	No. of fixes	The home rang (km^2) during six month after fledging
U 74	27/7/1994	34	7659
N 78	29/6/1994	38	11346
Gamma 80	15/6/1994	46	6395
Beta 88	11/5/1994	70	12115
O 90	29/6/94	38	6431

Table 8.4 The cause of mortality among the lappet-faced vultures in the study area

No. of bird	Age	Cause of mortality
3	5-6 months	probably starvation
2	6-8 months	Probably starvation and dehydration, and they were found hanging, one on the fence, the other on a tree.
3	two 6-8 months, the other more than 3 years old	Probably car accident
1	1 month	Unknown

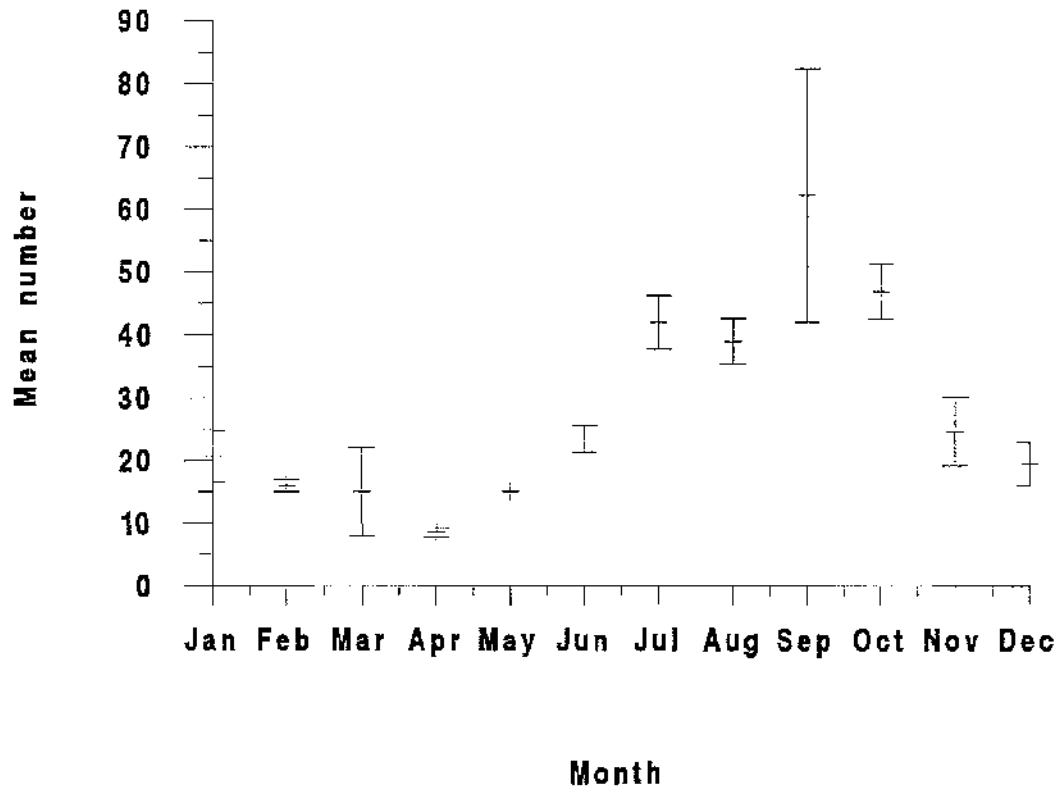


Figure 8.2 The average number of lappet-faced vultures recorded in the roost sites during 1994, n= 29, (bars represent the standard deveyation)

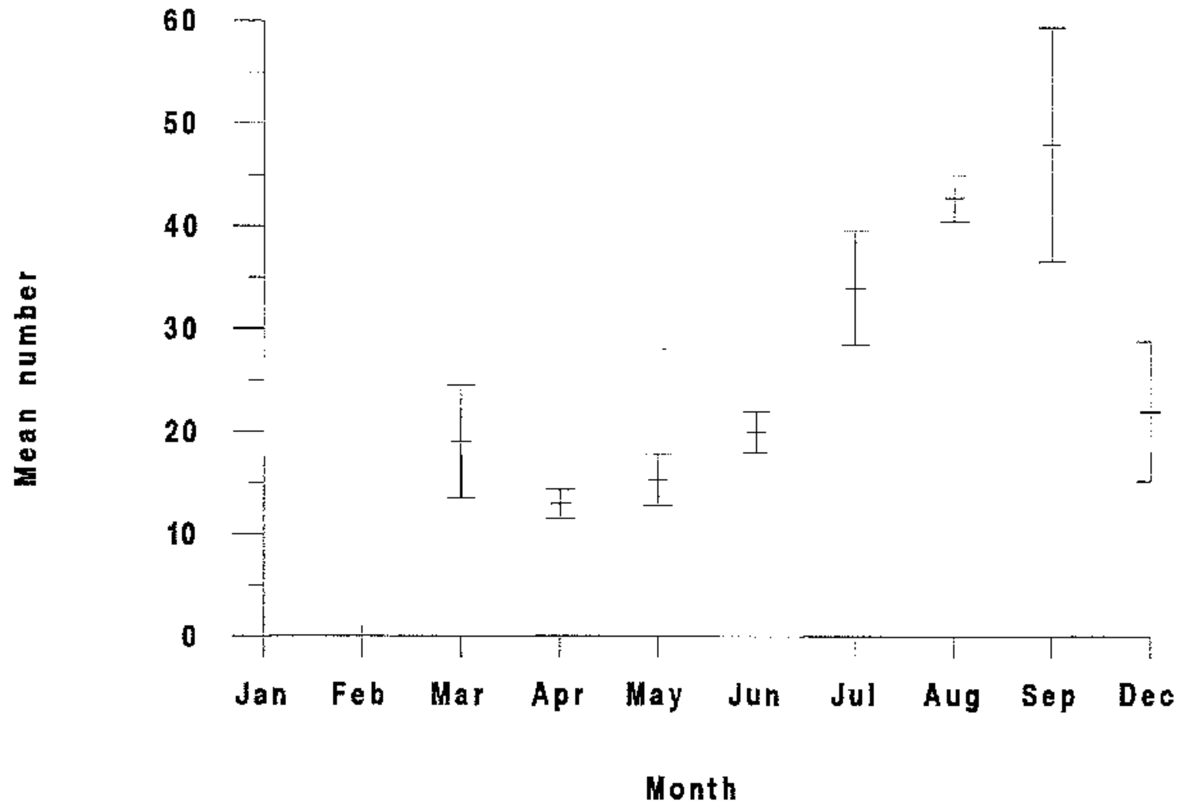


Figure 8.1 The average number of lappet-faced vultures recorded in the roost sites during 1993, n=24 (bars represent the standard Deveition)

