# Investigation into golden eagle predation of lambs on Benbecula in 2003

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# Contents

## Summary

1: Four flocks of sheep on four adjacent sites on Benbecula were monitored. Lambing percentages from these flocks varied from 60% to 90%. There was no evidence that low production was due to low pregnancy rates, and was therefore probably due to lamb mortality.

2: The condition (body fat index) of ewes varied between flocks, and within flocks. There was evidence of flocks with higher average condition scores having higher lamb survival, but this was probably an indirect effect.

3: There was some evidence that gimmers (ewes breeding for the first time) in one flock had poorer lamb survival than older ewes. However, there was no evidence that maternal behaviour score influenced lamb survival.

4: There were significant differences in lamb birth weight between flocks and some evidence that within flocks, lambs born small or light were more likely to die, although not due to predation.

5: There were one pair of territorial but non-breeding golden eagles in the study area and two other pairs approximately 7km to the North and South respectively, of which at least one pair were breeding.

6: In two flocks where it was possible to collect accurate production data, golden eagle predation losses were equal to 1% of lambs produced for one flock, and possible eagle predation was 3% in the second flock. Losses to other known causes were 7% and 23% respectively and to unknown causes 5% and 10% respectively. The losses due to golden eagles are comparable to figures reported in previous investigations in Scotland.

7: Lambing percentages for flocks on the four study sites fall within the ranges reported in previous Scottish golden eagle studies. They also fall within the range of average lambing percentages in the Western Isles over the preceding 20 years.

8: From the remains of large prey items collected at the eyrie of the known breeding golden eagles, around 50% were waterfowl or herons, 18% were other bird species, 18% were rabbits and 13-18% were lambs. All of the prey species recorded were commonly found on the study sites.

# 1. Introduction

This report results from an investigation in the spring and summer of 2003 into lamb mortality on several crofts in Benbecula. The investigation took place after several years of complaints by local crofters that they were losing a large proportion of their lambs due to the activities of golden eagles. The aim of the study was to try and ascertain the fate of lambs, and the role that eagles might have in these losses.

### 1.1 Golden Eagles in Scotland and the Outer Hebrides

The highest densities of golden eagles in the UK are in the Western Highlands and the Outer Hebrides. In 1992 there were estimated to be at least 422 golden eagle territories occupied by pairs of birds in Britain, with a further 69 territories held by non-paired individuals (Green 1996). The 1992 survey identified 94 territories containing pairs in the Outer Hebrides (including Lewis, Harris, Skye, the Uists and some smaller isles).

Census data from 1982-83 estimated 424 pairs of eagles in Britain, of these 92 were in the Outer Hebrides. The 1982 survey itself resulted in an increase to the previous population estimates for the country, but this was attributed to improved census methods and survey coverage rather than an increase in the number of birds (Dennis *et al*. 1984). The implication from the data is that overall, the golden eagle population in Scotland has been fairly stable in recent decades. Another national Golden eagle survey was being conducted at the same time as this study. At the time of writing, data from the 2003 Golden eagle survey was not fully released, but data that was available showed that the UK population was 431 pairs. Declines in some areas had been offset by increases in the Hebrides, for which figures indicated a 24.5% increase (117 pairs in occupied territories) (M. A. Eaton, *pers. comm*), although some of the apparent increase was possibly a result of greater survey coverage.

### 1.2 Golden eagle diet in Scotland

Watson (1997) presents a summary of data from 24 studies of Golden eagle diet in Europe and Asia. In many of the studies there is a single prey type that dominates the diet e.g. lagomorphs. However, Watson suggests that a ‘generalist’ diet which focuses on several prey types is common in Western Scotland but is atypical when compared to other geographic populations.

Lockie (1964) examined the diet of Golden eagles in Wester Ross and found that in summer it consisted of 60% large birds, 30% lamb, 5% lagomorphs and 5% deer calf. In winter it comprised 30% large bird, 20% adult deer carrion, 18% deer calf and 32% lagomorph.

Marquis *et al*. (1985), studying the diet of Golden eagles in Southern Scotland, found lagomorphs and large birds accounted for one third of identified remains and large mammals one quarter. In a study of diet in different regions of Scotland, Watson *et al*. (1993) concluded that in the Outer Hebrides sheep, rabbit and miscellaneous items (mainly birds other than grouse) each accounted for approximately 25% of the summer diet. The relatively high incidence of sheep in the diet was thought to be due to both high stocking densities and poor lamb survival. The survey indicated that rabbits and fulmars were the favoured prey in this region.

Watson *et al.* (1992) found that nesting density in the highlands and Inner Hebrides (the extent of their study area) was positively correlated with one food source, carrion. They also found that breeding success was positively correlated with the abundance of live prey. They suggest that the availability of food in winter (mainly carrion) may be the most important factor in determining the number of golden eagle pairs a given area can support.

Live prey is of increased importance in the diet during the summer, but carrion is still utilised. Hewson (1981) recorded eagles scavenging small lambs in April to June, and large lambs in September and October. In areas where sheep are kept on the hill, there are often significant numbers of lambs dying to provide a readily accessible source of carrion throughout spring and summer. However large items of carrion are often ignored during the nesting season, possibly because of difficulties in transporting them to a nest or perhaps due to some mineral deficiency that would make it less suitable for feeding to nestlings (Watson 1997). Brown (1969) noted that in Sutherland it appeared that adults may feed on carrion but that the young were fed mainly on live caught prey. He calculated that on a typical eagle territory in Sutherland 580-720 dead lambs would be available each year and that even if only 10% of these were available to eagles, in theory the eagles could have fed their chicks on lamb carrion alone. Yet he reported finding no lambs in any eyries, while at adult roosts wool was found in pellets. Brown (1969) also estimated that in an average eagle territory in Scotland a total of 271 kg of prey (of which 249kg was eaten) would be required each year. Of this he estimated 50 Kg to be carrion, 127 Kg mammals and 72 Kg birds. However, since the components of diet vary across Scotland (Watson *et al* 1993), then in some areas the proportion of live prey to dead prey could vary considerably.

### 1.3 Lamb mortality and Golden Eagle predation

There have been many reported instances of Golden eagles predating livestock including lambs; there have also been many investigations into these reports in several areas of the world. The general conclusion from studies in Scotland is that lambs form a varying proportion of the diet of golden eagles in different areas, but of the lambs eaten, only a small proportion (less than 3%) are actually killed by the eagles. Also, the number killed is very small when compared to lamb mortality due to other factors (Brown & Watson 1964, Lockie 1964, Weir 1973, Leitch 1986).

The high mortality of lambs born to hill sheep is well documented. Wiener, Woolliams and Macleod (1983) studied causes of mortality on a large upland flock of sheep over a six-year period (2453 lambs born). The mortality rate of lambs was 25.8%, predation did not figure as a significant cause of death although 2.2% of deaths were of unknown cause, and it is not clear if predation may have played a part in some of those.

The major causes of death were exposure/starvation or ‘weakly lamb’, non-infectious disease, infectious disease, stillbirths, dystokia and congenital defects that combined to account for 87% of all losses. It is worth noting that the flock involved in their study was closely shepherded at all times, assistance was given with difficult births along with temporary housing if needed. Hay, silage and concentrate supplements were available to ewes from mid-pregnancy until after lambing. Ewes were also given clostridial vaccine before lambing (lambs were given it at 9 weeks) and various dips doses and vitamin supplements were used as required. Therefore this flock probably had a higher quality of management than many hill flocks in areas such as the West of Scotland and yet still only achieved a lambing percentage of 74%. In areas where management is less intensive, grazing is poorer, terrain is more hazardous and weather is more adverse, it would be expected that mortality would be higher.

