CHAPTER 11

LIVESTOCK PREDATION BY BLACK EAGLES IN THE KAROO

INTRODUCTION

Nearly 9000 years ago the first sheep were domesticated on the steppes surrounding the Aral and Caspian seas (Zeuner 1963). This marked a transition in human foraging behaviour from hunter-gatherers to agriculturalists and pastoralists. With growing technologies, human beings have exercised progressively more control over the resources on which they depend. Domestic sheep have provided a very significant portion of the essential resources of food and clothing. The world population of domestic sheep has been estimated at over 1000 million animals (Squires 1975), and one third of these occur in six southern hemisphere countries. South Africa, being one of these, had an estimated population of 44 million woolled sheep in 1930, but after the boom in the wool industry this declined to about 17 million (Anon 1985). Total sheep and goat numbers in the Karoo are estimated at approximately nine and a half million (Table 41, p. 247).

With domestication, the influence of natural selection has been increasingly replaced by that of selective breeding. While sheep have been bred for efficient production of harvestable commodities, they have become more dependent on humans and progressively less capable at evading natural predators. Many large predators have taken advantage of such easy prey and thereby have come into direct competition with the farmer for this resource. This competition is aggravated further when the vulnerability of sheep elicits a surplus killing response by the predator (Kruuk 1972b; Stuart 1986). Farmers are more inclined to accept sheep losses caused by climate or disease, resignedly. But the violent loss of lambs or ewes to a predator evokes a more angry and defiant response.

The extent of predation on livestock as revealed by questionnaire surveys is often exaggerated by the majority of ranchers who do not carry out thorough investigations of mortality agents (e.g. Nesse, Longhurst & Howard 1976; Armentrout 1980; Boshoff 1980; Hewson 1981). Despite this, there is no doubt that predators can seriously detract from the success of sheep-farming operations under certain circumstances. Coyotes *Canis latrans* caused an estimated U.S.$ 50000 worth of damage to livestock on a western Montana ranch over a 30 month period (O'Gara *et al.* 1983), and led to an estimated 14 - 23% decline in revenue and an estimated 16 - 33% increase in costs on an Angora goat ranch in Texas (Schrivner & Conner 1984). Domestic dogs are also implicated as regular predators of livestock in North America (Schaefer, Andrews & Dinsmore 1981). The estimated value of sheep losses to coyotes and dogs in California was equivalent to 10% of the total income from a ranching enterprise (Schrivner, Howard, Murphy & Hays 1985). In Australia, feral pigs *Sus scrofa* (Moule 1954) and 'killer' foxes *Vulpes vulpes* (McDonald 1966) have caused extensive damage. In Scotland foxes are held to be the chief offenders (Lockie 1964; Hewson 1984). While in South Africa caracals, black-backed jackals and domestic dogs are responsible for most sheep depredations (Rowe-Rowe 1975; Roberts 1986; Lawson 1989; Bekker *in litt.*). The only costing of predation in the Karoo was by Siegfried (1963b), who estimated the damage caused to sheep in the Great Karoo by corvids at R10860 p.a..

Wildlife biologists point out that losses to predators often only account for a few percent of the flock each year. But when these proportions are applied to nationwide flock sizes under the questionable assumption of non-compensatory predation (i.e. all stock would have survived to market had they not been killed by predators), it is easy to see why the early wildlife managers introduced bounty systems on 'problem' animals in the vain hope that losses might be prevented through elimination of all non-human predation. The U.S. Fish and Wildlife Service (1978) calculated that sheep losses to predators over 17 western States in 1977 were worth between 19 and 38 million dollars. In Texas alone, small stock losses to predators were valued at U.S.$ 13 million during 1978 (Texas Crop & Livestock Reporting Service 1979). Lawson (1989) valued the annual toll of sheep taken by predators in Natal at three million Rands.

Bounty systems have been used in attempts to eradicate predators from all the major sheep-farming regions of the world, and have encouraged enormous efforts and sometimes expenses on the part of the ranchers and trappers. The bounty system proved very popular in the Cape Province, South Africa, earlier this century. It is estimated that 120000 caracals were destroyed for the bounty system between 1931 and 1981, and in a single year (1949) 656826 bounties were paid out for predators destroyed (Stuart 1987a). The main methods of control in the Cape were shooting, gin traps, poisons and the formation of hunt clubs using dogs (cage traps, coyote getters, toxic collars and 'humane' killer traps have been used more recently). In addition, jackal-proof fencing of Cape farms was completed by about 1920 at great expense. The cost of erecting just the 7600km of road-side jackal-proof fencing in the Cape Province was recently estimated to be nearly R23 million (Siegfried *in litt.*).

In the case of large predators such as lions *Panthera leo*, spotted hyenas, and cheetahs *Acinonyx jubatus* which are arguably incompatible with sheep-farming, this effort has been successful in the Cape Province (Stuart, MacDonald & Mills 1985). But smaller predators such as black-backed jackals and caracals which pose less threat on an individual basis and which are probably more difficult to eradicate, still persist in large numbers. Eradication of black-backed jackals has been partly successful in the Great Karoo below the continental escarpment. Norton (*in litt.*) provided bounty records from the Cape Provincial Administration which show that a gradual decline in the kill rate of black-backed jackals in the Karoo has been concurrent with a steady increase in the kill rate of caracals. The records reveal that in the Beaufort West district 728 jackals (this figure probably includes foxes) and only 2 caracals were killed during the 15 years preceding 1947, compared with a kill of 37 black-backed jackals, 825 Cape foxes, and 75 caracals in the eight years thereafter. They also indicate a gradual increase in caracal kill rates for the Fynbos, coastal and eastern Cape regions. This predator has now become the principal 'problem animal' in the Cape (Stuart 1987b). Caracals predominate in the rocky mountainous regions, and the inaccessibility of such broken terrain is often associated with heavier livestock depredations (e.g. Nass, Lynch & Theade 1984).

The discovery that the expensive bounty systems were largely ineffective at reducing the numbers of such predators (Connolly 1978; Stuart 1982), coupled with a change in conservation attitude led to their discontinuation in the Cape (Hey 1959) and other parts of the world. But the State paid out a subsidy of R58690 to hunt clubs in 1985/86 (Siegfried *in litt.*) and control measures are still actively employed by individual farmers and the problem animal control section of the Cape Nature Conservation Department. On one farm in rocky terrain near Victoria West, 141 caracals and 6 black-backed jackals were destroyed between 1978 and 1990 (records for other predators killed were only

maintained from 1978 to 1980 when 24 Cape wildcat, 9 Cape fox and 1 aardwolf were destroyed - Swiegers *in litt.*). It was a visit to this farm in 1984 and the observation of hyrax and other prey epidemics that prompted the present study (Chapter 1). Many farmers such as this spend a lot of time and resources on predator control without any indication that their caracal 'problem' is declining. Sadly, an enormous amount of non-target species are being killed in this process because of non-selective methods, notably poison and gin traps (Brown 1988a; Allan 1989). Furthermore, the expense of some predator control operations has been shown to actually exceed the value of the animals that are lost to predators (Schrivner & Conner 1984), and a new notion is that small improvements in flock management may have far more beneficial effect on harvests than large efforts to control predators (Hewson 1984; C.J. Brown pers. comm.).

Large eagles were not exempt from bounty systems, and have been persecuted wherever they occur in major sheep-farming regions (Brown 1975). An estimated 20000 golden eagles were shot from light aircraft in the states of Texas and New Mexico between 1942 and 1962, while 700 wintering eagles were shot by helicopter in Wyoming over one season (Spofford 1964, 1975). Single hunters boasted kill rates as high as 1200 eagles in a season, and 12000 over 20 years (Johnstone 1966). Unlike coyote and caracal populations, large eagles have a low potential for population increase (Brown 1976; Newton 1979) and such heavy persecution has undoubtedly been a major factor in the decline of many eagle populations around the world. Kill rates of wedge-tailed eagles in Australia were considered to be the highest for any large raptor (Brown, L.H. 1976: p. 195). It was estimated that the total eagle kill in Australia may have exceeded 30000 per annum (Serventy 1974). This persecution probably reduced eagle populations in the more unstable, arid areas (Ridpath & Brooker 1986). But these kill rates were far lower than those claimed by farmers for black and martial eagles in parts of the Karoo during the 1960's (Siegfried 1963a; Chapter 1: p. 3). Approximately 5000 eagles were destroyed in the Cape Province between 1935 and 1950 for the bounty system (Boshoff & Vernon 1980), and as many as 520 bounties were paid for dead eagles in one year (Stuart 1987b).

Since the bounty system was withdrawn in the Cape there has been a major, sympathetic shift in the attitudes of farmers towards eagles. This has been largely due to education programmes run by the Cape Nature Conservation Division and other organisations (Boshoff 1978, 1980; CDNEC undated). Today, eagles enjoy a greater degree of protection by karoo farmers (Janse van Rensburg 1991), and a generally more popular public image in many parts of the world (Kellert 1985). However, eagles are still being killed unintentionally by farmers in the Cape through the use of non-selective methods of predator control. The widespread and indiscriminate use of poison is considered to be responsible for the disappearance of bateleur eagles and other large scavenging raptors from the Karoo (Pickford, Pickford & Tarboton 1989; Allan 1989) and other small stock farming areas in southern Africa (Brown 1988a, 1991). Meanwhile, direct persecution of eagles continues unabated in certain isolated farming communities such as Merweville (pers. rec.) and Steytlerville (Anon 1992a unpubl.).