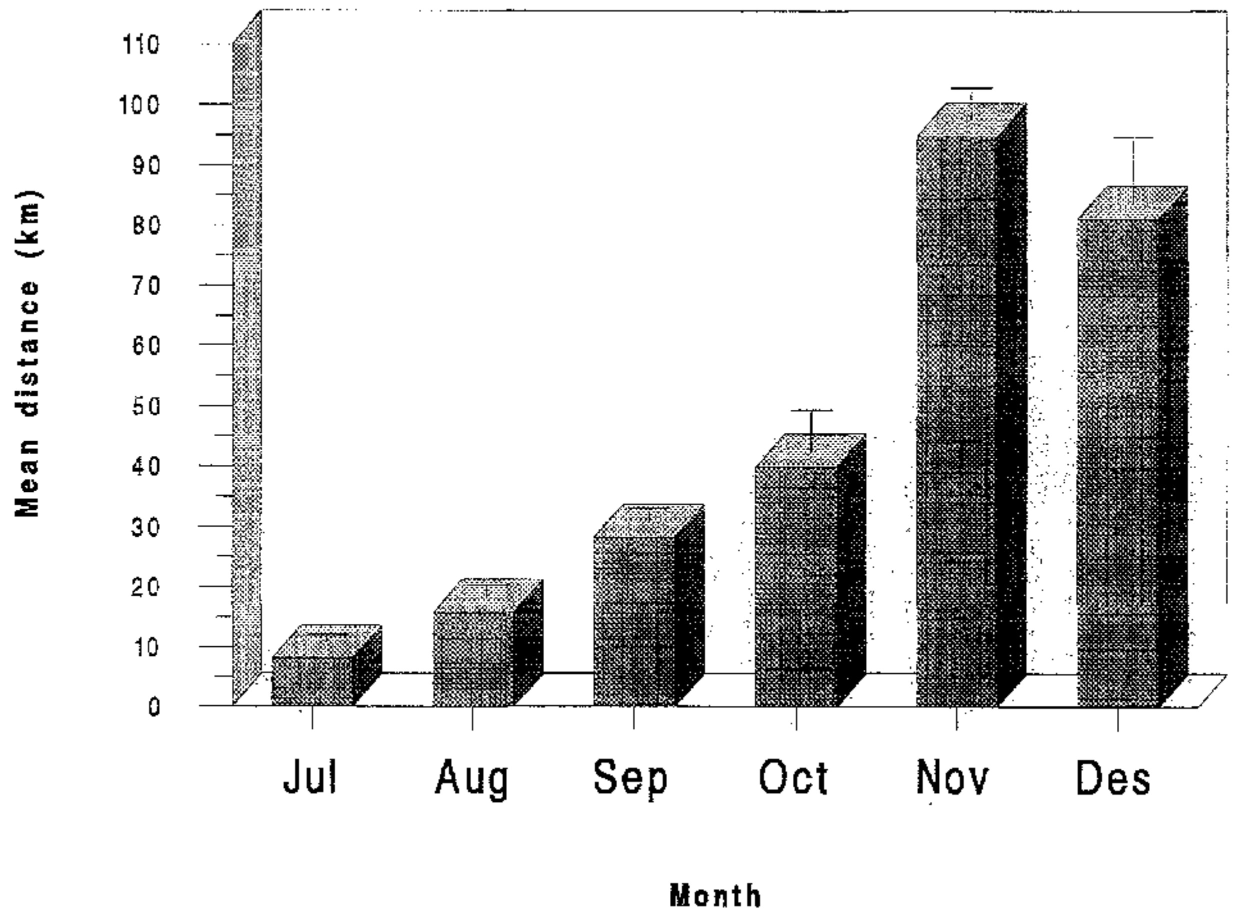


Figure 8.3 Mean distance from the nest site travelled by fledging birds in the six months following fledging