Henderson (1997) lists the relative importance of different causes of lamb deaths in hill flocks as abortion/stillbirth 31.1%, hypothermia/starvation 34.2%, misadventure/predators 16.1%, infectious diseases 8%, genetic defects 4.4%, dystokia 3.9% and miscellaneous as 3%. There are obvious differences in the figures when compared to Wiener *et al*. but it is worth noting that Henderson is giving generalised figures, whereas Wiener *et al*. are reporting actual observed figures. Houston (1977) found in Argyll that 47% of 297 lambs found dead had died of starvation ( fat levels exhausted), 22% were stillborn (including dystokia) and 9% had died of disease, 5% had died shortly after birth before walking, 5% suffered accidents (caught in fence, hit by car, attacked by dog). A further 5% had reduced levels of fat and may have died of exposure. The remaining 7% of animals had normal fat levels and only a small fraction (2 individuals) of those had been attacked by predators (in this case crows) while still alive, it could not be determined if these attacks were responsible for death but may have contributed to it.

## 2. Study Areas

### 2.1 General description of study area

The Isle of Benbecula is one of a chain of islands in the southern half of the Western Isles off the West coast of Scotland. It sits between the Isle of North Uist and the Isle of South Uist and is linked to them by tidal sand flats. The island is much flatter than its northern and southern neighbours, the majority of it being below 30m above sea level. The island consists of sand beaches and machair grassland in the west, the rest of the island is predominately acidic grassland progressing to blanket bog/wet heath in the East. The eastern coast is rocky and features multiple inlets and islands; the land is strewn with large numbers of freshwater lochs of varying sizes.

### 2.2 Study sites

The study area consisted of four study sites (A, B, C and D) each relating to the area used by each of the crofters who had volunteered to take part in the investigation. All of these sites consisted of varying amounts of coastline, some rocky, with tidal islands and/or narrow peninsulas. All of the sites had one or more freshwater lochans and all had unenclosed and/or tidal areas where sheep could wander across to islands or escape the site. The dominant vegetation on most sites was grazed heather and erophium/deer grass blanket bog, although some tidal islands and the coastal fringes were grassy. Most sheep could be found on these grassy areas. One site had a small area of machair grassland and dunes. Another site had two stockproof fields of improved, fertilised grass with a high moss content, and an area of erophium blanket bog. Another of the sites contained higher ground, with several steep-sided gullies and many crags. All sites had areas of stock fencing, although several of these fences were not stock-proof and sheep could wander to a greater or lesser degree, away from the main site.

## 3. Sheep Flocks

### 3.1 Management

3.1.1 Differences between flocks

The management of the sheep on the four different areas varied considerably as did the relative size of the flocks. All flocks have Scottish blackface ewes, although on Site A some of these ewes are crossed with Swaledales or are Swale crosses.

Essentially the flocks can be divided into two groups based on management practices.

The Site A and Site B ewes are brought back to inbye land in early April prior to lambing. Here they are given supplementary feeding and are closely tended during the lambing period before being released back onto the hill, when the lambs are between two and four weeks old. The lambs and ewes at this time are given a worming dose and an icaricide is applied. On Site A, ewes are given some feeding over the winter.

The two flocks at Site C and Site D, the ewes lamb on the hill with comparatively little monitoring. On one site the crofter checks on them approximately once a week and passes by regularly in a boat where he could observe some of the area. The second crofter visits the site less often although could observe some of his area in the distance from the main part of his croft. No supplementary feeding is provided on either of these two areas, and lambs remain untreated for worms or ticks until mid to late June when they are gathered.

3.1.2 Gathering, marking and condition scoring of ewes

Ewes on each site were gathered in late March or early April and their age was assessed by Agricultural Inspectors. They were age categorised as ‘Gimmers’, ‘2-3 year olds’ or ‘4 years +’, and any ‘broken mouthed’ ewes (i.e. missing teeth) were noted. On Site C and Site D a vet was present to assess the pregnancy status of ewes.

The sheep were given a body condition score based on standard techniques (http://www.defra.gov.uk/animalh/welfare/farmed/sheep/pb1875/sheeptoc.htm). Condition scoring was carried out by Agricultural Officers on all four flocks. On the two sites that the vet was present he also carried out condition scoring, thus allowing us to double check the accuracy of the scoring. Any general notes about the animal's condition were also made at this time (e.g. injuries or udder damage).

In order that the fate of lambs could be linked back to data we collected on the ewes, we numbered each ewe to enable us to determine if it had a lamb at a later date. Ewes had numbers sprayed on each side with stock-marker spray. Each ewe was given an individual number within its flock and each flock was given a different colour to avoid confusion should ewes from different flocks manage to mix. This was done on Site B and Site A when the ewes were brought in from the hill to lamb on the inbye land. On Site C and Site D it required a special gathering to take place in early April that normally would not have taken place. This method of ewe identification was later found to be sometimes unreliable, particularly when the fleece was long and conditions were windy. Sometimes the number just could not be determined and misreadings also occurred, these incidents increased with time due to fading of the spray.

### 3.1.3 Monitoring of ewes and lambs

Each site was visited approximately once every four days (Site A 'fields' were checked almost daily, since two of the other sites were accessed via these fields). During the visit a circuit was made around the site in order to look for ewes, lambs and any carcasses that may be present. If possible, each ewe's number was recorded and a note of whether a lamb was with it was made. The condition of lambs (and ewes) was also recorded, as was their location. No lambs were marked with stockmarker spray (other than that which the crofter would normally apply) since the intention was to alter the normal management practices as little as possible.

### 3.1.4 Marking of lambs

Lambs from the Site A and Site B flocks were ear tagged within 24 hours of birth using Dalton rototags (size 3.5 x 1 cm); each tag was white and had a unique number. The patch of skin excised by the attachment of the ear tag was also retained as a DNA sample. We intended using these samples to identify missing lambs in the event that unidentifiable remains were found in the eagle eyrie, in the event there were insufficient instances of unidentified remains to make this practical. At the same time the behaviour of the ewe in reaction to the handling of the lamb was assessed and a maternal behaviour score given based on that used by O'Connor (1985) who had found that the lambs of ewes that showed strong maternal reactions had higher survival.

On the Site A flock radio transmitters were fitted to twenty randomly selected lambs of several weeks of age, a day before they were released to the hill. This allowed the location of a lamb to be found should it go missing. Biotrack TW-4 transmitters were used, these had a weight of <4 grams and were fitted by clipping down a small patch of fleece on the back of the lambs neck and using cyanoacrylate glue (super-glue) to attach the transmitter to the shortened fleece. A vet approved the process and prior to their release to the hill the lambs showed no signs of irritation or annoyance due to the presence of the transmitters. When in the field none of the tagged lambs exhibited any unusual behaviour that might be related to the transmitter. The transmitters were hidden in the surrounding fleece and were extremely difficult to see, even when standing close to the lamb, so did not alter the appearance of the lamb.

### 3.1.5 Carcasses

When a dead lamb was found, its position was recorded and notes were taken on its condition, extent of any injuries, and any signs of predators. Hindfoot measurements were made and a sample of fleece was taken. We considered using the fleece samples to estimate the age of unidentified carcasses by comparison with samples from know age lambs. However there were ultimately too few unidentified carcasses to warrant this approach. Photographs were also taken of carcasses as a record so that others who have experience of examining lambs predated by eagles could assess them.