Do eagles really compete with farmers by preying on livestock, and is the persecution of eagles at all justified? Black eagles are known to perch boldly on carcasses of dead sheep or lambs which may have been killed by more secretive predators or died non-violently (C.J. Brown pers. comm.), so to what extent is the notion that eagles kill lambs a perceptual problem? It is certainly based on very little documented evidence. However, eagles are powerful avian predators and there are records of at least two species killing young ungulates weighing up to and over 30kg (see

Table 26, p. 178). Although exceptional, the records in Table 26 do indicate that the larger eagles should be capable of overpowering young sheep up to about half size. To many farmers this may be justification enough for getting rid of them. But on the basis of very few documented observations and some hearsay accounts, the issue appears to be not whether eagles kill lambs, but rather to what extent does lamb-killing by eagles occur, and under what circumstances?

Most studies and hearsay accounts indicate that only very young lambs (up to about 10d old) are susceptible to eagle predation (Arnold 1954; Wiley & Bolen 1971; Tjernberg 1981; Hewson 1984). Lambs born under open-range conditions (as practised in the Karoo) are most vulnerable to any eagle attacks (Phillips & Blom 1988). There is also evidence that younger, less experienced (non-breeding) eagles are more inclined to kill lambs (Foster & Crisler 1978). One instance of eagles causing extensive damage to small stock farming involved an aggregation of predominantly juvenile golden eagles in Montana following a major decline in the natural prey base. This investigation by O'Gara (1978) suggested that eagle damage on two ranches amounted to U.S.$ 38000 in 1974 and U.S.$ 48000 in 1975. Littauer & White (1981) valued damage to livestock by golden eagles in New Mexico during one lambing season at U.S.$ 87000.

Most studies of eagle-livestock depredations have implicated the golden eagle in North America (e.g. O'Gara 1978; Phillips & Blom 1988) and in Europe (e.g. Weir 1985; Bergo 1987), but bald eagles *Haliaeetus leucocephalus* in America (Wiley & Bolen 1971; McEneaney & Jenkins 1983) and white-tailed sea eagles *Haliaeetus albicilla* in Europe have occasionally been implicated. In Australia the wedge-tailed eagle is known to kill lambs and there are some reports of white-bellied sea eagles *Haliaeetus leucogaster* feeding on domestic stock (Leopold & Wolfe 1970; Rowley 1970; Brooker & Ridpath 1980). Here in Africa the martial, black and crowned eagles (the most rapacious species) may kill lambs (Boshoff 1980; Boshoff *et al.* 1990; Boshoff *et al.* 1991; Bekker *in litt.*), with some indication that the smaller tawny eagle also uses this food resource (Boshoff, Rous & Vernon 1981). Large forest eagles such as the crowned eagle, the harpy eagle *Harpia harpyja* in South America and the Philippine eagle *Pithecophaga jefferyi* may kill livestock, but their ranges do not overlap with major small stock farming regions. New Zealand is the only major sheep-farming region where large eagles do not presently occur (Brown & Amadon 1968).

An objective assessment of the black eagle as a livestock predator in the Karoo was needed. A major, applied motivation for the present study was to assess the 'role' of black eagles on karoo farms, so this chapter is intended as a summary of the harm that they can do on farmland. I have attempted to address the following questions: to what extent and under what circumstances do black eagles kill lambs in the Karoo? how does this predation influence livestock numbers and the revenue from ranching operations? and in the event of livestock predation by black eagles, what management steps are effective and practical for the prevention or reduction of losses? Nest-based studies of eagle feeding habits have serious limitations when used to address these questions, so I rely on other methods such as the collation of farmers' reports and field necropsies on lamb carcasses. The relative brevity of this chapter is due to the extreme difficulty that I experienced in finding any evidence of lamb-killing by black eagles, and the need to focus on the main predator-prey (hyrax) relationship. In consequence, I draw heavily on the literature regarding questionnaire surveys and investigations of lamb predation world-wide, to draw conclusions about the compatibility of large eagles with the open-range farming of small livestock. Some of these observations have been published earlier (Davies 1988).

METHODS

Methodology used for nest-based studies of black eagle feeding habits in the present study was described in Chapters 8, 9 & 10. Collections of prey remains from eagle nests give a poor indication of the extent of stock depredations by the eagles because: they only reflect diet during the breeding season; non-breeding birds generally cause more harm; many lambs would be too large to be transported to nests; and most important, they give no indication of whether lambs were scavenged or killed (Matchett & O'Gara 1987). On the other hand, many raptors are known to take a wider spectrum of larger prey items when under strain to feed nestlings, and over-representation of domestic lambs in the diet of the eagles might also be caused if larger skeletal material tends to accumulate in collections of prey remains over time (Chapter 9). The latter bias may be overcome by time-lapse photography and other observations at nests (Chapter 9), but results from these methods are still influenced by the other shortcomings of nest-based methods of diet determination. Direct observations of the eagles within their ranges (Chapter 6) are time-consuming but can yield small amounts of bias-free information on stock predation by territorial birds, or the absence of it. Prolonged observations of eagles in the vicinity of lambing paddocks is probably the best way of getting eye-witness accounts (Brooker & Ridpath 1980), but insufficient time was available for this method in the present study.

Data on stock predation by black eagles were gathered from three other sources: personal interviews with farmers; literature search; and field necropsies of carcasses in the lambing camps. Interviews with karoo farmers were conducted between 1983 and 1990. I delivered several talks to the Beaufort West farming community and asked any farmers to call me out if they were experiencing problems with eagles on their farms. Most visits were restricted to an area within a 250km radius of Beaufort West. I also obtained information on stock predation from casual discussions with members of the farming and conservation communities. A literature search on stock predation was conducted using key-words through 'Dialog Information Services, Inc.' in order to provide data on lamb predation by eagles and other predators around the world. All articles which were readily accessible through libraries were consulted.

Field necropsies were carried out on any lamb carcasses that I came across on visits to farms or during other field work, where an eagle might be implicated as the agent of mortality. The success of these post-mortem examinations depended largely on the state of decay and 'intactness' of the carcasses. The examination involved skinning the carcass and inspecting for characteristic wounds delivered by predators. For eagles, these wounds have been described by a number of authors (Rosko 1948; Rowley 1970; Wiley & Bolen 1971; Alford & Bolen 1972; Bowns, Davenport, Workman, Nielson & Dwyer 1973; Davenport, Bowns & Workman 1973; White 1973; Brown, J.E. 1976; Nesse, Longhurst & Howard 1976; Tigner & Larson 1977, 1981; O'Gara 1978, 1981; Wade & Bowns 1980). Massive subcutaneous haemorrhaging surrounding irregularly-spaced talon punctures on the neck and upper back are the primary indications for eagle-killed lambs. These and other signs of lamb mortality agents were summarised in a short field guide for farmers and conservationists entitled 'Innocent Until Proven Guilty' (published by S A Eagle Insurance Company Ltd., and available through the Endangered Wildlife Trust, Private Bag X11, Parkview 2122, Johannesburg, South Africa).

RESULTS AND DISCUSSION

Nest-based investigations of stock predation by eagles

The most extensive data on eagle predatory habits derives from collections of prey remains from nest sites. Domestic bovids comprised 1,12% of 3586 prey items collected in and around the Karoo National Park between 1986 and 1990 (Table 28, page 183). All were considered to be immature animals with a mean mass of 4180g (n=40). On account of their relatively large size, domestic bovids fulfilled a slightly larger portion (1,82%) of the eagles' food needs (Table 29, page 185).

Lamb remains were observed relatively more frequently on visits to nests (Table 32, page 189). This is likely to be due to slower consumption of large prey items by the eagles. Lockie (1964) considered that lambs would be over-represented amongst fresh prey remains at golden eagle nests. Analyses of actual prey deliveries monitored by time-lapse photography in the present study did not suggest that domestic lambs were significantly over- or under-represented in collections of prey remains (page 203).

As expected and as revealed in Chapter 9, domestic bovids made up a significantly greater amount of the diet of eagles which hunted predominantly over farmland (viz. 1,6%) than that of eagles which hunted predominantly over parkland (viz. 0,6%). At an average annual predation rate of 174 prey per eagle territory (Chapter 8), this would imply that on mountainous farmland an average of 2,8 lambs would be consumed by eagles per territory (@2300ha) each year, or 5,6 lambs for the average karoo farm (@4687ha: Olivier *in litt.*).

However, underestimation of the lamb component in the present study of black eagle diet may have occurred through some confusion with klipspringer remains (page 202), and because the territories of most eagles nesting on adjoining farmland to the KRNP still encompassed some of the park, from which domestic stock were excluded. In other regions of the Cape Province, black eagles have been recorded to consume more domestic lambs in their diet. Further down the Nuweveld escarpment towards Fraserburg, domestic bovids made up 3,9% of black eagle diet (Boshoff *et al.* 1991). This consumption rate should be free of the influence of conservation areas and would correspond to a consumption rate of up to 6,7 lambs per eagle territory and up to 13,6 lambs per farm in the mountainous parts of the Karoo each year.

East of the Karoo the short shrublands are replaced by eastern Cape grasslands and thick bush. Here black eagles may take up to 8% domestic bovids in their diet (Boshoff *et al.* 1991). Martial eagles were also found to feed on more domestic stock in this region (Boshoff *et al.* 1990). This may be a convergent situation to that observed by Bolen (1975) in Texas, where golden eagles were found to take more domestic lambs in areas of thicker brush. These areas actually contained more natural prey (lagomorphs), so Bolen attributed the higher incidence of stock predation by both eagles and carnivores in the brushlands to the relative inaccessibility of natural prey in this dense vegetation. Wade (1982) also reported high losses to predation among isolated goat populations in thick Texas brush.

Brown (1975) estimated that between lambing and weaning, 500 - 700 domestic lambs lie dead in the average golden eagle territory in Scotland, and stressed that the eagles do not need to kill lambs in the presence of this food glut. It is estimated that about 145 lambs die on the average karoo farm each year (Table 41, p. 247), and most of these would be available as carrion within two weeks of the lamb births. One would expect an annual mortality of about 70 lambs within the average black eagle territory on farmland. Earlier breeding by farm-nesting eagles suggests that the birds are indeed taking advantage of the food resource resulting from the main lambing period in March in the Beaufort West district (Chapter 6).