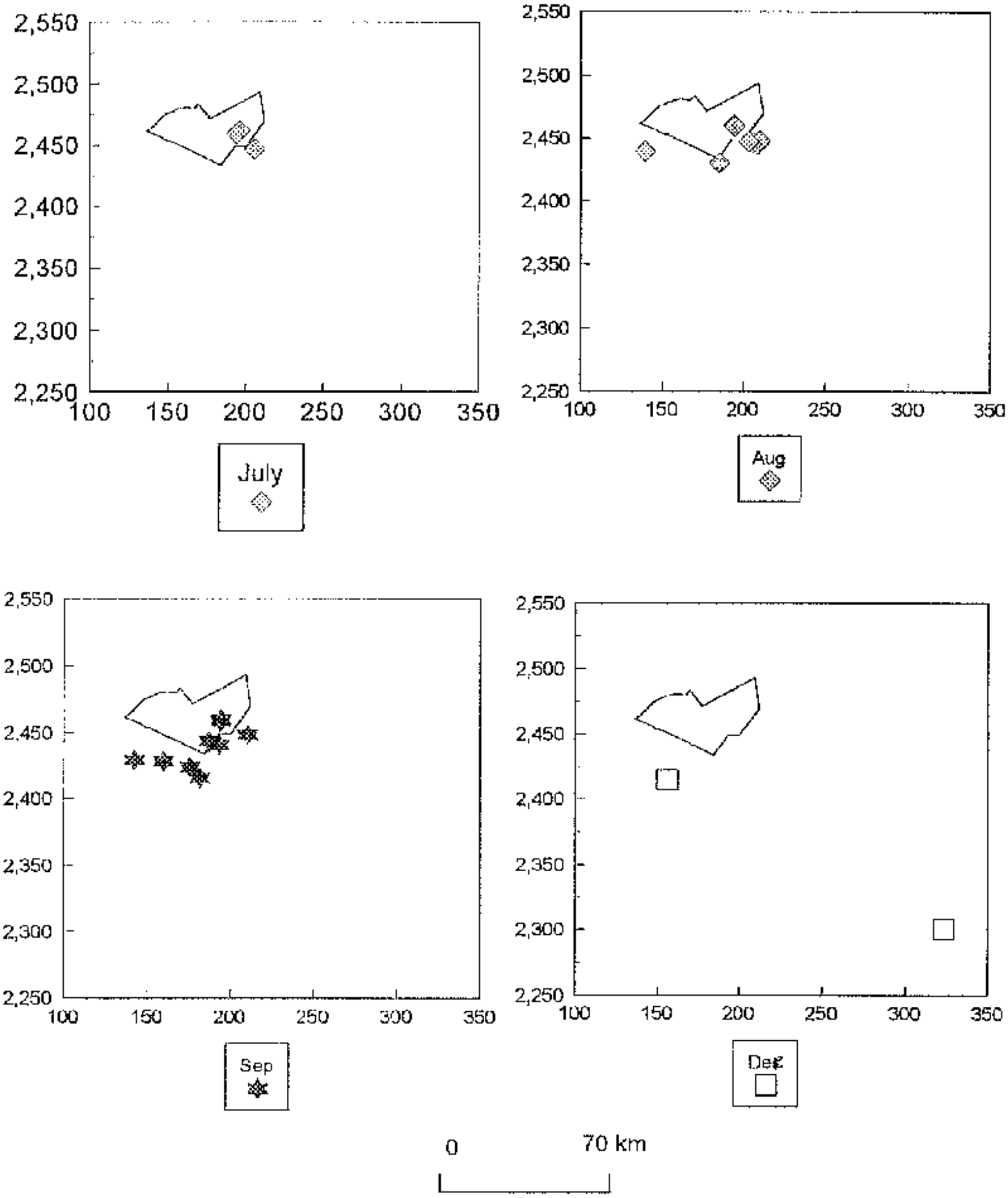


Figure 8.4 The movements of the young radio-tagged lappet-faced vulture No. 74,

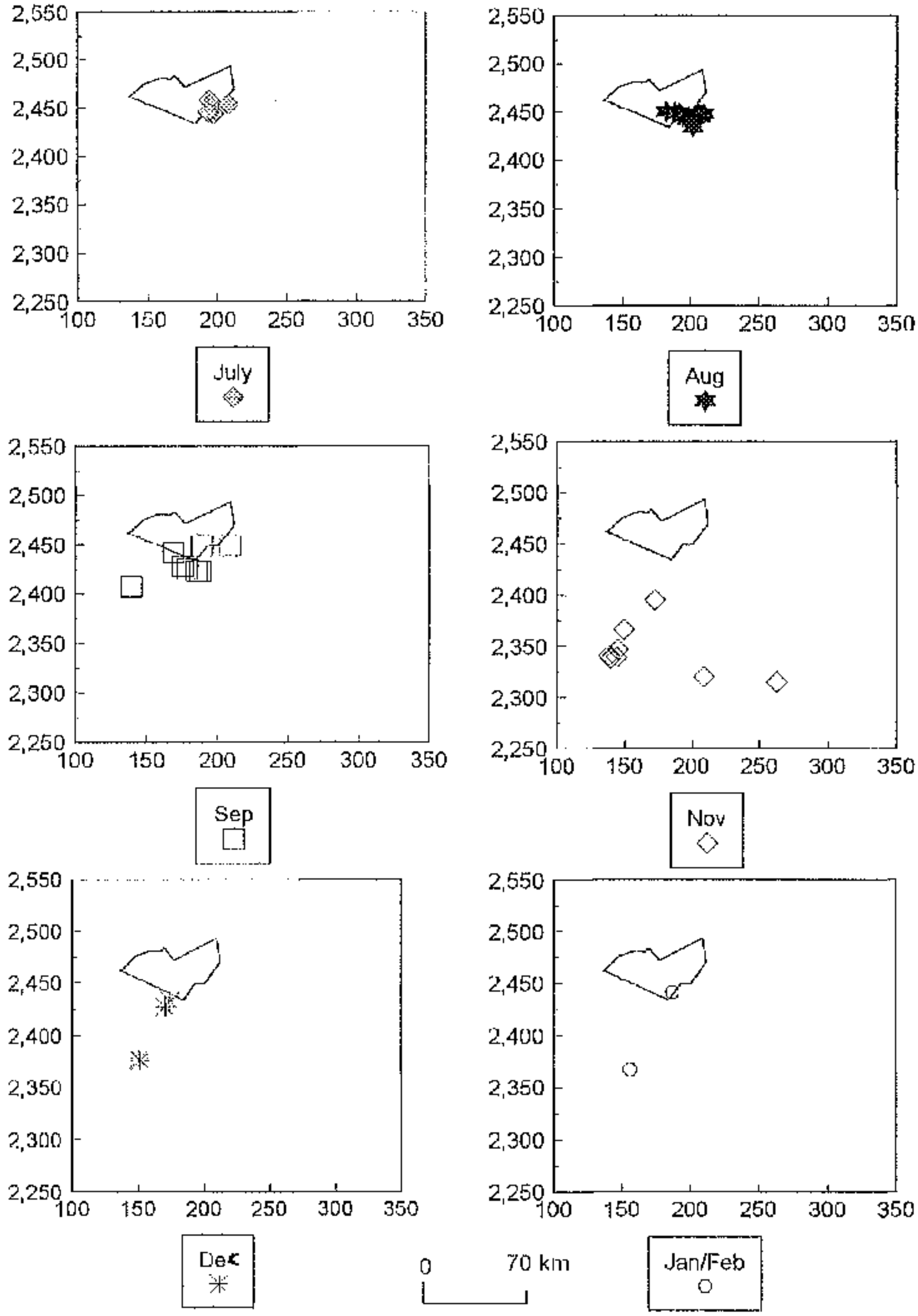


Figure 8.5 The movements of young lappet-faced vulture radio-tagged No. 78

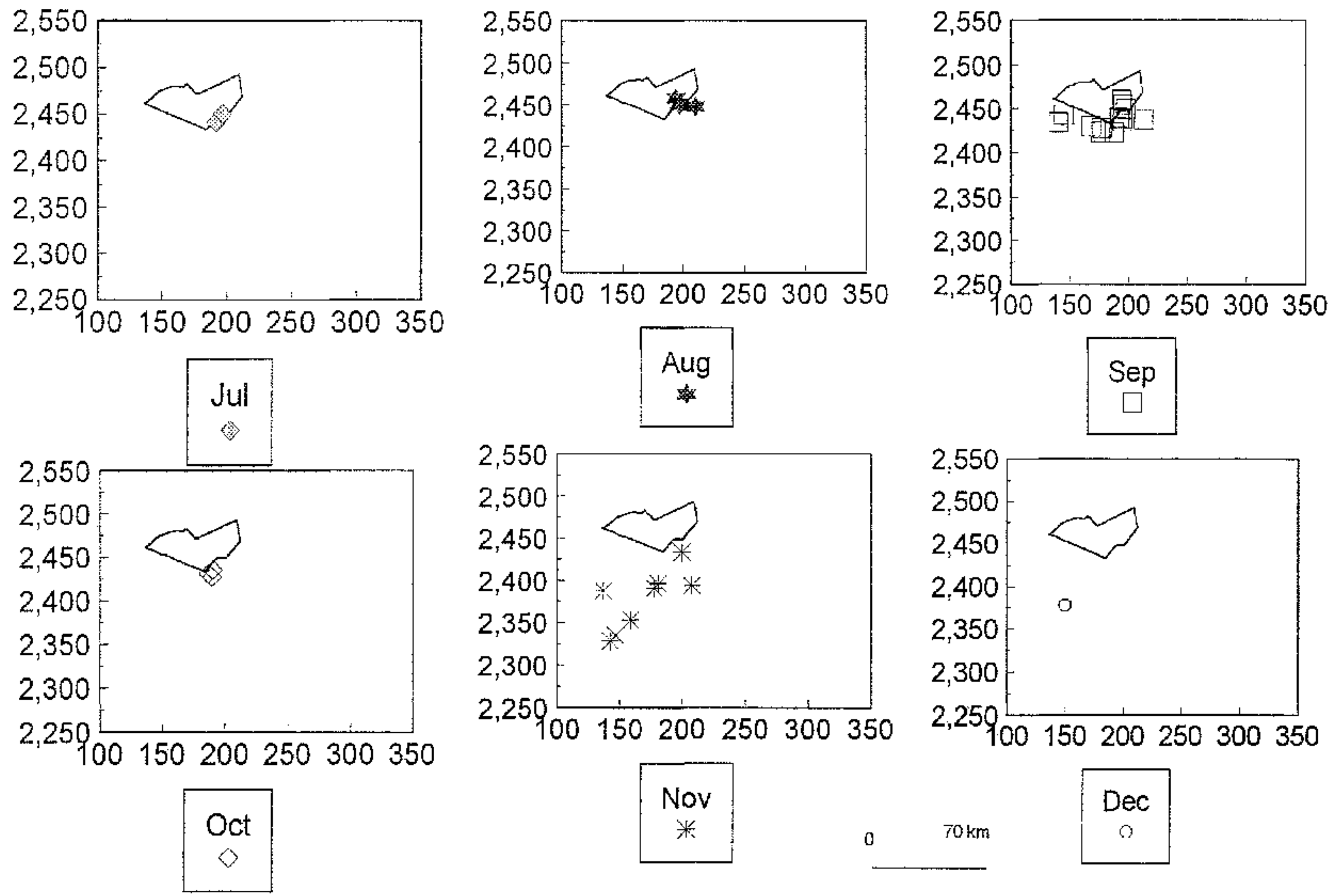