## 3.2 Numbers

3.2.1 Flock size

**Table 1 Flock sizes**

| | Number of ewes gathered for study | Number of ewes not gathered | Number of males gathered | Total ewes |
|---|---|---|---|---|
| Site C | 84 | 5 | 1 | 89 |
| Site D | 16 | 4 (6) * | 10 | 20 |
| Site A | 106 | 0 | 0 | 106 |
| Site B | 69 | 2 | 2 | 71 |

* Not including three that were inside a fenced plantation for the duration of the study. Due to the percentage of males in the sample rounded up it has been assumed that there may have been some in the group not gathered. Allowing for the fact that two of the sheep not gathered had lambs, then of the remaining four sheep it has been assumed that approximately two were ewes and two were males.

3.2.2 Stocking rates

The stocking rates (adult sheep per $km^2$) for some of the study sites were difficult to calculate because the boundary fences were not secure and sheep could wander on to other ground for which measurements were unavailable. In addition, only a proportion of the sheep tended to wander therefore they were not evenly spread over the area available.

Site A: Stocking densities varied from 327 adult sheep per $Km^2$ to below 200 $Km^2$, and considerably below that for a large minority of sheep that wandered beyond the boundary.

Site B: Approximate stocking density was 42 adult sheep per $Km^2$.

Site C: Stocking density was approximately 62 adult sheep per $Km^2$.

Site D: Stocking density was approximately 43 adult sheep per $Km^2$.

## 3.3 Pregnancy and Birth rates

Pregnancy diagnosis by external manipulation was undertaken by a vet for the Site C and Site D flocks. Due to the time interval between diagnosis and lambing, this method was not reliable for all ewes although the majority were diagnosed correctly. The alternative of waiting to see if the ewe produces a lamb was less ideal because some ewes that have stillborn lambs or ones that die very soon after birth may end up as being classed incorrectly as having not been pregnant. The use of an ultrasound scanner was rejected because of the short notice at which the investigation was organised and the difficulty of getting the equipment to the remote areas it would be required in. The numbers pregnant are shown in table 2. In contrast, the close monitoring of ewes on inbye land for the other two flocks allowed a precise count of the number that gave birth, and these are shown in table 3.

**Table 2 Pregnancy diagnosis for Site C and Site D flocks**

| | Number | Pregnant | Possibly pregnant | Barren | Possibly barren |
|---|---|---|---|---|---|
| **Site C** | 84 | 67 (79.8%) | 5 (6%)* | 10 ** | 2*** |
| **Site D** | 16 | 13 (81.3%)^ | 1 (6.3%)^^ | 2 | 0 |

* Several of these ewes probably did not lamb (difficult to judge due to id errors).

** Between two and four of these may have had lambs, two for certain.

*** One of these ewes had a lamb the other did not.

^ Of these, two were only seen once with lambs, one was never seen with a lamb and another was seen once but the id was questionable; between one and three probably never gave birth.

^^ This ewe was never seen with a lamb suggesting that she may not have been pregnant.

Due to nature of the monitoring that took place on Site C and Site D it is impossible to be certain that some ewes did not give birth and lose lambs very quickly, thus giving the impression that they never gave birth. However on balance this is unlikely to be the case for all ewes that appeared unproductive. It is also impossible to be certain that when a ewe was recorded only once or twice with a lamb and many times without, that the ewe had not just been misidentified on the occasions it was reported with lamb. This could occur due to the fading of spray-marker numbers, lighting conditions, viewing angle and distance. It is however likely that some of the ewes that were thought to be pregnant that were later never seen with lambs may have lost their lamb at birth.

**Table 3 Number of ewes giving birth on Site A and Site B**

| | N | Gave birth | Barren |
|---|---|---|---|
| Site A | 106 | 99 (93.4%) | 7 (6.6%) |
| Site B | 69 | 63 (91.3%) | 6 (8.7%) |

### 3.4 Lamb losses

**Table 4 Actual lamb losses on Site B and Site A**

| Flock | Ewes | Total lambs | Lambing % @ birth | Died on inbye | % died on inbye | Died/lost on hill | % died/ lost | Lambing % mid June |
|---|---|---|---|---|---|---|---|---|
| Site A | 106 | 109 | 103% | 7 | 6.4% | 6 | 5.5% | 90.5% |
| Site B | 69 | 67 | 97% | 10 | 14.9% | 15 | 22.4% | 60.8% |

Lambing % is based on the number of lambs produced as a percentage of the number of ewes and is a standard measure of lamb production; it can therefore exceed 100%.

**Table 5 Estimated lamb losses on Site C and Site D**

| Flock | Ewes | Estimated pregnant | % estimated pregnant | Lambs in mid June | Lambing % mid June |
|---|---|---|---|---|---|
| Site C | 84 (89)* | 72 | 86% | 64 | 71.9% |
| Site D | 16 (20)* | 14 (16) | 87.5% | 12 | 60% |

*The figures in brackets include sheep not rounded up. Total lambs in June are compared with the ewe figures in brackets to give the lambing percentage.

**Table 6 Proportion of missing lambs found**

| Flock | Lambs put on hill | Total dead or missing | Number found | % of total dead found | Number Missing | % of total missing |
|---|---|---|---|---|---|---|
| Site A | 103 | 6 | 2 | 33.3% | 4 | 66.6% |
| Site B | 57 | 15 | 10* | 66.6% | 5 | 33.3% |

*This total includes 2 sets of remains that were found but no ear tag was present so the individual could not be identified.

### 3.5 Discussion

The rounding up of sheep was most successful on Site A and Site B where virtually all sheep were gathered by the crofters and brought back to inbye land for lambing. Proportionately fewer sheep were gathered on Site C and Site D, which reflects the fact that these sheep are less accustomed to being gathered, particularly at this time of year. We estimate that approximately 6% of Site C ewes and 20% of Site D ewes were not gathered in for processing.

It is unsurprising to find the occasional wedder or tup in amongst a flock, however it is worth noting that there was a large number of male sheep in the relatively small Site D flock. This has some bearing on our assessment of sheep that were not gathered. The percentage of sheep that were male (10 out of 26, i.e. 38%) was sufficient to lead us to consider that at least some of the ungathered sheep may also have been male.

The actual percentage of lambs being born on Site A and Site B was relatively similar (103% and 97%), however the final lambing percentages show a much greater difference (90% and 61%), reflecting higher losses at Site B.

If we compare the numbers of ewes estimated to be pregnant on Site C and Site D with the numbers of ewes giving birth on Site A and Site B, we see that the figures for the first two are slightly lower (86-87.5% vs. 97-103%). This could suggest a slightly lower pregnancy rate. However we must bear in mind that the first set of figures are estimates with potential errors while the second set are actual figures of sheep giving birth. It is not possible therefore, to say for certain if the pregnancy rate was significantly lower on Site C and Site D, only that it may have been.

Overall lambing percentages based on the June round ups do however differ more widely, from 60% for Site D to 90% for the Site A flock. This suggests that the lambing percentage is determined mainly by lamb survival rather than pregnancy rate of the ewes.

The stocking rates appear very much higher on Site A than on the other sites, however this is a reflection of the way in which the ground is managed. For the first month when ewes and lambs were put out on the hill (after spending their first weeks on inbye land), they were kept at high densities on good quality ground. At the end of May they were moved to a lower quality area which although still at a relatively high density enabled many sheep to roam further and lower the density still further. Stocking densities cannot really be compared between the sites because suitable densities will be determined by the quality of the ground. Sheep tended to concentrate in areas where there was better quality grass so although densities may look low on some sites they may actually be quite high in the areas that the sheep utilise. A determination on whether these approximate stocking densities are too high would have to involve an assessment of the nutritional quality of the vegetation on each site and its availability to all sheep. However we cannot rule out that even at low stocking densities, some of these sites may not provide particularly good grazing.