While black eagles were twice observed to scavenge on domestic sheep, actual predation was neither observed nor inferred in the present study (see later). It thus seems highly likely that a significant proportion of the domestic lambs conveyed to black eagle nests were scavenged rather than killed by the eagles. Two studies at scottish golden eagle nests provide data on this aspect of eagle feeding habits - signs of predation rather than scavenging were evident on three of ten assayable lamb carcasses delivered to one nest (Lockie 1964) and on two to four of six assayable lambs delivered to another (Weir 1985). This suggests that about 40% of lambs consumed by scottish golden eagles may actually have been killed by the eagles, but the sample is very limited. Most of the various biases inherent in analyses of prey remains mean that this method should yield a worst-case scenario or an upper limit to the maximum levels of stock predation by resident eagles (Methods). One might conclude that the real predation rate of resident eagles would fall well below these indications of their consumption rate of domestic lambs. It is not possible to gauge the exact extent of this predation from collections of prey remains. Furthermore, golden eagle studies (in Matchett & O'Gara 1987) indicate that wandering, food-stressed immature eagles are more responsible for lamb-killing than resident breeding pairs of eagles who might enjoy a more reliable natural prey base. To truly be free of such biases, one must depart from the nest-based food studies and consider the other methods pertaining to the actual lambing paddocks.

Direct observations

In the course of fieldwork I did not observe any attacks by black eagles on domestic stock, but I saw eagles scavenging on sheep carcasses twice. In one instance (3/6/87), an adult eagle was flushed from a carcass of a Merino lamb which had recently been killed by a small carnivore immediately south of the Karoo National Park (see field necropsies). On 2 January 1988 I watched an adult pair of black eagles descend from their nest cliffs and alight on the slopes below to feed off the carcass of an adult sheep on the farm Lemoenfontein, Beaufort West.

Direct observations of eagles in the vicinities of lambing paddocks were not conducted in the present study. However in 1983 and 1984, as part of another study, I was conducting observations on springbok and Merino sheep on the farm Biesjiesfontein near Victoria West and had the opportunity of observing eagle behaviour in the presence of lambs of both species. On one occasion, a single adult black eagle was seen to alight on the back of an old and sickly springbok ram, but the eagle flew off when the ram bolted. The remaining observations were of an immature martial eagle which frequented the camp in which I was conducting observations. This young bird may have fledged from a nest in the same camp. Although not the species under study, it shows a similar degree of rapaciousness to the black eagle and I think that the observations are pertinent here.

Over a period of a few months, I witnessed several attacks by this martial eagle at prey. A young springbok (estimated to be two thirds adult mass) escaped one attack by sprinting up a steep slope; a small springbok lamb and a young bat-eared fox (three quarters adult mass) both escaped the eagle through intervention by nearby adults of their own species (probably parents); an adult suricate was the only kill directly observed; but on another occasion the young martial was flushed from a freshly-killed and mostly-consumed springbok lamb. Throughout this period there were young Merino lambs in the study camp which were probably more vulnerable to attack than any of the natural prey. These lambs occasionally bedded directly beneath a tree which was regularly used as a perch by the eagle. Not once was the eagle seen to attack any of these lambs or to feed on the lamb carcasses that were available.

Young raptors often attack very large prey (Mueller & Berger 1970; pers. obs.) and learn through experience to choose the right prey size. The observed attack on an immature springbok may have been of this nature, which makes it all the more surprising that this young eagle did not attack the Merino lambs. Bird behaviour is often highly influenced by early experiences during sensitive developmental stages. Acceptance of parents or surrogate parents by young birds during their first couple of weeks as nestlings dictates future acceptance of sexual mates when they reach maturity. This process, called 'imprinting', is very different from normal associative learning (Lorenz 1935, 1937; Hess 1973) and can be very difficult to reverse or change (Jones 1981). Besides parents and mates, young birds and other animals have also been shown to imprint on nesting habitat (Klopfer 1963), and on food types (Rabinowitch 1968, 1969; Hess 1973; Meyer-Holzapfel in Lorenz 1973; Immelmann 1975). These strong food preferences can be very persistent (Rabinowitch 1969) and may remain manifest even after a change in diet (Burghardt & Hess 1966). Hess (1973) considers that modification of innate feeding behaviour in domestic chicks during the sensitive period is "apparently permanent". Falconers are well acquainted with the great partiality that trained hawks develop for particular prey species, and describe this affinity as 'wedding' to a particular prey (Woodford 1966). It may take several days of food-deprivation before captive raptors will switch from a diet of white mice to one of day-old chicks (pers. obs.). I think it is highly likely that the young martial eagle under observation was fed natural prey items as a nestling and consequently became wedded or imprinted on these prey types. As a result it simply did not recognise the Merino lambs as potential prey.

Most of the large African eagles will kill newly-born antelope, especially when left unattended (e.g. Mooring 1993). Martial eagles attack lambs of the smaller antelope species even in the presence of their dams, as recorded photographically by Scott (1985: p. 33) and Kunkel (1992). Many of the farmers interviewed in the present study considered that eagles preferred to attack goat kids rather than sheep lambs. Goats often suffer heavier predation than sheep (Nass *et al.* 1984; Wade 1982). Mortality rates for Boer goat kids in the Karoo were indeed higher than those of Merino and Dorper lambs (Roux *et al.* 1981). Greater incidence of goat kid predation by eagles may be due to their closer resemblance to juvenile antelope, but could also be due to poorer attendance by nannies (Glover & Heugly 1970) and to the isolation of goat herds in thick brush and rough terrain (Nass *et al.* 1984).

The favouring of a common prey type by foraging birds has been explained by Tinbergen (1960) who maintains that the birds form a 'specific search image' for that prey type. Specialised predators such as black eagles might be expected to have a very strong 'search image' for their preferred prey, and be even less inclined to switch to a new prey type. This might explain why black eagles are notoriously difficult to trap (Gargett 1990; the present study).

Attitudes of farmers to eagles

During the course of fieldwork, I interviewed over 30 farmers and 11 members of the conservation community with regard to problem animals, particularly eagles. In addition to these casual interviews, I made 29 visits to farms in the Beaufort West, Victoria West, Murraysburg, Hopetown, Kimberley, Swartberg, Graaff Reinet, Fraserberg, Craddock, Tankwa Karoo and Middleberg districts of the Karoo.

Six farmers provided details on eagles that they claimed to have killed. Many farmers maintained that eagle problems became more manifest during drought conditions when natural prey might be in decline. Farmers in the Camdeboo area near Graaff Reinet took action against eagle problems during the 1983 drought: one killed three black eagles and two martial eagles; another killed three black eagles; and a third claimed to have killed nine black eagles in the same locality over a two-week period. Merweville farmers claimed extremely high kill rates of eagles during the 1980's: one claimed that he killed 26 eagles in a single year, and that he had removed a total of 86 eagles from his farm; his neighbour claimed he killed 51 eagles in a single year; another farmer in the area admitted to removing a pair of martial eagles. Most of these birds were captured in gin traps or shot. Other mortalities for black eagles (post-fledging) that I heard of were one electrocution, two drownings in farm reservoirs and one collision with a communications tower. A single poisoning incident did not prove fatal. Trapping, poisoning and shooting are the major causes of mortality in North American golden eagles (Bortolotti 1984) and Australian wedge-tailed eagles (Ridpath & Brooker 1986).

Laingsburg farmers who returned questionnaires in 1963 claimed kill rates which were equivalent to 166 eagles killed per 10000km^2 per year (Siegfried 1963a). Most of these were black eagles, and the reported number of this species destroyed was equivalent to nearly twice the expected annual production of black eagle chicks in the district (p. 3). This kill rate is more than nine times that of wedge-tailed eagles in Australia (Ridpath & Brooker 1986), supposedly the most persecuted large raptor in the world (Brown 1975). It became evident during the present study that despite changing attitudes towards eagle conservation, intense persecution of the birds continues in some localities. Most recently, two farmers from Steytlerville claimed to have killed 140 black eagles on their farms over a two year period (Anon 1992a unpubl.). It is not possible to know how accurate these claims of eagle-killing by farmers are. It seems highly unlikely that a single farmer would actually be able to kill 51 eagles on his farm in a single year. Some of these claims may be gross exaggerations to impress peers, or to upset eagle biologists! There is no indication that black eagles are declining in the Karoo, and the population just along the escarpment through the Karoo and into the eastern Cape may exceed 1300 birds (Chapter 6). If these claims of eagle persecution are accurate, then alarming as they seem, they indicate a healthy floating population of non-breeding birds which quickly fill vacant territories. Extremely intense persecution of black eagles in districts such as Laingsburg in the past may have caused these districts to act as 'sinks' for the Cape population. But today eagle persecution, like that of caracals, appears ineffective at controlling predator numbers.

Only 0,6% of 14761 Cape farmers interviewed by questionnaire admitted to persecuting raptors, perhaps in fear of legal action (Boshoff 1980). Information on the beneficial effects of raptors was volunteered by 3,7% of the same farmers. Of all the farmers interviewed in the present study, only two took active steps to encourage eagles on their

farms (by provision of artificial nest sites, and rehabilitation of injured birds). However many of the farmers, especially around Beaufort West, were prepared to protect their nesting eagles. Some of the farmers who persecuted carnivores intensely (even yellow mongooses *Cynictis penicillata* in one instance) were inclined to tolerate resident eagles. When I visited these farmers, they would often refer to information pamphlets on raptors which had been sent to them by the Cape Department of Nature and Environmental Conservation.