Figure 8.6 The dispersal of the young radio-tagged lappet-faced vulture No. 80

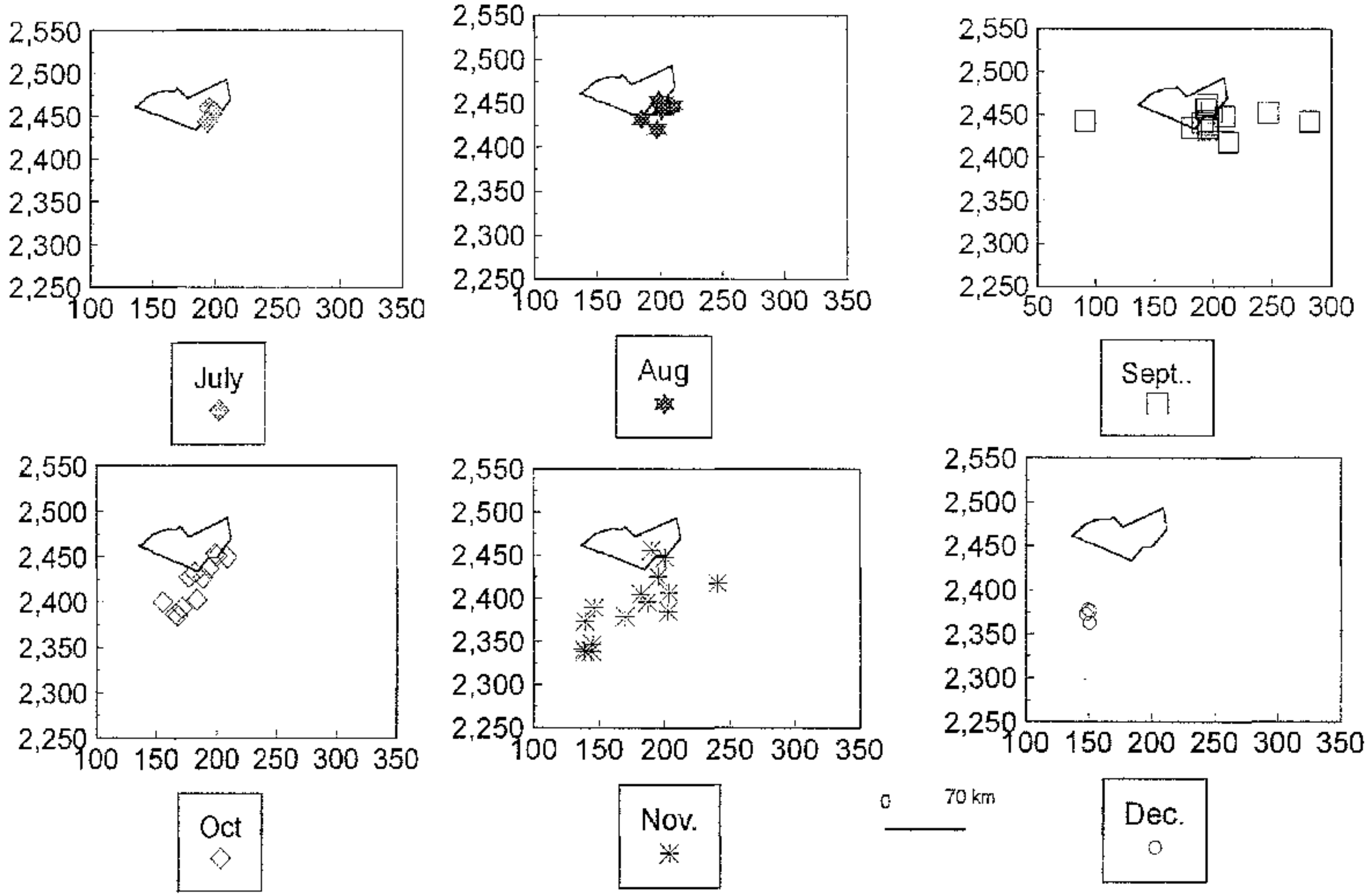


Figure 8.7 The dispersal of radio-tagged young lappet-faced vulture No. 88

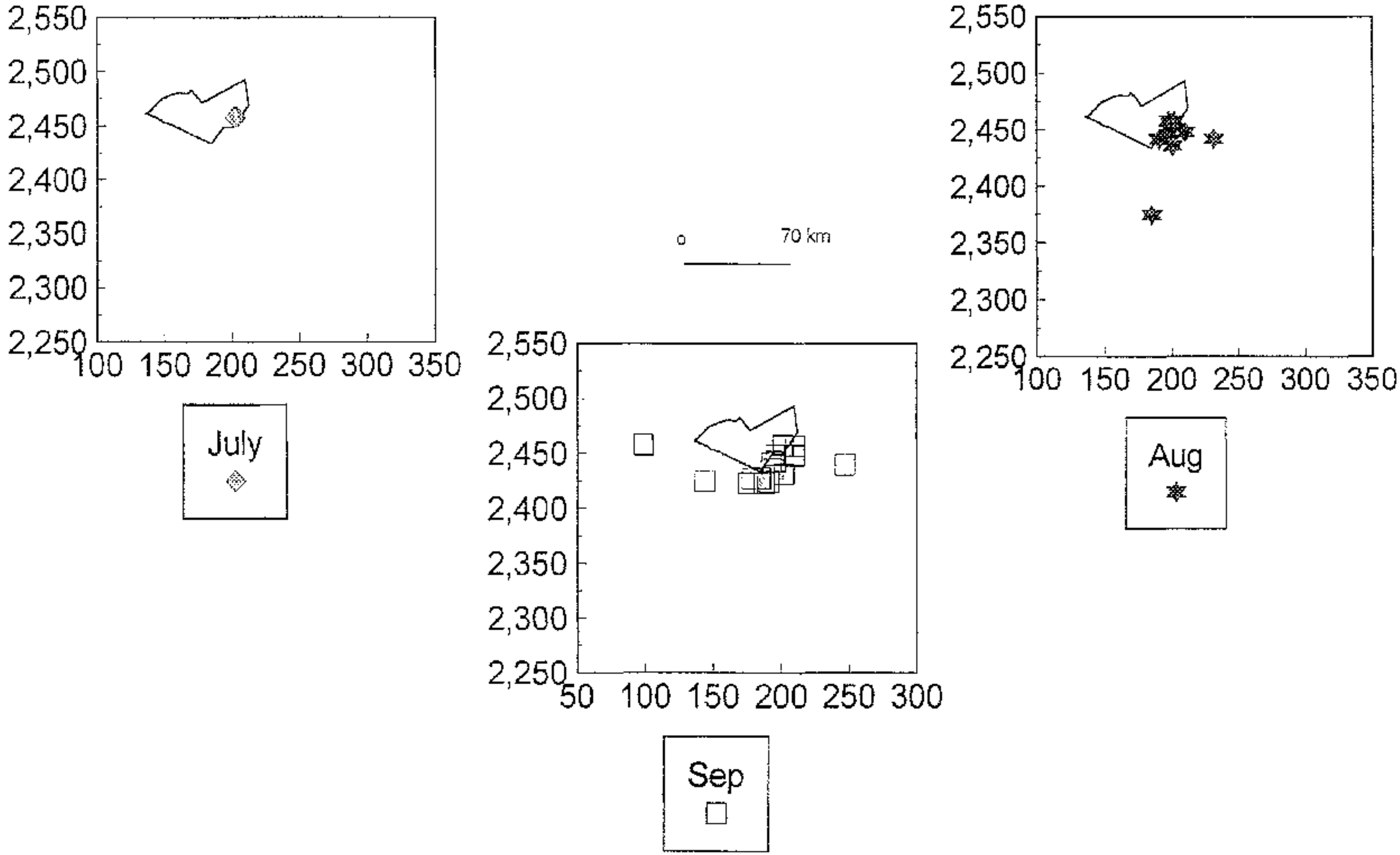