## 4. Condition Scores

### 4.1 Condition scoring

DEFRA guidelines state "condition scoring gives a clear indication as to whether the nutrition of the ewe in the recent past has been correct…. The aim of condition scoring is to assist the farmer to achieve balanced nutrition which maximises productivity and minimises welfare problems in the ewe and her lambs.". Generally, the lower the condition score, the fewer reserves the ewe has to support its lamb either during pregnancy or after birth. Ewes with poorer condition scores (<2) or that are overweight (>4) are more likely to suffer pregnancy toxaemia or vaginal prolapse in mid to late pregnancy, they may have difficult births, they have a poor colostrum and milk supply and produce fewer and weaker lambs (MAFF 1994). Stable condition scores should be maintained throughout the ewe's pregnancy. DEFRA state that a condition score of 2 is the ideal for hill sheep 8 weeks prior to lambing. They also state that "a condition score of less than 1.5 in a significant number of a flock of hillsheep can indicate inadequate management and the need for positive steps to rectify the situation" (MAFF 2000).

By condition scoring ewes, particularly on Site B and Site A, it gave us the opportunity to examine if there was a relationship between the ewes' condition and ultimate lamb survival.

### 4.2 Numbers of sheep gathered and assessed for condition

See 3.2.1 for details on the numbers of sheep gathered.

### 4.3 Ewe condition

The relative numbers of ewes that were given a particular condition score in each flock are listed in table 7; the data are also shown in Figure 1 using the condition scores from the Agricultural staff only.

**Table 7 Number of sheep in each flock with a particular condition score**

| Flock | N | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | Scorer |
|---|---|---|---|---|---|---|---|---|---|
| **Site C (Ag)** | 84 | 0 | 7 | 19 | 27 | 23 | 8 | 0 | Ag staff |
| **Site C (vet)** | 84 | *1* | *8* | *19* | *25* | *18* | *9* | *2* | *Vet* |
| **Site D (Ag)** | 16 | 0 | 2 | 5 | 3 | 6 | 0 | 0 | Ag staff |
| **Site D (vet)** | 16 | *0* | *1* | *4* | *4* | *5* | *2* | *0* | *Vet* |
| **Site A** | 106 | 0 | 0 | 0 | 79 | 26 | 1 | 0 | Ag staff |
| **Site B** | 68* | 0 | 8 | 19 | 34 | 4 | 3 | 0 | Ag staff |

*One ewe had already lambed when scoring was being carried out.

On Site C and Site D the Vet was present and was asked to give an additional condition score as a comparison with the Agricultural staff. There was no evidence for a difference between assessors at Site D (t= -1.69 df=15 P=0.111) or Site C (t=0.00 df=81 P=1.000). Assessors were in complete agreement for 58% of sheep, and for 93% there was either agreement or only 0.5 difference.

**Figure 1 Percentage of each flock given a particular condition score**

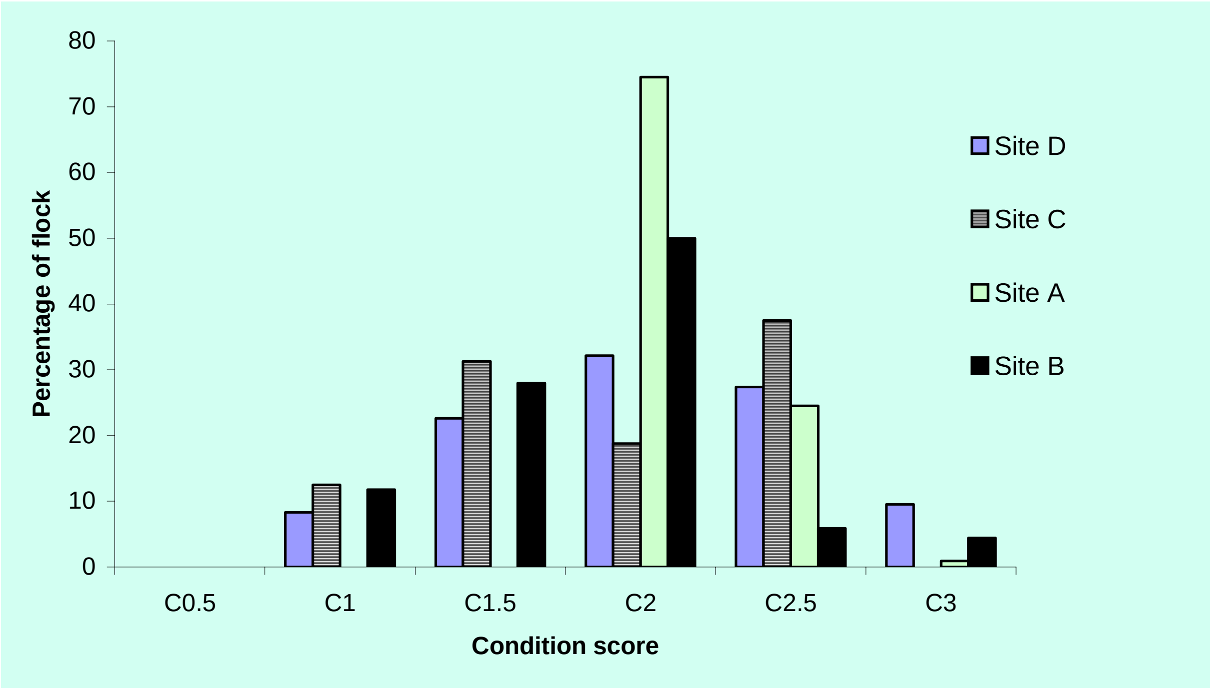



**Table 8 Means and standard deviations of condition scores for each flock (data from agricultural inspectors only)**

| Flock | Mean | Std Dev. |
|---|---|---|
| Site A | 2.13 | 0.23 |
| Site C | 2.04 | 0.55 |
| Site D | 1.90 | 0.54 |
| Site B | 1.82 | 0.46 |

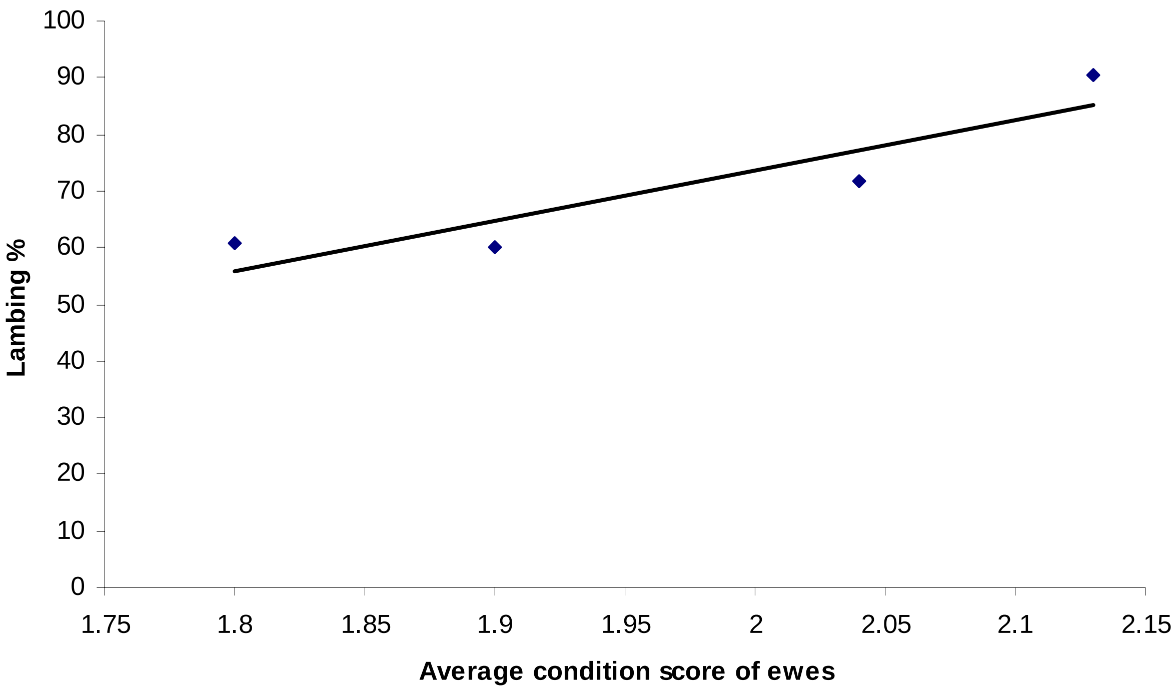
Site A showed less variation in scores (but this is difficult to assess with an ordinal scale). Using an ordinal regression of scores in flock (i.e. treating the scores as ordered categories), there was strong evidence for differences between flocks ($p<0.001$). An analysis of variance also showed strong evidence for differences in mean scores between flocks ($p<0.001$).