Farmers' reports of stock losses to eagles

Of 37 farmers interviewed, 18 (49%) reported that they had suffered no domestic stock losses to eagles. One of these farmers however reported that he often lost springbok lambs to a resident pair of black eagles. A search at this nest site revealed the remains of at least four springbok lambs. Ten of the farmers (27%) reported that eagles occasionally killed domestic lambs on their farms. The remaining nine farmers (24%) reported significant losses to eagles. Of these, three farmers described eight eye-witness accounts of eagles killing domestic lambs or kids. Most farmers considered that lambs were vulnerable to eagle attack up until 4 - 6 weeks old. One of the eye-witness accounts described a pair of black eagles and their fledgling killing a Merino lamb which was two and a half months old. However this incident and two others were recounted by a farmer who is renowned as something of a story-teller in Beaufort West. I have no grounds to refute the eye-witness accounts of the other two farmers, one of whom lost four Angora goat kids and one maltese poodle to a black eagle which he considered to be too old to catch hyrax. Surprisingly, this farmer refrained from killing the eagle and instead captured it in a padded gin trap for translocation. The other farmer saw a black eagle kill one of his 'stud' lambs close to a homestead. Most farmers considered both black and martial eagles to be responsible for stock losses, but some held martial eagles more responsible. Four farmers reported sudden incidences of lamb-killing by eagles which they attributed to drought and a decline in natural prey. Accounts of stock losses were varied by nature: 17 lambs recently; 9 lambs in one month; 14 carcasses under the eagles' nest; 14 goat kids etc.. Consequently it is not possible to accurately quantify the extent of stock predation by eagles in the Karoo from these reports.

Notions held by farmers in the present study were however very similar to those reported in other investigations. Farmers in Ladismith (Palmer unpubl.), Steytlerville (Anon 1992a unpubl.), Laingsburg and Philipstown (Siegfried 1963a), and in the Cape Province as a whole (Boshoff 1980) also maintained that eagle problems became manifest during drought due to low natural prey populations, and agreed that lambs were only really vulnerable to eagles during their first month. There are various indications that hyrax actually become more available to black eagles when conditions get more arid (pp. 274, 306-307), and I think that greater perception of predator problems by farmers during drought is probably prompted by high lamb mortality caused by drought. Questionnaire surveys have indicated that small-scale farmers tend to report higher losses to predators (Boshoff 1980; Nass et al. 1984). This might concur with observations in the present study that small-scale farmers are more sensitive and less tolerant to lamb-predation, and that areas of intense eagle persecution were low-income areas. Seventy one percent of Ladismith farmers claimed losses to eagles of up to 70 lambs per month, but no eagle-killed lambs were found on a follow-up investigation. Steytlerville farmers claimed that 5 - 100 goat kids were killed by eagles on their farms each season, and that losses in the district amounted to R140000 per annum. These claims have yet to be substantiated. Sixty four percent of Steytlerville farmers reported losses to eagles (75% in the mountainous areas)

and only 2% wished to conserve the birds. These reporting rates for stock losses to eagles are higher than those recorded during the present study (51% of farmers), and from the results of 13857 questionnaire returns, where 26% of Cape farmers claimed losses to eagles (Boshoff 1980). In the 1960's, a majority of Laingsburg farmers (71%) reported stock losses to eagles (mainly to black eagles), and a smaller portion of Philipstown farmers (37%) reported stock losses to eagles (mainly to martial eagles) in a questionnaire survey conducted by Siegfried (1963a). These questionnaire surveys have been used to glean information on the abundance of raptors (Boshoff & Vernon 1980), and on the persecution of raptors (Siegfried 1963a). They have also been used, especially in North American studies, to assess the proportion of lambs lost to predators and the relative contribution of mortality agents.

The portion of mortality that is attributed to predators is not a parameter that can be compared across studies because total mortality is so variable with environmental conditions. For instance, when conditions are excellent, predation may account for a large portion of mortality, but this might be misleading if overall losses are negligible. The indeterminable portion of lamb mortality is also highly variable in reports. For these reasons and for the purposes of this review I shall be expressing lamb losses to predators between birth and weaning as their proportion of the total born rather than of the total dying.

Summaries of such findings from questionnaire surveys are presented in Table 38. The percentage of lambs lost to predators is given for 11 surveys (in RSA and USA), and these yield an average figure of 6,65% lambs killed. This average is lowered to 5,22% if one 'problem flock' (see later) is omitted. The percentage of lambs lost to other causes is given for 7 surveys, and these yield an average figure of 8,91% lambs lost to other causes. The sum of these figures suggests that small stock farmers in South Africa and North America believe they lose 14-16% of their lambs between birth and weaning. Records at Grootfontein Agricultural College in the Karoo suggest a mortality rate of 10-12% for juvenile small stock in this region (Olivier *in litt.*). But farmers' estimates of total lamb mortality may be under-estimated due to the large number of newly-born lambs which disappear without a trace. Most studies indicate that 20%, or more, of lambs die between birth and weaning (Rowley 1970; Squires 1975; Houston 1977; Hewson 1984; Weir 1985).

Few stockmen carry out post-mortem examinations on lamb carcasses so losses to predators are usually based on signs of external feeding and tend to be exaggerated in these questionnaire surveys (Nesse, Longhurst & Howard 1976; Andrews & Boggess 1978; Sterner & Shumake 1978; Armentrout 1980; Boshoff 1980; Hewson 1981). Investigations which reveal that farmers' reports on stock losses to predators can be honest and accurate are in a minority (Balser 1974; Boggess *et al.* 1978; Schaefer *et al.* 1981; Robel *et al.* 1982). In the Swartberg mountains at the southern limit of the Karoo, sheep ranchers claimed they were losing up to 66 lambs each season to predators, and they estimated that the predators removed 11% of their lambs and that another 5% of the lambs died non-violently. A follow-up investigation by Bekker (*in litt.*), who carried out extensive post-mortem examinations, revealed that predation was the primary cause of death for less than one percent of lambs while other mortality factors were claiming as much as 15% of lambs born. Evidently the results of questionnaire surveys need to be interpreted with caution, but they do indicate that most ranchers see canids and possibly felids (in RSA) as the main threat to their livestock, rather than eagles (Table 38). This is exemplified by the numbers of livestock-loss claims that were allocated to respective predators by ranchers in Iowa (Table 39).

TABLE 38
FINDINGS ON THE PREDATION AND NEONATAL MORTALITY OF LAMBS FROM QUESTIONNAIRE SURVEYS OF RANCHERS

Losses refer to the percentage of total lambs born that die before weaning.
The relative importance of various predators in lamb-killing (as indicated by ranchers) is highlighted with asterixes.

						PREDATOR TYPE RESPONSIBLE FOR LOSSES													
SOURCE	REGION	BREED	SAMPLE SIZE	% LAMBS LOST TO PREDATORS	% LAMBS LOST TO OTHER CAUSES	EAGLES	UNSPEC. NON - EAGLE	CORVIDS	FOXES	JACKALS	COYOTES	DOGS	WOLVES	WILDCAT	CARACAL	PUMA	BEAR	BABOON	PIGS
Boshoff (1980)	Cape, RSA	various	14761 farmers			**		***		****				***	*****				
Lawson (1989)	Natal, RSA	various	159 farmers	3,4	6,4	?		?		*****		****			***			*	
Bekker (in litt.)	Swartberg, RSA	various	5 farmers	11	5														
Reynolds & Gustad (1971)	four west states, USA	* whole flock	farmers	5,3	16,1														
Dorrance & Roy (1976)	Alberta, USA	various	75 farmers	2,8	12,9						95%	3%	*			*	*		
Early et al. (1974a & b)	Idaho, USA	* whole flock	farmers	3,4	9,1														
Nielson & Curle (1970)	Utah, USA	* whole flock	farmers	6,1															
Gee et al. (1977)	15 west states, USA	various	farmers	8,1															
U S Fish & Wildl. (1978): 1972-78	Western states, USA	various	literature	4 - 8							*****								
Schrivner & Conner (1984)	Texas, USA	Angora kids	101 farmers	20,3 - 22,6							*****								
Schaefer et al. (1981)	Iowa, USA	various	1251 farmers	5,2	5,9						*****	***							
Robel et al. (1981)	Kansas, USA	various	109 farmers	0,9	7,0						224	54							

TABLE 39
FINDINGS ON THE PREDATION AND NEONATAL MORTALITY OF LAMBS FROM ANIMAL DAMAGE CLAIMS AND MISCELLANEOUS INCIDENTS

The relative importance of various predators in lamb-killing is shown by asterixes or by the number of claims/incidents.

						PREDATOR TYPE RESPONSIBLE FOR LOSSES													
SOURCE	REGION	BREED	SAMPLE SIZE	% LAMBS LOST TO PREDATORS	% LAMBS LOST TO OTHER CAUSES	EAGLES	UNSPEC. NON - EAGLE	CORVIDS	FOXES	JACKALS	COYOTES	DOGS	WILDCAT	CARACAL	BOBCAT	PUMA	BEAR	BABOON	PIGS
Lockie & Stephen (1959)	Scotland, UK		incidents			1													
Lockie (1964)	Scotland, UK		21 prey			3													
Bergo (1987)	Norway		18 incidents			1													
Pearson & Caroline (1981)	Texas, USA	sheep & goats	claims	0,27 flock							***				***				
Boggess Andrews & Bishop (1978)	Iowa, USA	various	5800 claims	1,5			2684				6557	9068							

Field necropsies

Post-mortem examination of lamb carcasses in the field can yield more data on livestock predation than direct observations. Farmers' estimates of lamb losses to predators may be exaggerated when scavenging is mistaken for predation. The presence or absence of blood and bruising on a carcass is a sure sign of whether the lamb died violently or non-violently. Predation should not be considered the primary cause of death when the predation response is triggered by the weakened behaviour of a dying lamb. Thorough examinations of fresh carcasses will indicate whether a lamb was viable or not when killed (Rowley 1970).