Figure 8.8 The dispersal of radio-tagged young lappet-faced vulture No. 90

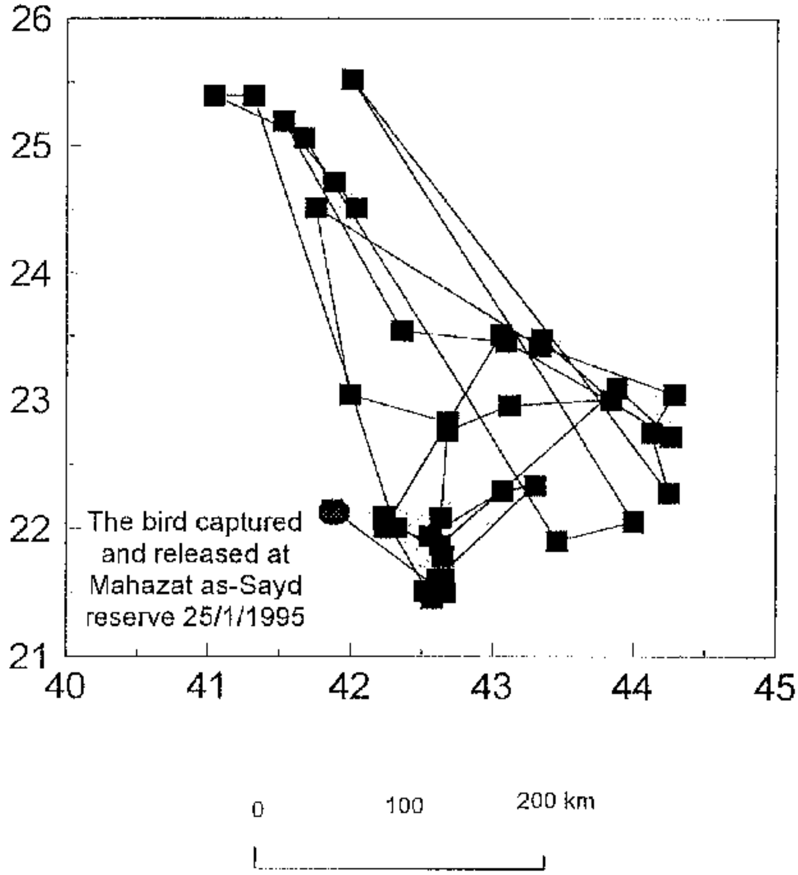


Figure 8.9 The movement of the immature lappet-faced vulture with PTT No. 23628, between 25/1/1995 and 27/8/1995

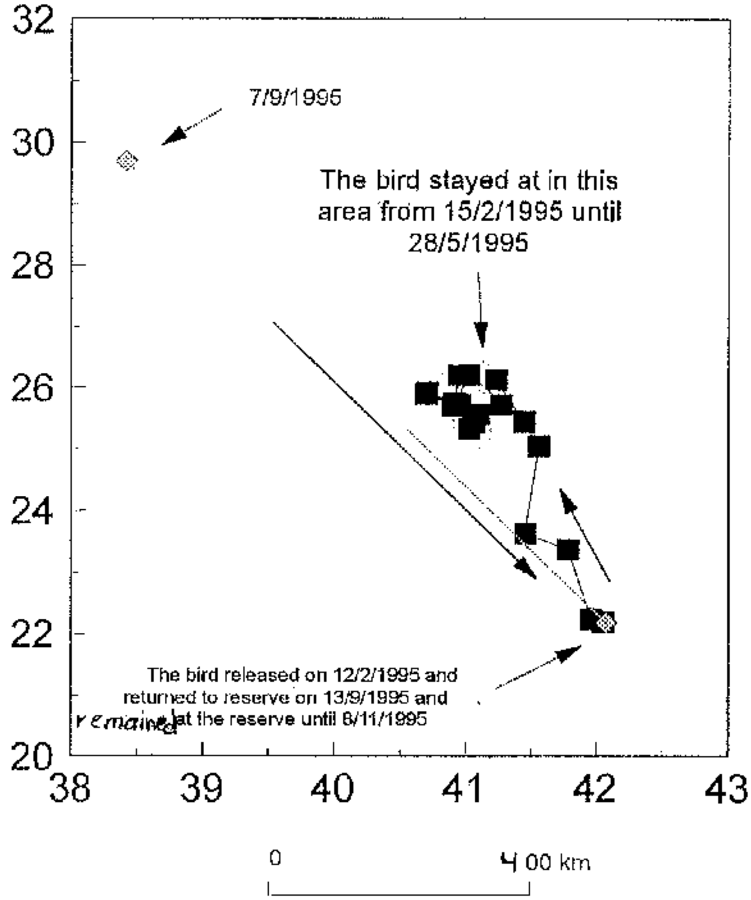


Figure 8.10 The movement of the lappet-faced vulture with PTT No. 23629 between 12/2/1995 and November 8/11/1995, (No records received between 28/5/1995 and 7/9/1995)

Photograph 8.1 chick at the nest marked with plastic leg reing.

Photograph 8.2 Chick at the nest marked with plastic wing tags.