From table 8 and figure 1 it is clear that condition scores from ewes at Site A were within a tighter range than any other flock, with the majority of the sheep attaining a score that suggests they have the right amount of resources for lambing. Other flocks were less consistent and had significantly more ewes in the lower end of the condition score range (<2) than Site A ewes.

### 4.4 Mean condition score and lambing percentage

When the mean condition score from each flock is compared with the lambing percentage there is some evidence of a positive relationship (see figure 2), indicating that the higher condition score may be linked in some way to higher lambing percentage. However this does not necessarily imply a direct relationship (i.e. that higher condition score causes greater lamb production and/or survival in the study flocks).

**Figure 2 Average condition score vs. lambing percentage**




**4.5 Ewe age, condition score, maternal behaviour and lamb survival**

We compared the condition scores of individual ewes with the survival of their lambs. This was complicated by the fact that a few of the lambs were fostered to other ewes for a variety of reasons. Therefore we carried out the analysis twice, once for the condition of the ewe that gave birth to the lamb (birth mother) and again for the ewe that raised the lamb (rearing mother), but for most lambs this was the same ewe. The data were examined using Chi-squared tests with the 'expected' values based on equal proportions of surviving lambs in each category of the variable being examined.

A few ewes were excluded from the analysis because of incomplete data collection. The two flocks were analysed separately because it was evident that Site B had a higher rate of losses than Site A (p-value<0.001) and this may have been due to various causes including the condition/age/behaviour of the mothers.

4.5.1 Birth Mother

Site A, 103 lambs were born, 11% died

Site B, 67 lambs, 37% died

4.5.1.1 Site A

**Table 9 Frequency of lamb survival by ewe age Site A**

| | Gimmer | 2/3 years | 4+ years |
|---|---|---|---|
| Alive | 13 | 21 | 53 |
| Dead | 1 | 4 | 6 |
| Proportion dead | 7% | 16% | 10% |

There was no evidence of a relationship between a lambs survival and mother's age (Chi-square p=0.65).

**Table 10 Frequency of lamb survival by ewe condition Site A**

| | 1 | 1.5 | 2 | 2.5 | 3 |
|---|---|---|---|---|---|
| Alive | 0 | 0 | 65 | 21 | 1 |
| Dead | 0 | 0 | 7 | 4 | 0 |
| Proportion dead | N/a | N/a | 10% | 16% | 0% |

There was no evidence of a relationship between the mothers condition score and lamb survival (Chi-square p=0.47)

**Table 11 Frequency of lamb survival by maternal behaviour score Site A**

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Alive | 1 | 20 | 33 | 24 | 4 |
| Dead | 0 | 2 | 6 | 1 | 0 |
| Proportion dead | 0% | 9% | 15% | 4% | 0% |

There was no evidence of a relationship between the maternal behavioural score and lamb survival (Chi-square p=0.46)

4.5.1.2 Site B

**Table 12 Frequency of lamb survival by ewe age Site B**

| | Gimmer | 2/3 years | 4+ years |
|---|---|---|---|
| Alive | 4 | 34 | 3 |
| Dead | 8 | 17 | 0 |
| Proportion dead | 67% | 33% | 0% |

There was some evidence of a relationship between the mothers age and the survival of lambs (Chi-squared p=0.036), with younger mothers being associated with more deaths.

**Table 13 Frequency of lamb survival by ewe condition Site B**

| | 1 | 1.5 | 2 | 2.5 | 3 |
|---|---|---|---|---|---|
| Alive | 4 | 12 | 20 | 4 | 2 |
| Dead | 4 | 8 | 12 | 0 | 1 |
| Proportion dead | 50% | 40% | 38% | 0% | 50% |

There was no evidence of a relationship between mothers condition score and lamb survival (Chi-squares p=0.60).

**Table 14 Frequency of lamb survival by maternal behaviour score Site B**

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Alive | 1 | 0 | 9 | 16 | 8 |
| Dead | 0 | 1 | 5 | 4 | 4 |
| Proportion dead | 0% | 100% | 36% | 20% | 33% |

There was no evidence of a relationship between the maternal behaviour score and lamb survival (Chi-square p=0.47)

4.5.2 Rearing Mother

Site A, 98 lambs 5% died

Site B, 59 lambs 27% died

4.5.2.1 Site A

**Table 15 Frequency of lamb survival by ewe age Site A**

| | G | 2/3 years | 4+ years |
|---|---|---|---|
| Alive | 0 | 1 | 86 |
| Dead | 0 | 0 | 5 |
| Proportion dead | N/a | 100% | 5% |

A formal test was not appropriate because there was only one class with substantial lamb numbers.

**Table 16 Frequency of lamb survival by ewe condition Site A**

| | 1 | 1.5 | 2 | 2.5 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Alive | 1 | 0 | 21 | 1 | 32 | 25 | 4 |
| Dead | 0 | 0 | 1 | 1 | 3 | 0 | 0 |
| Proportion dead | 0% | N/a | 5% | 50% | 9% | 0% | 0% |

There was no evidence for a relationship between the rearing mothers condition score and lamb survival. (Chi-square p= 0.12).

4.5.2.2 Site B

**Table 17 Frequency of lamb survival by ewe age Site B**

| | G | 2/3 years | 4+ years |
|---|---|---|---|
| Alive | 17 | 24 | 2 |
| Dead | 5 | 11 | 0 |
| Proportion dead | 23% | 31% | 0% |

There was no evidence of a relationship between the age of the rearing mother and lamb survival (Chi-squared p=0.51).

**Table 18 Frequency of lamb survival by ewe condition Site B**

| | 1 | 1.5 | 2 | 2.5 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Alive | 0 | 1 | 1 | 0 | 9 | 16 | 8 |
| Dead | 0 | 0 | 2 | 0 | 3 | 2 | 4 |
| Proportion dead | N/a | 0% | 67% | N/a | 25% | 11% | 33% |

There was no evidence of a relationship between the rearing mothers condition score and lamb survival (Chi squared p=0.25)

### 4.6 Discussion

Overall it appears there is no evidence for lamb survival being related to the condition of the ewe or to maternal behaviour score. There is however some evidence that on Site B, younger ewes may be more likely to have a lamb die in the early stages of its life. However this relationship is weak and is only evident in the data for birth mothers and not for rearing mothers, suggesting perhaps that these higher losses may be linked to birth problems.

There is some evidence of higher production from flocks with higher average condition scores. This is not in evidence between individuals within flocks and therefore it is possible that the higher production and higher condition scores are both a result of a particular management regime rather than one being a direct effect of the other.