An extensive carcass inspection survey still needs to be carried out in the Karoo. But in the course of fieldwork and visits to farms I had the opportunity of examining 23 lamb and kid carcasses where eagles were implicated as the main mortality agent. On 3 June 1987, I was called by a Karoo National Park ranger to investigate a lamb on the southern border of the park which had apparently been killed by an eagle. On arrival at the scene, an adult black eagle was flushed from the carcass of a Merino lamb which was thought to be approximately 15% of adult mass, i.e. about 8kg alive. A hindleg was missing and about three quarters of the carcass had been devoured. The carcass was very fresh and my first impression was that the eagle was indeed responsible for the death of the lamb. However, when we removed the carcass by vehicle, we flushed a Cape fox from nearby shrubs. On skinning the carcass we found matching bite wounds to the throat indicating that a small canid or felid had killed the lamb, and there was no massive haemorrhaging on the back or neck. This incident emphasized to me the ease with which scavenging by eagles can be mistaken for predation if a necropsy is not carried out.

Most of my visits to farms were prompted by landowners complaining of eagle problems. Despite this, only one visit in 29 yielded an opportunity to examine lamb carcasses for signs of eagle predation. Searches for lamb carcasses on other farms were unsuccessful, and it transpired that most of the farmers were referring to problems in the past when they called me out. In August 1988 however, Wynand Fourie of the farm Paardebond near Calitzdorp (in the Little Karoo) claimed that he was losing up to two goat kids per day to a black eagle (Allardice & Erasmus unpubl.). On this farm a Boer goat herd of 155 nannies was confined in a 130ha camp of degraded succulent karoo veld. Most nannies were giving birth in an area of 10ha. We advised Mr Fourie to place a shepherd with the kids. I joined Allardice and Erasmus in an investigation of Mr. Fourie's losses. These conservation officers had found no goat remains beneath the nearest black eagle eyrie. They had posted two observers in the kidding area for two days. A black eagle was roosting in the camp and fresh goat remains were found beneath the roost. No kills were observed, but on two occasions the eagle swooped low over a goat kid herd and was chased off by the shepherd.

During a search of the main kidding area, we found 22 goat kid carcasses which we examined in the field. Eighteen of these carcasses did not show any signs of damage by a predator or scavenger. Four carcasses had been fed on but cause of death was indeterminable for one. The absence of major subcutaneous haemorrhaging indicated that the three other carcasses were not killed by an eagle. There was evidence of carnivore predation on one of these. Droppings and triangular sections removed from the scapula indicated that the eagle had certainly fed from one carcass.

We ascribed the high kid mortality to the confinement of the nannies in an overgrazed environment. Many of the nannies that twinned were evidently abandoning one of their offspring. The habitat did not support many hyrax and did not afford nesting sites to eagles. In the absence of territorial birds it is not surprising that a non-breeding black eagle was attracted to the abundance of carrion. The eagle may have killed some unattended kids but we could find no direct evidence of this. Palmer (unpubl.) also found no evidence of lamb-killing by eagles when investigating an 'eagle problem' on farms in the Ladismith district. On one of these farms, high goat kid mortality to caracals attracted eagles and corvids in 1979-80, but post-mortem examinations of carcasses convinced the farmer that eagles were not responsible for the deaths in this case.

The findings of documented, field necropsy surveys in South Africa and other sheep-farming regions worldwide are summarised in Table 40. It is evident that of > 585 lamb carcasses examined in South Africa, none were considered to have been killed by eagles. This is despite the fact that these South African surveys were conducted in black eagle habitat. However, I have come across three undocumented reports of eagles killing lambs in South Africa which were confirmed by necropsies: black eagles may have been responsible for the death of one out of seven carcasses (including two ewes) examined by Brown (pers. comm.) in the early 1980's in the Underberg, Drakensberg; crowned eagles were certainly responsible for the death of two sickly five-week old lambs in April 1989 in the George District (S.J. Bekker pers. comm.); and black eagles killed one, possibly two lambs and seriously wounded another in September 1993 in the Kimberley District (Anderson & Esterhuizen pers. comm.). These reports were of isolated incidents where researchers were called out to investigate farmers' complaints. They did not comprise comprehensive surveys of lamb mortality. Although they indicate that eagles do kill lambs in South Africa, they do not afford quantitative data on the extent of this mortality factor for lambs in this part of the world.

The spread of estimates for lamb losses to predation are shown in Figure 103 for all questionnaire and necropsy surveys that I could access in the literature. As suspected, surveys by necropsy yielded generally lower estimates of predation. The average estimate of lamb predation in 32 surveys by necropsy was 4,91% of lambs born

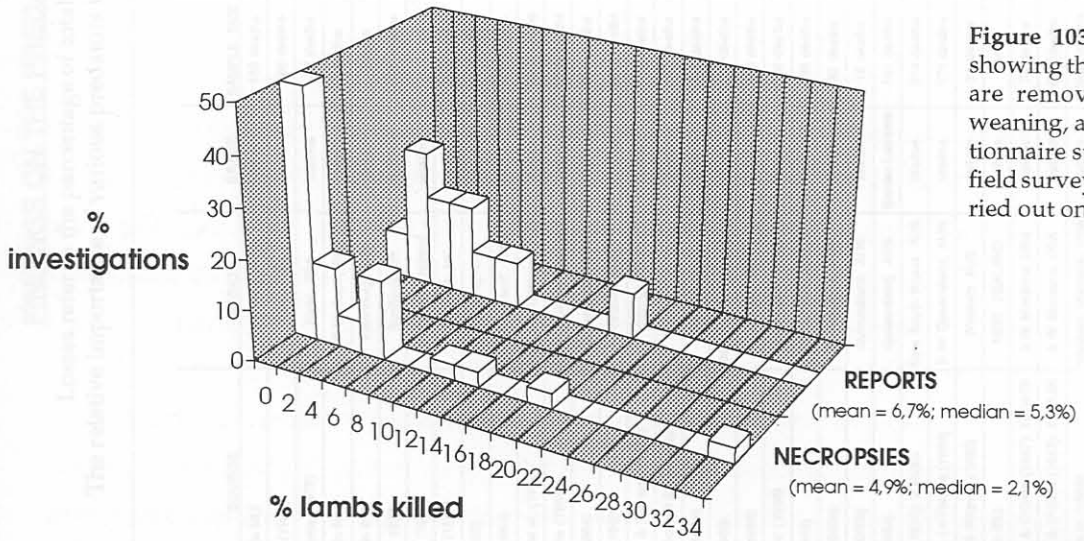

Figure 103. Frequency histograms showing the percentage of lambs that are removed by predators before weaning, as estimated from 11 questionnaire surveys (REPORTS) and 32 field surveys based on necropsies carried out on lamb carcasses.

TABLE 40

FINDINGS ON THE PREDATION AND NEONATAL MORTALITY OF LAMBS FROM FIELD NECROPSY SURVEYS

Losses refer to the percentage of total lambs born that die before weaning. Asterixes indicate where predation losses refer only to viable lambs.
The relative importance of various predators in lamb-killing is indicated by the number or percentage of lambs killed that could be attributed to those predators.

						PREDATOR TYPE RESPONSIBLE FOR LOSSES													
SOURCE	REGION	BREED	SAMPLE SIZE	% LAMBS LOST TO PREDATORS	% LAMBS LOST TO OTHER CAUSES	EAGLES	UNSPEC. NON - EAGLE	CORVIDS	FOXES	JACKALS	COYOTES	DOGS	WILDCAT	CARACAL	BOBCAT	PUMA	BEAR	BABOON	PIGS
Bekker (in litt.)	Swartberg, RSA	various	133 deaths	0,9*	15					4				54					
Roberts (1986)	Natal, RSA	various	395 deaths							50		330		9					
Rowe-Rowe (1975)	Natal, RSA	various	>57 deaths	<1,0						57									
Bekker (in litt.)	S W Cape, RSA	various	deaths		16,5														
Bekker (in litt.)	Elsenburg, RSA	various	deaths		16,0														
Houston 1977	Scotland, UK	blackface	297 deaths	0,12*				24											
Burgess (1963)	Northern England	unspec.		0,05%*?				**											
Hewson (1984)	Scotland, UK	blackface	204 deaths	0,7-2,8	25-46	11			26										
Weir (1985)	Scotland, UK	sheep	(800 deaths)			2 - 9 (30)			unknown			40							
Moule (1954)	Queensland, AUS.	Merino	453 deaths	6,28	12,08			>6											>100
Hughes et al. (1964)	New South Wales, AUS.	various	3503 deaths	0,64*															
McFarlane (1964)	New South Wales, AUS.	various	3039 deaths	1,96*	(18,04)														
Smith (1964)	Queensland, AUS.	Merino	981 deaths	0,65*															
Dennis (1969)	Western AUS.	various	4417 deaths	0,54*															
McHugh & Edwards (1958)	Victoria, AUS.	various	512 deaths	0,95*	6,05														
Moore, Donald & Messenger (1966)	Southern AUS.	Merino	157 deaths	3,0*	21,80														
Davies (1964)	Western AUS.	Merino	308 deaths	7,0*	20,18														
Anon (1965)	New South Wales, AUS.	Merino	323 deaths	1,2*	12,38														
Turner (1965)	Victoria, AUS.	Polwarth	260 deaths	2,15*	15,89				31										
McDonald (1966)	Melbourne, AUS.	Polwarth	390 deaths	12,2*	24,45				@129										
Anon (1968)	Southern AUS.	various	695 deaths	0,13*	9,26														
Smith (1965b)	Queensland, AUS.	Merino	32 deaths	6,4*	2,54														
Smith (1965b)	Queensland, AUS.	Merino	18 deaths	2,2*	4,27														
Smith (1964)	Queensland, AUS.	Border-Leiceste	131 deaths	15,3*	27,23			30											
Rowley (1970): 2 flocks	New South Wales, AUS.	Merino	314 deaths	(1,96*)	(34,22)	5		73	44										
Jordan & Le Feuvre (1989)	S W Queensland, AUS.	Merino	171 deaths	1,2 - 2,0*	>15,0	1			8										11
Brooker & Ridpath (1980)	Western AUS.	various	53 deaths			5	1		5										
Bekker (in litt.)	NEW ZEALAND	various	deaths		16,0														
Matchett & O'Gara (1987): 1974-75	S W Montana, USA	various	73 deaths	(38)	(6)	59	3												
Matchett & O'Gara (1987): 1976-85	S W Montana, USA	various	865 deaths	(3)	(16)	59	74												
O'Gara et al. (1983)	Western Montana, USA	various	1944 deaths	20,8	11,5	2		6	7		854	6							
Wiley & Bolen (1971)	Southwestern USA	* whole flock	23 deaths			3	>1												
Bowns et al. (1973)	Utah, USA	spring lambs	236 deaths	0,8	1,6						71								
Bowns et al. (1973)	Utah, USA	summer lambs	371 deaths	6,6	1,2						238								
Taylor et al. (1979)	Utah, USA	lambs	3345 deaths	5,8	3,6						3144	(50)				(50)	(50)		(50)
Klebenow & McAdoo (1976)	Nevada, USA	* whole flock	351 deaths	(4%)	(5%)	1					110	2			3				
Tigner & Larson (1977)	Wyoming, USA	lambs	3600 deaths	2,3	5,0	*					77%	*			*		*		
Schrivner et al. (1985)	California, USA	unspecified	953 deaths	2,7 - 10,4		5					665	63				5	6		
Schaefer et al. (1981)	Iowa, USA	various	227 deaths								129	95							
Glover & Heugly (1970)	Texas, USA	lambs		1 - 2															
Glover & Heugly (1970)	Texas, USA	kids		<25%															
Littauer & White (1981)	New Mexico, USA	various																	