Photograph 8.3 Conventional VHF transmitter attached to the chicks a few days before they fledged

Photograph 8.4 The Satellit transmitter fitted as back-packs on immature lappet-faced vulture

Chapter 9. General discussion and conservation

9.1 General discussion

The main aim of this study was to obtain data on the lappet-faced vulture at Mahazat as-Sayd reserve which might assist in the conservation of the species in Saudi Arabia (Chapter 1). The factors investigated were those known to be the main cause of decline in other bird of prey species (Newton 1979; Houston 1987c; Mundy *et al.* 1992), such as the size of the food supply, competition over this food with other scavengers, breeding & chick rearing, and the movements of young and immature birds.

9.1.1 Food supply

Changes in the food supply have been a major factor in the recent decline of some species of vultures (Houston 1987c; Mandelssohn and Leshim 1983; Mundy *et al.* 1992). However, in this study there was no evidence of food shortage for the vulture population, which may have caused a decline of the lappet-faced vulture numbers (Chapter 3). Similar findings have been reported from other areas, such as the study in the Cape vulture on Cape province and Transvaal regions of South Africa (Robertson and Boshoff 1986; Komen 1986) and the studies of Perco *et al.* (1983) on European griffons in Yugoslavia.

The density of domestic ungulates was estimated as nine times the predicted carrying capacity of the study area. This increase has been due to changes in husbandry practices in the study area and the rapid disappearance of the natural vegetation and its replacement as animal feed by subsidized barley. Following these changes diseases have started to increase the mortality rates in domestic ungulates. This increase provides a good source of food for avian scavengers in the area, especially the lappet-faced vultures. The estimated food availability greatly exceeded the food requirements of scavengers in the area.

Furthermore, this increase in the domestic herds has effected the natural vegetation, and overgrazing together with the severe hunting on the wild ungulates has resulted in the decline in wild herds of species such as gazelles and Arabian oryx, and also in the small mammals. Additionally, large carnivores, which used to prey on wild mammals, have started to feed on the increasing domestic herds, leading to a negative attitude by local people towards all wildlife. Predators such as wolf and hyena are now absent from most areas in Saudi Arabia (Child and Grainger 1990). Therefore, the lappet-faced vultures in the study area are now heavily reliant on domestic ungulate carcasses (sheep, goats and camels) which are available all over the country. During the spring, which is the chick rearing period, the adult lappet-faced vultures might occasionally feed on live prey such as rodents and spiny-tailed lizards, but this is not a major source of food (Chapter 4)

9.1.2 Competition over the food supply

(I) With mammals

There were other mammalian scavengers in the area such as the foxes, and feral carnivores which could compete with vultures over carcasses. The foxes have other alternative food supplies, and the studies of Olfermann (1993) and Olfermann (1994) showed that they mainly feed on insects and small mammals. Moreover, these mammals were nocturnal and this reduces the competition with avian scavengers (Chapter 5). The amount of food these scavenging fox species obtained from the carcasses was very small around 4.4% (Chapter 6). The other feral mammals occur only near the small towns and villages where wild dogs can be found feeding from the garbage dumps. None of them were observed at carcasses away from human habitation. Persecution has virtually eliminated all the large, wild mammalian carnivores, such as woles and hyenas and this may have benefitted the avian scavengers.

(II) With other birds

The study suggested that lappet-faced vultures were not roosting communally in order to acquire information about food (Chapter 5), but it might enable the birds to form a network in the sky and thus search effectively for food over a large areas. Most birds started foraging singly or in pairs and they moved in different directions enabling them to cover the area co-operatively. The majority of birds arrived at carcasses singly, and they were usually the last species to arrive or to approach a carcass, whereas the ravens were the first avian species to arrive and feed from the carcass (Chapter 5).

The amount of food utilised by the avian scavengers was 30.4% from the total food available in the area, and the lappet-faced vulture utilised the majority of this percentage (Chapter 6). The bill structures of the smaller scavenging birds such as ravens, eagles and Egyptian vultures, are not adapted for tearing the skin, and they have alternative food sources. The lappet-faced vulture concentrates on carrion and has a deep, powerful beak with a strong hook at the tip which is adapted for tearing skin and feeding on the meat of mammals (Houston 1979; 1980; Mundy *et al.* 1992). This clearly shows that the lappet-faced vulture is probably the most important species in utilising this source of food. The remaining 65% of carcasses are left for the insects and invertebrates to consume with time. Each bird species differs in the time of day they attend carcasses, which probably reduces competition between species (Chapter 6). There was no evidence that competition at the food sources had any effect on the lappet-faced vulture population in the study area (Chapter 5 & 6).

9.1.3 Breeding and chick rearing

The egg laying of the lappet-faced vulture in the study area started in late December and early January (Chapter 7). Several factors probably influence the timing of breeding and favour the winter season for egg laying, but the most important is probably the need to minimise the thermal stress on both the egg and the incubating adults. Daylight in winter is shorter than other seasons, which will reduce the time exposed to direct sunlight and in addition thermal radiation is less intense in winter which will reduce the heat stress on the birds (Chapter 7).

There was a far higher density of nests inside the reserve than outside. This could be because the reserve provides an undisturbed place for lappet-faced vultures to breed and most of the trees outside the reserve were surrounded by fences for over-nighting the domestic herds. It is known from other birds of prey that disturbance at the nesting sites is one of the major reasons for the decline of raptors (Newton 1979; Mendelssohn and Leshem 1983; Mundy *et al.* 1992), and vultures in particular are highly vulnerable to disturbance (Houston 1987c).

The large size of the lappet-faced vulture and the long breeding season have a negative effect in the alttitude of the local people against this species, because they think that this bird will attack their livestock. Large stones were found in most of the abandoned nests outside the reserve (Chapter 7). The majority of large trees outside the reserve were also occupied by the local inhabitants for their livestock shelters. Therefore, the availability of trees for nesting must have declined outside the reserve as a result of this human disturbance, which probably is one of the main factors effecting the vulture population in the study area.