## 5. Lamb Measurements

Lambs on Site A and Site B were caught within 24 hours of birth, were ear tagged, weighed, and their hindfoot measurement was recorded. A few weeks later their hindfoot was measured again prior to their release onto the hill.

### 5.1 Lamb size and weight

**Table 19 Average hindfoot length and weights of lambs tagged within 24 hours**

| Flock | sex | N | Hindfoot length (mm) | Weight (Kg) |
|---|---|---|---|---|
| Both (sites A & B) | All | 168 | 174 | 3.95 |
| Both (sites A & B) | M | 90 | 175 | 3.99 |
| Both (sites A & B) | F | 77 | 173 | 3.90 |
| Site A | All | 105 | 173 | 3.85 |
| Site B | All | 63 | 174 | 4.11 |

There was no evidence that either sex or Flock affected the initial hindfoot measurement (p-values 0.23 and 0.73 after taking the other factor into account). However there was evidence that flock affected the initial weight of the lamb (p-value 0.037 after taking into account sex; p-value for sex was 0.41). Average weight for newborn lambs from the Site A flock was 3.85kg, for the Site B flock it was 4.11kg; standard error for difference was 0.12kg.
As would be expected, weight and hindfoot measurements were closely correlated (0.758 df=167 $p<0.01$).

### 5.2 Dead lambs

**Table 20 Average measurements taken from lambs within 24 hours of birth in terms of their subsequent survival.**

| Lambs | Hindfoot | Weight (Kg) |
|---|---|---|
| All lambs (Sites A & B) | 174 | 3.95 |
| Site A all lambs | 174 | 3.85 |
| Site A surviving lambs | 174 | 3.92 |
| Site A lamb mortalities | 169 | 3.25 |
| Site A lamb mortalities on inbye | 174 | 3.13 |
| Site A lamb mortalities on hill | 168 | 3.34 |
| Site B all lambs | 174 | 4.11 |
| Site B surviving lambs | 177 | 4.24 |
| Site B lamb mortalities | 169 | 3.84 |
| Site B lamb mortalities on inbye | 173 | 3.37 |
| Site B lamb mortalities on hill | 172 | 3.99 |

The results of unpaired t-tests comparing the measurements taken from lambs which subsequently died with those that survived in each flock, showed that there was a significant difference in initial weight between mortalities and survivors on Site A (p=0.008), with survivors having a greater initial weight than those that died. There was no significant difference in hindfoot length between survivors and mortalities.

On Site B there was weak evidence of a difference in initial weight but it was not significant (p=0.052). However there was a significant difference in hindfoot length (p=0.007); in both cases the survivors had larger average measurements.

These results suggest that within flocks (i.e. under a given management regime), lambs born small or light may be more likely to die than larger or heavier ones. Sample sizes of dead lambs from the Site A flock were not sufficient to further examine this relationship in terms of lambs dying on inbye land and on the hill. For Site B there was also insufficient data to carry out an analysis of inbye mortality. Analysis of the data from lambs put out on the hill on Site B shows no significant difference in initial weight between survivors and mortalities, and a weak, but not significant difference in hindfoot length (p=0.069), with survivors having larger average measurements. This might suggest that once the smaller lambs have survived to a few weeks old they are no longer any more vunerable to various mortality factors than lambs born larger, and in this study, none of the inbye deaths were due to predation.

## 6. Causes of death

### 6.1 Determining cause of death

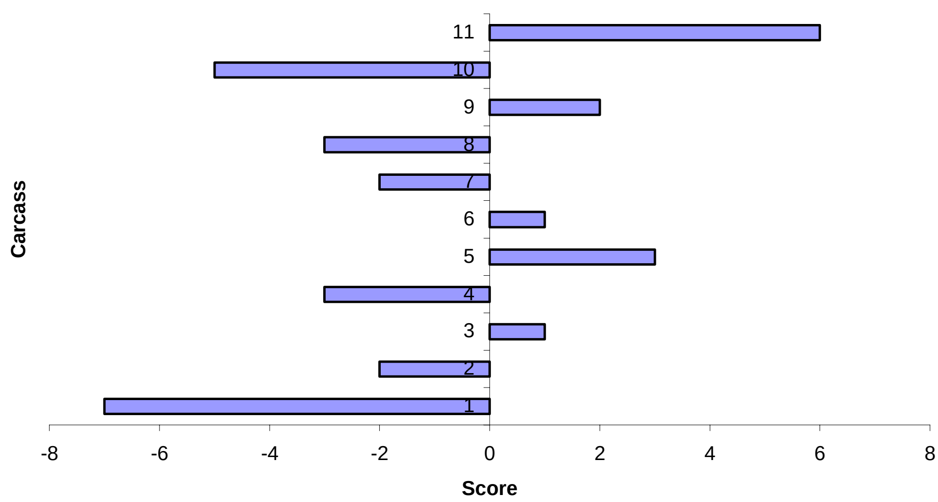
Regular monitoring of the ewes and lambs allowed us to determine the cause of death or at least rule out certain causes for a number of the lambs that were found. Other carcasses were examined for signs of damage and an assessment was made of the likelihood of eagle predation. For many carcasses, eagle predation could be ruled out with certainty. Detailed video and photography were shown to the local veterinary surgeon to confirm the cause of death in these cases. With 10 carcasses it was not possible to conclusively determine if predation had taken place. In these cases, photographs of the carcass remains were recorded on CD-Rom along with information describing the carcass, and copies were sent to several experts who have extensive experience and knowledge of examining predated livestock, eagle predation or who regularly undertake post-mortem examinations of animals. The CD also included one carcass that was thought to almost certainly be an eagle kill. In the text accompanying the photographs only descriptions and factual details were given, no opinion was expressed, thus allowing those reviewing the pictures to come to their own conclusions. A simple questionnaire (see Annex for sample copy and list of reviewers) was provided, so that comments could be made on the potential cause of death and any other relevant information. Unfortunately some carcasses were too incomplete or scavenged to form any kind of reasonable conclusion as to the cause of death.

As a way of quantifying the responses we used a scoring system, where 'unclear' or no comment was scored as zero, Possible and Unlikely were scored at 1 and –1 respectively and Yes and No were scored at 2 and –2 respectively. The totals for each carcass were calculated and the scores used to allocate the carcass to a particular category. The higher the positive score the more likely the carcass was to be an eagle kill, the more negative the score, the less likely it was considered to be an eagle kill. Table 21 shows how the scoring system was used. The relative scores of the eleven carcasses for which opinions were sought are shown in figure 3.

**Table 21 Categorisation of lamb carcasses using review scores**

| Category (Eagle kill?) | Score | Number of carcasses |
|---|---|---|
| Yes | Greater than or equal to **6** | 1 |
| Possibly | Greater than or equal to **2** | 2 |
| Unclear (not possible to tell) | Less than **2** and greater than **–2** | 2 |
| Unlikely | Less than or equal to **–2** | 5 |
| No | Less than or equal to **-6** | 1 |

**Figure 3 Relative scores of carcasses based on responses of reviewers**



The assessments of the cause of mortality were combined with those lamb carcasses for which we had determined the cause of death and are summarised in table 22. Further details on the cause of mortality of lambs that were determined not to be the victims of eagle predation are detailed in table 23. Table 24 gives a further, more detailed breakdown of cause of death on the two flocks that lambed on inbye land.