(median=2,06). This average is influenced equally by extensive surveys and by surveys of small problem flocks. When each survey is weighted in accordance with the number of carcasses examined (nearly 30000), the average estimated loss to predation is 3,91% of lambs born. The average estimate of lambs lost to other causes among the same surveys is 13,7% of lambs born (or 11,2% when weighted in accordance with sample size). These figures suggest that farmers do tend to over-estimate predation and under-estimate other losses.

The surveys indicate some variation in lamb predation between the major sheep-farming regions. The results of all documented field studies of lamb mortality by necropsy are summarised by geographical region in Figure 104. Evidently ranching operations in Australia and especially South Africa and Scotland experience relatively low losses of lambs to predators, whereas North American operations experience relatively high losses. This can be attributed partly to severe problems with coyotes in some of the United States.

The most detailed and extensive investigations of lamb mortality have been carried out in Australia (nearly 16000 necropsies). Many of these studies were routine investigations of flocks rather than problem situations. Under the influence of pioneering methods (Alexander 1964; McFarlane 1965), nearly all of the Australian studies have distinguished true predation of viable lambs from the removal of dying animals by predators. As Rowley (1970) points out, "Since lamb starvation is usually irreversible, for economic reasons, in Australia, it is financially insignificant whether or not a predator hastens the inevitable end; this situation could have been avoided if the onset of starvation had been prevented". Most American studies did not distinguish between the killing of lambs that were dying already and the killing of healthy lambs, and this is probably mostly responsible for the high rate of loss of lambs to predators reported in this region. The average loss of lambs to predators, taken from 17 Australian surveys involving necropsies, was 3,77% of lambs born (s.d.=4,35; median=1,96%). The most extensive carcass surveys indicated lower levels of predation. So a weighted average of 1,66% of lambs lost to predators (in accordance with the number of carcasses examined) includes problem situations but is not unduly influenced by them. The average loss of lambs to other causes, taken from 14 Australian surveys involving necropsies, was 16,0% of lambs born (s.d.=9,1; median=15,7). This estimate was not much changed when sample size was taken into account (16,8%).

These discussions pertain to lamb predation by all types of predators. Where accessible, I noted the amount of lambs lost to different types of predators in these surveys by necropsy (Table 40). In Figure 104 the number of lambs lost to various predator types are shown for the different major sheep-farming regions. It is clear that wild and domestic canids cause the most damage to ranching operations. In South Africa caracals *Felis caracal* cause significant losses, and in Australia feral pigs *Sus scrofa* are significantly involved. Avian predation was less frequent than mammalian predation in all regions and losses to corvids exceeded those to eagles. Only in Scotland were eagles significantly involved in livestock predation, but this is based on only three studies and overall losses to predators were exceptionally low. Eagles were least involved in livestock predation in South Africa.

Black, martial and crowned eagles are all highly territorial, and are not inclined to scavenge. There are no records of these eagles being attracted in large numbers to an abundance of dead or dying lambs, unlike golden eagles and wedge-tailed eagles. It is important to bear in mind that these estimates of the relative responsibility of eagles in lamb-killing are based on all records of lambs killed (healthy or sick). It may be that eagles are more likely to attack

weak and sickly lambs than the larger and possibly more powerful carnivores, in which case eagles would be responsible for a smaller proportion of the viable lambs killed by predators than indicated.

Region	Number of carcasses examined	% lambs lost to predators	% lambs lost to other causes	total lambs lost	% kills made by eagles
RSA	191	0.9 *(healthy)*	16.15	17.05	0
UK	1423	0.32 *(healthy)*	35.5	35.82	15.9
AUS	15704	1.66 *(healthy)*	16.81	18.47	2.46
NZ	?	?	16	?	0
USA	12660	6.42 *(all)*	6.42	12.92	2.25
WORLD	29978	3.91 *(mixed)*	11.23	15.14	2.38

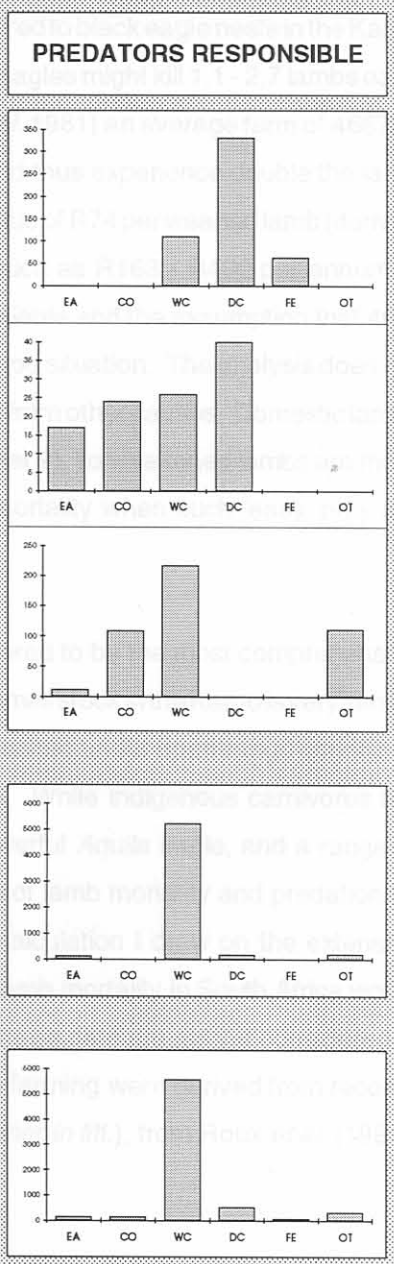

Figure 104. The findings of worldwide field necropsy surveys on lamb mortality summarised by geographical region (LEGEND: RSA - South Africa; UK - Scotland; AUS - Australia; NZ - New Zealand; USA - United States of America; WORLD - all surveys combined). Column 2 gives an indication of the extent of these surveys but it refers only to lambs dying and not to the total number of live lambs monitored. The percentage lambs lost to predators (Column 3) refers to the period between birth and weaning - I have indicated whether these estimates include all lambs killed by predators, or only viable (healthy) lambs. These estimates can be added to lambs dying non-violently (Col. 4) to give the percentage of total lambs lost (Col. 5). The histograms to the far right indicate the relative involvement of the different types of predators in lamb-killing (healthy or sick) for all surveys which provided such information (KEY: EA - eagles; CO - corvids; WC - wild canids; DC - domestic canids; FE - felids; OT - other e.g. pigs in AUS, bears in USA). The percentage involvement of eagles is listed in column 6.

Economics of livestock predation by black eagles in the Karoo

As mentioned earlier, the collections of prey remains suggested that breeding pairs of black eagles on karoo farmland may be delivering 2,8 - 6,7 lambs to their nests each year. This estimate is prone to much bias discussed earlier and in Chapter 9. If we assume that the feeding habits of black eagles on karoo farmland are similar to those of golden eagles on scottish farmland (see earlier), and that 40% of lambs delivered to black eagle nests in the Karoo were killed rather than scavenged, this would imply that a resident pair of black eagles might kill 1,1 - 2,7 lambs each year. In strictly mountainous terrain (which spans 15% of the Karoo: Roux *et al.* 1981) an average farm of 4687ha could accommodate two black eagle territories (2300ha each - Chapter 6), and thus experience double the lamb killings estimated for a single pair. With this reasoning and at a current market value of R74 per weaned lamb (derived from Table 41, overleaf), black eagles might be costing karoo farmers as much as R163 - R400 per annum in mountainous districts. However, this estimate of lamb predation is not very reliable and the assumption that 40% lambs are killed rather than scavenged is very arbitrary for the black eagle - Karoo situation. The analysis does not take into account the possibility that some of the lambs killed were already dying from other causes. Domestic lambs are close to the upper limit of prey size that black eagles prefer to attack (Chapter 9), so weakened lambs are more likely to elicit predation especially during the period of high neonatal lamb mortality when such 'easy' prey are abundant.