The observations at the nest showed that there may be a difference in parental care between the sexes in the lappet-faced vultures, and the female probably incubates more than the male (Chapter 7). The post-fledging dependence period in the lappet-faced vultures in the reserve was probably 4-5 months (Chapter 7). This period was the critical time in the lifetime of the lappet-faced vulture, as mortality was high in this post-fledging period. No observations of predation by mammals or birds were recorded.

9.1.4 Bird movements

The study showed that some of the lappet-faced vultures probably use the reserve for only part of the year. The factors driving this cycle are not clear, however the peak in bird numbers seems to be in autumn when the chicks had already fledged and started to spend more time away from the nesting area and to be more independent. Other factors could be dominance at food sites by the breeding adults during the period of chicks rearing in early spring which may cause immature birds to leave the area. Finally, the drop in temperature in the north of the country in winter, and the shorter day length, probably encourages some birds to move to the south for longer day light and better thermals which will increase the foraging time (Chapter 8). However, more data is needed to determine the cause of seasonal movements.

The home range of the fledging chicks increases with time after the birds leave the nest. Factors affecting the size of the home range for these birds are difficult to determine. The differences in the size of the home range between the birds could be related to individual variation or difference between the sexes (Chapter 8). Furthermore, the disturbance in the areas outside the reserve could have also had an effect on the home range of the species. Two radio tagged birds disappeared from a nursery area 80 km to the south of the reserve after a new camp became established in the area., suggesting that disturbance does alter the range of individuals.

The two birds fitted with satellite transmitters showed different kinds of movements. One individual was largely sedentary, whereas the second was much further ranging. However, in September of the same year the sedentary bird moved 1000 km to arrive again at Mahazat as-Sayd eight months after being caught there (Chapter 8). This could support the results of the changes in seasonal abundance of the lappet-faced vultures in the reserve, and suggest some birds engage in short-distance migration within Saudi Arabia.

9.2 Factors affecting the lappet-faced population

This study presents basic information on the factors which may be affecting the lappet-faced vulture population in Mahazat as-Sayd reserve. Relating this study with that of Newton (1979) on other species of raptor, in which he divided the causes of mortality into natural and unnatural: natural causes in the lappet-faced vultures included starvation among the fledging young, and perhaps extreme weather. The unnatural factors probably related to human disturbance (Photograph 9.1). This effect could be divided into deliberate and unintentional human disturbance. The deliberate factors include throwing stones at the nest, and probably shooting. The unintentional factors included using the good nesting sites for camps and the large trees for overnight shelter for the livestock, poisoning, and collision with man-made object such as road-accidents or trapping of the young in fences.

Data on causes of natural mortality in the lappet-faced vulture population was only obtained among the fledging birds. The long breeding season in this species and the lack of experience of the fledging nestling probably results in more mortality in this age group than among experienced birds. Also feeding the chicks by the adults during the post-fledging period probably has an effect on the mortality. Out of the nine birds found dead in the study area eight were less than one year old. As regard to the weather, two nests were destroyed by strong wind (Photograph 9.2). Sand storms can also reduce visibility, which might effect the foraging of the birds, and could also cover small carcasses which the vultures could not then locate and probably so reduces the amount of food available for the birds. Furthermore, the availability of natural water pools is also important for the birds especially for the juveniles in the post-fledging period where they were observed to visit these sites regularly.

The unintentional disturbance by humans at the nesting areas is probably the major factor for the decline of lappet-faced vultures in Saudi Arabia. Poisoning might have effected some birds, but this poisoning seems to be limited to the west of the country. Poisoning would also have an effect on other vulture populations such as griffon vulture or wandering juvenile lappet-faced vulture. Birds died from road accident in the area, and probably this is becomming more of a problem as more of the shepherds and farmers move their livestock near to the main roads or car tracks. The large size of the birds makes it difficult for them to escape from a fast car.

9.3 Conservation implication

9.3.1 Nest management

The major requirements for the breeding of lappet-faced vultures in Saudi Arabia is the availability of undisturbed open areas with large trees for nesting. This problem could be resolved by protected all the active breeding sites, which probably is unrealistic as the bird has such a wide distribution. During this study and from Jennings's study for the atlas of the breeding birds in Arabia (in Press) it seems that the birds have recently started to occupy and breed on some of the other protected areas with flat terrain such as al-Khunfah and Majamea al-Hadb. These protected areas probably will provide secure areas for future breeding populations of the lappet-faced vulture and need to be monitored regularly.

9.3.2 Public awareness

No conservation programme can hope to succeed without the support of the public in general. Therefore, extensive publicity outside these protected areas should be carried out. Ground visits to camps and farms around these protected areas should take the priority in the public awareness programmes. The main aims of this programme should be to show the importance of the lappet-faced vulture in utilising the carcasses, which will help in preventing the spread of disease among their livestock. Furthermore, these visits could help the local people to understand the benefit of wildlife and the importantce of the protected areas.

9.3.3 Monitoring and future research

No conservation measure can be carried out successfully, nor their effectiveness be tested without proper information and documentation. Therefore, in the future years the monitoring of lappet-faced vultures should be continued with the help of the NCWCD and NWRC staffs with the following aims

- Monitoring the population at the other protected areas to obtain data on the breeding and the seasonal cycles of the species, using the same methods used at Mahazat as-Sayd reserve.

- To obtain basic data on the food supply for the breeding population in the other protected areas.

- To determine the foraging range of the breeding birds.

- Continue tracking the young birds to understand the factors which may affect the movements of the lappet-faced vulture.

- Similar study should be carried out for the other vulture species such as the griffon vultures, Egyptian vultures and lammergeir, which with this study will help to draw a management plan to conserve all the avian scavengers, so they can play their role in this desert ecosystem.

- To obtain further data on the causes of mortality, and develop conservation programmes to minimise the risk to the birds in the future.

Photograph 9.1 Human disturbance.

Photograph 9.2 A strong wind moved the nest

Photograph 9.3 A poisoned goat carcasses in a tar field.

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