**Table 22 Assessment of proportion of lamb carcasses found from each flock that were killed by eagles.**

| | Site C | | Site D | | Site A | | Site B | | All flocks | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Eagle Kill?** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** |
| Yes | - | - | - | - | 1 | 50 | - | - | 1 | 4 |
| Possible | - | - | - | - | - | - | 2 | 22 | 2 | 8 |
| Unknown | - | | - | - | 1 | 50 | 2 | 22 | 3 | 13 |
| Unlikely | 3 | 27 | - | - | - | - | 1 | 11 | 4 | 17 |
| No | 8 | 73 | 2 | 100 | - | - | 4* | 44 | 14 | 58 |
| Total | 11 | - | 2 | - | 2 | - | 9* | - | 24 | - |

*does not include a lamb that went missing after the ewe died, because the carcass was not found.
Percentage is of lambs found dead on hill on each site

**Table 23 Non predation causes of mortality, where it could be determined, for lambs found dead 'on the hill' (excluding lambs dying on inbye land on sites A & B, and unknown causes of death)**

| | Site C | | Site D | | Site A | | Site B | | All flocks | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cause of mortality** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** | **n** | **%** |
| Starvation | 1 | 9 | 1 | 50 | - | - | - | - | 2 | 8 |
| Birth problem/defect | 3 | 27 | 1 | 50 | - | - | - | - | 4 | 17 |
| Misadventure | 1 | 9 | - | - | - | - | 1 | 11 | 2 | 8 |
| Illness/disease | 3 | 27 | - | - | - | - | 3 | 33 | 6 | 25 |
| Totals | 8 | 73 | 2 | 100 | - | - | 4* | 44 | 14 | 58 |

* does not include a lamb that went missing after the ewe died, because the carcass was not found
N.B. The percentages are calculated as a percentage of the total carcasses found from each flock not just those that had not been killed by eagles (see totals in Table 22)

**Table 24 Causes of mortality in lambs from Site A and Site B as a percentage of lambs born, including lambs lost while sheep were on inbye land before being put on to the hill.**

| | Site A | | Site B | |
|---|---|---|---|---|
| **Cause of mortality** | **n** | **%** | **n** | **%** |
| Birth problem | 2 | 2 | 4 | 6 |
| Weak lamb/illness | 4 | 4 | 7 | 10 |
| Misadventure | 1 | 1 | 3 | 4 |
| Starvation | 0 | 0 | 0 | 0 |
| Death of ewe | 0* | 0 | 1** | 1 |
| Eagle kill | 1 | 1 | 0 | 0 |
| Unknown (possible eagle kill) | 0 | 0 | 2 | 3 |
| Unknown, found | 1 | 1 | 3 | 4 |
| Unknown, missing | 4 | 4 | 5 | 7 |
| **Totals** | **13** | **12%** | **25** | **36%** |

*One lamb on Site A was rescued from starvation when an observer working on this project found a ewe that had become stuck in a bog.
** Ewe on Site B died, lamb carcass was not found but assumed to have died due to starvation.
N.B. The percentages are calculated as a percentage of the total number of lambs in the flock (figures are rounded to nearest whole number.)

### 6.2 Discussion

From table 22 it appears that 50% of lambs from the Site A flock found dead on the hill were likely to have been killed by eagles, whereas 100% of those from the Site D flock were definitely not killed by eagles. It is difficult to read too much into those figures because they are based on sample sizes of 2 dead lambs found for each flock. However for the other two flocks, Sites D and B we have samples of 11 and 9 respectively. Of these, there are no definite eagle kills, and the proportion of lambs found from these flocks that were definitely not killed by eagles is 73% and 44%. For Site A and Site B flocks, lambs that died on inbye land are excluded from these totals.

The accurate lambing data for Sites A and B, where the losses on inbye land are included, allows the overall percentage of lambs that died due to different causes to be calculated. The most important cause of death in both flocks was illness followed by birth problems (stillborn or difficult births); combined, these accounted for 46% of the losses on Site A and 44% on Site B. When misadventure (accidents e.g. falling in ditches and drowning) is also added, these three factors account for 54% and 56% of losses on Sites A and B respectively.

Losses to eagle predation accounted for 1% of all lambs born in the Site A flock. Unknown cause of death which could not be discounted as eagle predation accounted for 3% of lambs born in the Site B flock. As a proportion of the overall losses on Site A the eagle kill is large, however this is because losses to other causes of mortality are much lower than we might expect, particularly in comparison with deaths on Sites B and C.

Unknown causes of mortality (mainly because the lamb went missing, but also because the cause of death could not be determined from the remains) account for 38% and 36% of losses on Site A and Site B. Without the discovery of some remains, it is not possible to identify the cause of mortality in those lambs that went missing. However, if the assumption is made that these lambs died of causes in proportion to those lambs where cause of death was identified, and extrapolate the figures for eagle kills (and possible eagle kills), then an estimated 1.5% of lambs were predated by eagles from Site A, and 4.1% of lambs from Site B. A predated carcass is no less likely to be found than one that died by other means, and indeed Hewson (1984) states it is more likely to be found. Eagles would have been unable to carry lambs the size of the Site A or B animals any significant distance. Any attempt to dismember the carcass and carry it off in parts would most likely result in unwanted parts left behind or at the very least, signs of plucking and other remains. It is worth noting that at the final area survey of all sites, all of the carcasses found over the 12 week study were still present, with no evidence of removal by scavengers. It would seem, therefore, that any extrapolation of predation from those lambs found, to the missing lambs is likely to be an overestimate, and should be treated as an upper limit on the number predated.

## 7. Production comparisons

Comparisons were made between data at the time of the study, with figures for recent years from some of the crofters, along with annual agricultural census data for Scotland as a whole, and for the individual Scottish regions.

### 7.1 Lambing production in previous studies

Lambing percentages (lambs produced per 100 ewes) vary greatly between different types of farming practice. Intensively managed sheep flocks on good quality lowland ground can produce in excess of 200%, whereas on many poorer upland areas it may be a struggle to reach even 100% and the norm may be well below this.

Studies on eagles have noted typical lambing percentages in the areas in which the eagles are found. Brown and Watson (1964) referred to a lambing percentage of 80% on their study area in Argyll, with the returns for the whole county from 1945 to 1958 having a mean of 68.1% (and a range of 52.1% to 78.3%). They noted that the area was thought to be better farmed than areas in the West Highlands where lamb losses could be higher. Lockie (1964) reported that in many areas of Wester Ross and Sutherland, a lambing percentage of 65% was considered an average yield. Hewson (1981) reported percentages on hill ground in the west of Scotland at around 55-70% although it could range from 45% on exposed high ground to 91% on sheltered low ground near the coast. Leitch (1986) reported a lambing percentage of 70% for 1982-1985 in his Glenelg study area, although for the whole Glenelg parish it was 60% and the six adjoining parishes ranged from 57% to 68% (mean =65%). It is quite clear therefore that in some areas of Western Scotland, high lamb mortality can be quite normal and lambing percentages below 70% are not unsual.