For reasons given above, the Australian surveys of lamb mortality are considered to be the most comprehensive and detailed, and the least biased (towards problem situations). The farming of small stock in the Karoo is very similar to that in Australia. Merino sheep are the preferred breed, and these are maintained under open-range conditions and low stocking rates in drought-prone southern hemisphere environments. While indigenous carnivores are scarce in Australia, lambs are still exposed to corvids, an abundant and powerful *Aquila* eagle, and a range of introduced meat-eaters including foxes and feral pigs. No extensive surveys of lamb mortality and predation by necropsy are available for the Great Karoo. So in the following economic calculation I draw on the extensive Australian research on the grounds of the given similarities. Current data on lamb mortality in South Africa would indicate lower rates of loss to predators, and less involvement of eagles. But these data are not yet considered to be sufficiently complete for the following calculations. The statistics on karoo farming were derived from records held by the Department of Agriculture at Grootfontein, Middelberg, Karoo (Olivier *in litt.*), from Roux *et al.* (1981), and Anon (1992b).

Total extent of the karoo agricultural region (in South Africa) is 29 062 000ha. Within this area there are 8972 farms owned by 6200 farmers. On average, individual karoo farmers manage about 4687ha. Population parameters for the major classes of small stock in the Karoo and on the average karoo farm are given in Table 41 (overleaf). About 819 new lambs or kids are born from these small stock on the average farm each year. At predation and non-violent mortality rates of 1,66% and 16% respectively, one would expect that 13,6 of these lambs would be killed by predators before weaning, and that 131 would die from other causes over the same period. Most of this mortality would occur within two weeks of birth. In mountainous regions this means that about 70 dead lambs would be available to each resident pair of black eagles as carrion in one or two major pulses each year.

TABLE 41

A SUMMARY OF THE NUMBERS AND ANNUAL MORTALITY OF SMALL LIVESTOCK IN THE KAROO AND ON THE AVERAGE FARM FOR CALCULATING THE ECONOMIC SIGNIFICANCE OF PREDATION

Information sources for livestock numbers and population composition are given in the text. The last four columns refer to an analysis representing the average karoo farm. The number of lambs dying non-violently (column 10 - 16% of total) and to predation (column 11 - 1,66% of total) between birth and weaning were based on the results of extensive, detailed Australian research on the open-range farming of Merino sheep, which was considered to be most appropriate for the karoo situation (in the absence of sufficient local information).

LIVESTOCK CLASS	Rand value per weaned lamb	Karoo nos.	Average farm nos.	Ppn. adult female	Lambs produced per adult female/yr	Karoo lamb nos.	Farm lamb nos.	Total no. dying per year	No. dying from other causes/yr	No. killed by predators per year	estimated annual value (Rands) of predation
Woolled sheep	60	4745363	765.38113	0.6	0.7	1993052	321.460	56.7698	51.4336	5.33624	320.174
Mutton sheep	90	3449110	556.30806	0.7	1	2414377	389.416	68.7708	62.3065	6.46430	581.787
Angora goats	35	959803	154.80694	0.6	0.6	345529	55.7305	9.84201	8.91688	0.92513	32.3794
Boer goats	75	354996	57.257419	0.7	1.3	323046	52.1043	9.20161	8.33668	0.86493	64.8698
TOTAL		9509272	1533.7535			5076005	818.710	144.584	130.994	13.5906	999.210

The overall cost of predation on viable lambs, to the average karoo farmer, is estimated to be 13,6 lambs at a current market value of R999 (U.S.$ 289). Only a fraction of this cost can be attributed to eagles. If we assume that lamb predation by black or martial eagles in the Karoo occurs in similar proportion to lamb predation by eagles worldwide (American and Australian studies were very similar in this regard - see Fig. 104), then the overall cost of eagles to the average karoo farmer is estimated to be 0,32 lambs with a current market value of R 23,78 (U.S.$ 6,88). This figure is more likely to be over-estimated than under-estimated because current limited data indicate lower rates of lamb losses to predators in South Africa (Fig. 104), and because black and martial eagles are not known to converge (in numbers) on lambing paddocks, as has been observed for golden eagles in America and wedge-tailed eagles in Australia. This estimate of the cost of eagles to karoo farmers is free from the bias and arbitrary assumptions of the earlier estimate, and is the most considered (upper) indication for the overall cost of true predation (of viable lambs) by eagles in the Karoo, be they martial eagles on the plains or black eagles in the mountains.

Managing problem situations

The previous calculations can give an indication of the scale of the problem, but most studies indicate that it is not appropriate to consider lamb predation in overall or average terms. The variation in lamb predation rates from Australian field necropsy surveys, as represented by their standard deviation, was roughly equivalent to their mean. This indicates that lamb predation was not evenly dispersed from flock to flock. The high incidence of low predation rates and low incidence of high predation rates as revealed among the necropsy surveys in Figure 103, is typical of a poisson distribution. The same phenomenon has been noticed by Wagner (1972), Wagner & Pattison (1973), Balser (1974), Dorrance & Roy (1976) and Gee *et al.* (1977). Over 80% of all predator losses in Kansas were reported by only 22% of questionnaire respondents (Robel *et al.* 1981).

These observations confirm the sporadic occurrence of problem flocks or situations. A number of the example studies given in Tables 38 - 40 which yield high estimates of predation can be described as such. For instance the ranches in southwestern Montana where coyotes were killing up to 12 lambs per night (O'Gara *et al.* 1983), and where golden eagles caused such extensive damage (Matchett & O'Gara 1987). Usually, extenuating circumstances can be found which explain these high predation rates: aggregations of young eagles after a crash in natural prey in the latter instance; high losses to foxes in Australia were associated with a toxic element and overgrazing in one case (McDonald 1966), and a 'killer' or rogue fox in another (Turner 1965); conspicuous lambs of Border Leicester sheep were found to be highly susceptible to disease after attack by ravens (Smith 1964), etc..

The golden eagle predation described by Matchett & O'Gara (1987) is the only serious problem situation that I found in the literature where eagles were held responsible. Aside from a few isolated lamb kills, there have been no confirmed 'problem situations' to date where African eagles were involved. In two cases, claims of severe lamb predation by black eagles proved unfounded (Palmer unpubl.; Allardice & Erasmus unpubl. / the present study). A similar claim has been lodged in the Steytlerville district but this has yet to be investigated. Farmers from this district do claim to have seen aggregations of up to 30 black eagles at a time. There are no such records in the abundant ornithological literature on this highly territorial species, so this claim is likely to be the result of exaggeration or confusion (possibly with white-necked raven). Despite this, two post-mortem examinations of lamb carcasses and a couple of credible eye-witness accounts of kills indicate that black eagles have killed lambs in the past and will do so again. One cannot expect a few unlucky farmers to tolerate unusually high levels of livestock predation on the basis that predators do little damage overall. Management techniques which can be expected to help minimise any lamb losses to eagles are now considered.

Much effort at reducing the threat of eagle depredation in the past has been geared towards managing eagles rather than managing lambs. The shooting incidents described earlier represent this in the extreme, and current, localised 'blanket control' of eagles is ineffective at diminishing numbers. Furthermore, removal of resident territorial eagles might allow an influx of immatures and non-breeding adults which may be more prone to kill lambs. Other indiscriminate methods of predator control such as poison and gin traps are ineffective and inhumane methods for controlling problem animals, but they may be highly damaging to vulnerable non-target wildlife species. Their use on South African rangelands should be discontinued and they should be replaced by more selective methods such as toxic collars, cage traps, and padded gin traps. Problem animal control should move from the concept of problem species to that of problem individuals (Stuart 1987b).

Four karoo farmers reported to me that they used padded gin traps, and any eagles they caught were sent to nature conservation officers for translocation. Conservationists with the responsibility for solving conflicts between wildlife and domestic stock, have favoured this less drastic course of action whereby 'problem' eagles are captured unharmed and transported for release in other areas, preferably devoid of livestock. A growing body of evidence however, indicates that this is not a satisfactory option. Of eight eagles which were moved up to 290km in the Cape and then seen or recaptured once again, five (63%) had returned to their original site of capture (Boshoff & Vernon 1988). Of 14 golden eagles which were moved 416 - 470km in and around Wyoming and then seen or recaptured again, twelve (86%) had returned to their original site of capture, and most of these were able to regain their territories

and mates despite rapid replacement from the non-breeding population (Phillips, Cummings & Berry 1991). Neimeyer (1977 unpubl.) also noted the return of translocated golden eagles. Areas devoid of livestock are usually conservation areas which already have resident eagle populations, so 'problem' eagles released into these situations will often be displaced into neighbouring farmland where they may continue a lamb-killing habit and antagonise farmers who were previously well-disposed towards eagles. An eight-year programme involving the translocation of 432 golden eagles from a problem area failed to reduce eagle depredations on livestock and cost an estimated U.S.$ 112 771 - "Eagle translocation is a reactionary measure, does not prevent depredation, could be expensive if large numbers of eagles were involved and may only transplant the problem, not solve it" (Matchett & O'Gara 1987).

In a comprehensive assessment of methods to control eagle depredations on livestock, Matchett & O'Gara (1987) found that neither taped eagle alarm calls nor sporadic harassment of eagles in lambing areas by aircraft and by using explosive charges were practical or effective at reducing depredations. Human activity has however sometimes proved a deterrent to eagles (McAdoo & Klebenow 1978; O'Gara & Matchett 1985 unpubl.). A karoo farmer reported to me that shooting just behind black eagles was usually sufficient to scare them away from lambing camps (Morgan *in litt.*).

Taste aversion is a possible option for reducing livestock predation by eagles. Birds especially can show extremely rapid aversion to a particular prey type after only one unpleasant experience, and the effectiveness of such anti-predator strategy is evident in the extent of mimicry of distasteful aposematic species among insects (Brower *et al.* 1968; Brower 1969, 1984). Juvenile sheep and goats are very distinct from natural eagle prey in looks, so it is conceivable that eagles might learn to avoid these prey types if they experience illness after eating them. Lithium chloride has been used as a taste-aversion agent to reduce stock losses by coyotes with mixed results (Griffiths, Connolly, Burns & Sterner 1978; Burns & Connolly 1980; Burns 1983a, 1983b), but it has successfully caused taste-aversion for particular prey types in red-tailed hawks *Buteo jamaicensis* and great horned owls *Bubo virginianus* (Brett, Hankins & Garcia 1976; Cheney, Vander Wall & Poehlmann 1987).

In response to farmers' requests for assistance in dealing with eagle problems, I drew up recommendations for the use of lithium chloride based on these studies whereby lamb carcasses should be treated with two injections of lithium chloride solution, one into the shoulder and one into the rump, which would amount to a total dose of 250mg lithium chloride. If a black eagle was to consume the entire carcass it would receive a maximum oral administration equivalent to 63mg lithium chloride per kg body weight. The dosages used by Cheney *et al.* (1987) which led to taste-aversion were approximately 40mg lithium chloride per kg body weight. These recommendations were distributed to eleven farmers in the Cape and Orange Free State by myself and by Nature Conservation Officers, but no rigorous examination of the trials were carried out. Brand (1992) assessed the results of these trials as largely inconclusive, but taste-aversion may have occurred in one instance.

Three dead jackal buzzards were picked up around two of the treated carcasses which Brand (1992) attributed to lithium chloride poisoning, on the basis that certain small birds have been known to voluntarily consume lethal amounts of the substance in captivity (Rogers 1974). Raptors however, regularly regurgitate pellets and the

regurgitation process should be stimulated by the strongly emetic nature of lithium chloride (Burns & Connolly 1980). Black eagles feeding on the treated lamb carcasses were observed to vomit (Brand 1992). If the recommended dosages were adhered to, the jackal buzzards in question could not have received more than 290 mg lithium chloride per kg body weight, even if one bird consumed the entire lamb carcass which is very unlikely. Red-tailed hawks survived intramuscular injections of lithium chloride at dosages of up to 320mg per kg body weight without any serious negative consequences (Brett *et al.* 1976) - these birds could not get rid of the lithium chloride by vomiting. It therefore seems highly improbable that lithium chloride caused the death of the jackal buzzards unless the recommended dosages were greatly exceeded and the birds, for some reason, were unable to regurgitate. Unfortunately, no necropsies were carried out on the dead jackal buzzards. I would have to agree with Brand (1992) though, that at this stage field trials of taste-aversion in eagles using lithium chloride are inconclusive, and they should be postponed until captive trials have demonstrated whether this method is practical for use on wild raptors. Captive trials are currently being planned by Dr. E. Verreyne (P.O. Box 1667, Kuruman 8460, Cape Province).

More recent studies suggest that the emphasis of management to reduce lamb predation should shift from attempts at managing predators to improved management of the flock (Hewson 1984; C.J. Brown pers. comm.). An obvious and immediate advantage in management to reduce losses to eagles, is that eagles only pose a serious threat to very young lambs (Arnold 1954; Wiley & Bolen 1971; Tjernberg 1981; Hewson 1984), and these are normally only available for 6 - 8 weeks each season. Intensive management over this short period may well prove worthwhile. Penning sheep in corrals reduced losses to predators in North America (Robel *et al.* 1981) and Namibia (C.J. Brown pers. comm.), and would undoubtedly reduce the threat of eagle predation in the Karoo but is not practised in this region any more. By far the simplest and most effective management technique to prevent eagle depredations in the Karoo is to place a shepherd with the flock during the crucial lambing period. All the farmers around Beaufort West who used this management practice did not experience problems with eagles. To be effective, shepherding must be carried out in a lambing camp which is not too large to patrol.

Unfortunately, many open-range sheep flocks in the Karoo are not very habituated to humans. Failure of the ewe-lamb bond is the biggest killer of young lambs (Rowley 1970), so any human disturbance which may lead to desertion of lambs is highly undesirable. For unhabituated flocks, scarecrows may prove to be a good option (O'Gara & Matchett 1985 unpubl.). Matchett & O'Gara (1987) showed experimentally that the use of scarecrows could alter the dispersion patterns of aggregating golden eagles and reduce lamb predation rates tenfold. This was despite a greater availability of young lambs in the areas where scarecrows were used. The authors emphasised that scarecrows should only be erected for the crucial lambing period, close to the bedding grounds. Moving the scarecrows and attaching shiny objects to them may help prevent eagles from becoming habituated to them.

It has also been suggested that lambing should take place outside of the eagle breeding season and away from areas of eagle activity (Anon 1987; Anon 1992a unpubl.). However, farmers complain that lambing seasons are geared to the maximum reproductive output of the flock and should not be changed. Indeed, autumn matings (late winter lambings) can double the reproductive output of ewes in some regions if supplements are provided (Roux *et al.* 1981), but for various reasons spring matings and autumn lambings (March - April) are preferred in the Beaufort West district. Although this lambing schedule may bring resident eagles into breeding condition early (Chapter 6), it means

that lambs are past their vulnerable first month by the time breeding eagles have nestlings to feed. Careful attention needs to be given to spring lambings to avoid the crucial imprinting phase of eagle nestlings (July - August), and lambing flocks should be moved away from eagle nesting areas and shepherded. Two farmers adjoining the KRNP said they reduced losses to eagles by simply moving their flocks away from the hills during lambing (Mocke & Nel, pers. comm.). This appears to be a common, effective and practical management option.

In at least two cases black eagles have been attracted to a lambing area by high mortality of the lambs to other causes (Palmer unpubl.; Allardice & Erasmus unpubl. / present study). In similar circumstances, golden eagles turned to lamb predation when lamb carrion was temporarily unavailable (O'Gara *et al.* 1983). Basic veld and flock management which ensures enough food and shelter for lambing flocks will impede the major mortality factors and ensure a healthy lamb crop. In consequence there will be less carrion to attract eagles and more natural prey to hold their attention. It is important to realise that eagle chicks may be likely to wed or imprint to a lamb diet whether lambs are scavenged or killed by the eagles. So the removal of any lamb carcasses from the lambing camps is an excellent and very feasible management practice (Robel *et al.* 1981; O'Gara et al. 1983), especially when high mortality is unavoidable due to disease or climate. Natural removers of carcasses such as Cape vultures which have been eradicated from the Karoo by the indiscriminate use of poison (Allan 1989) should be restored to their former haunts.

CONCLUSION

It is a common notion held by karoo farmers that eagles are responsible for sometimes extensive depredation of their lambs. The present study indicates that scavenging on livestock carcasses is prevalent among karoo black eagles but two investigations of 'problem situations' involving black eagles (Palmer unpubl. and the present study) using limited necropsy surveys demonstrated no direct evidence of lamb-killing by the eagles. Larger scale necropsy surveys in South Africa provided no evidence of lamb-killing by eagles, but such surveys still need to be done in the Great Karoo, in the Steytlerville district and in the northern Cape. Using best estimates of lamb predation rates and the relative involvement of eagles, it is calculated that the removal of viable lambs by eagles costs the average karoo farmer less than R24 per annum (0,32 lambs).

As a possible explanation for this extremely low incidence of lamb-killing by eagles, it is suggested that unlike other predators, the majority of eagle chicks are fed on natural prey items during sensitive developmental phases and so become imprinted or wedded to natural prey. Sheep-farming in the mountainous regions of the Karoo might be expected to experience greater losses to avian predators if these regions were not patrolled by the highly prey-specific black eagle which excludes conspecifics and other large eagles from breeding territories. Karoo plains are patrolled by a more generalist avian predator, the martial eagle, which may be more inclined to take domestic stock but which occurs at extremely low density (Van Zyl 1992). Neither species is known to converge on lambing paddocks.

Although lamb killing by eagles in the Karoo is very rare, some evidence confirms that it does occur and it is probable that such losses would be concentrated on a minority of farms. Large-scale efforts involving indiscriminate persecution of predators to reduce such losses appear futile, and are highly damaging to vulnerable non-target species. It is suggested that efforts to manage predators (including translocation of eagles) be replaced by more intensive management of flocks, especially during the short, vulnerable lambing season. Shepherding or the use of scarecrows, and moving lambing flocks away from areas of eagle activity are probably the most effective and practical options. But taste-aversion may prove useful in the future. In the prevention of a lamb-killing trait amongst eagles, it is important that vulnerable young lambs be unavailable to breeding eagles when they are feeding young nestlings going through sensitive developmental phases. For black eagles in the Karoo this critical period would be July and August, so special attention needs to be given to spring lambings. The removal of carcasses from lambing camps will remove an incentive for predation and will help prevent eagle chicks from becoming wedded to lambs as prey. If lamb losses to eagles persist despite intensive flock management, the culprits should be removed from the population to prevent the inheritance and spread of a lamb-killing trait. Zoological gardens, captive breeding institutions and falconers should be considered as destinations for these eagles.

On the grounds that lamb-killing by eagles in the Karoo is very rare and of negligible financial importance overall, and on the basis that any localised eagle problems can be dealt with, I would argue that black eagles are certainly compatible with the open-range farming of small stock in the Karoo, especially if one considers the beneficial effects of black eagles to sheep grazing (Chapter 12).