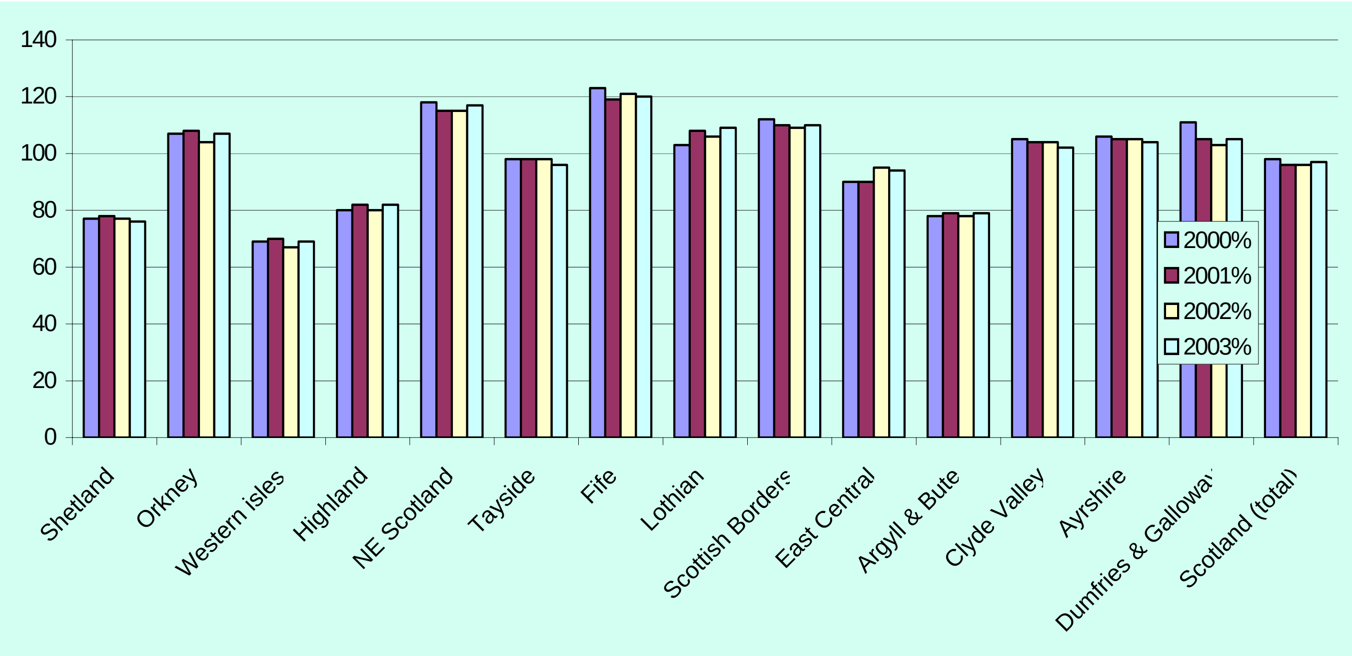
On the Uists, sheep management practices are often quite low intensity, the climate can be quite harsh, and the grazing on the hill is relatively poor. Thus it may be expected that lamb survival would be towards the lower end of the scale. On Uist, Hall (1975) reported average survival to market was 40-45% with a good year yielding about 50%, although it is not clear whether these figures take account of lambs kept for breeding and not sold on.

### 7.2 Lambing percentages in Scotland

The Scottish agricultural survey that is carried out each year carries details of breeding ewes and lambs present in June of each year. This corresponds closely to timing of the final count on our study sites and thus allows us to calculate estimates of lambing percentage on a larger geographic scale for comparison with our study sites.

Electronic data split by Scottish local authority sub-groups from the Scottish annual agricultural census was available at the time of writing for the 2003 study year and the three previous years. The data are shown in graph form in figure 4.

**Figure 4 Average lambing percentages  for Scottish regions 2000-2003**




From the graph it is notable that the Western Isles has the lowest average lambing percentage in the last four years at 70% or below, the next lowest regions are Shetland, and Argyll and Bute, each with around 78%. The overall values for Scotland are around 97% and the most productive area is Fife with 120%+. The graph clearly illustrates that the relative productivity of the regions has been fairly constant in recent years.

Going back to paper records of the similar data, figures were extracted for the Western Isles, Shetland, Argyll & Bute, Fife and Scotland as a whole (figure 5). Figure 5 demonstrates that since the mid 1970's lambing percentages across Scotland have on average risen by about 8%. In the Western Isles and Argyll & Bute percentages have risen by slightly greater amounts. It is possible that this reflects gradual changes in sheep husbandry practices, and that the greater improvement in the Western Isles reflects its lower starting point and greater room for improvement. In contrast, in Fife percentages have fluctuated, rising and then falling over the period to remain broadly at the same level if not slightly lower than in the early to mid seventies.

The average lambing percentage for the first complete ten year period (1976-1985) for which we have data was 58% in the Western Isles compared with 72% for both Shetland and Argyll and Bute, for Scotland it was 91%. Whereas for the last complete ten year period (1994-2003) the figures are Western Isles 70% (+12%), Shetland 79% (+7%), Argyll and Bute 80% (+8%) and Scotland 99% (+8%) respectively. It is interesting to note that in Fife, one of the most productive areas, the average lambing percentage was almost the same in the two periods at 123% and 122% (-1%).

We can fit a simple line to the graph plot of each data set and from this calculate the slope of the line and thus the average rate of increase in the lambing percentage over the period from the mid 1970's to 2003; the figures for this are shown in table 25.

The data clearly show that while lambing productivity on the Western Isles is currently the lowest of all the Scottish Regions it has still improved since the 1970's, and that improved productivity has risen to a greater degree than the rest of Scotland as a whole.

**Figure 5 Lambing percentages in four Scottish regions since 1971**

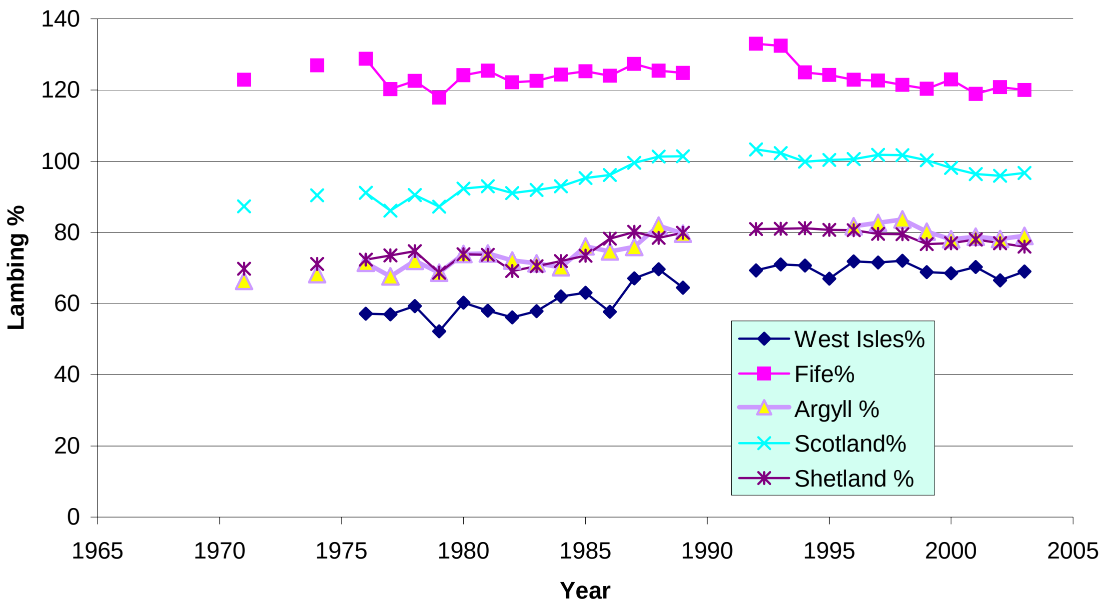



**Table 25 Average increase per year in lambing percentage**

| Region | Average rise per year in lambing % |
|---|---|
| Western Isles | 0.60 |
| Shetland | 0.30 |
| Argyll | 0.44 |
| Fife | -0.06 |
| Scotland | 0.42 |

### 7.3 Lambing percentages from flocks on study sites

There is considerable variation in productivity both between flocks, but also from year to year within flocks (table 26 & figure 6), with no obvious pattern or relationship between flocks. However it is a relatively short period of time and relatively few flocks, so trends may not be obvious even if they did exist.

**Table 26 Lambing percentage for flocks in 2003 and years previous to study**

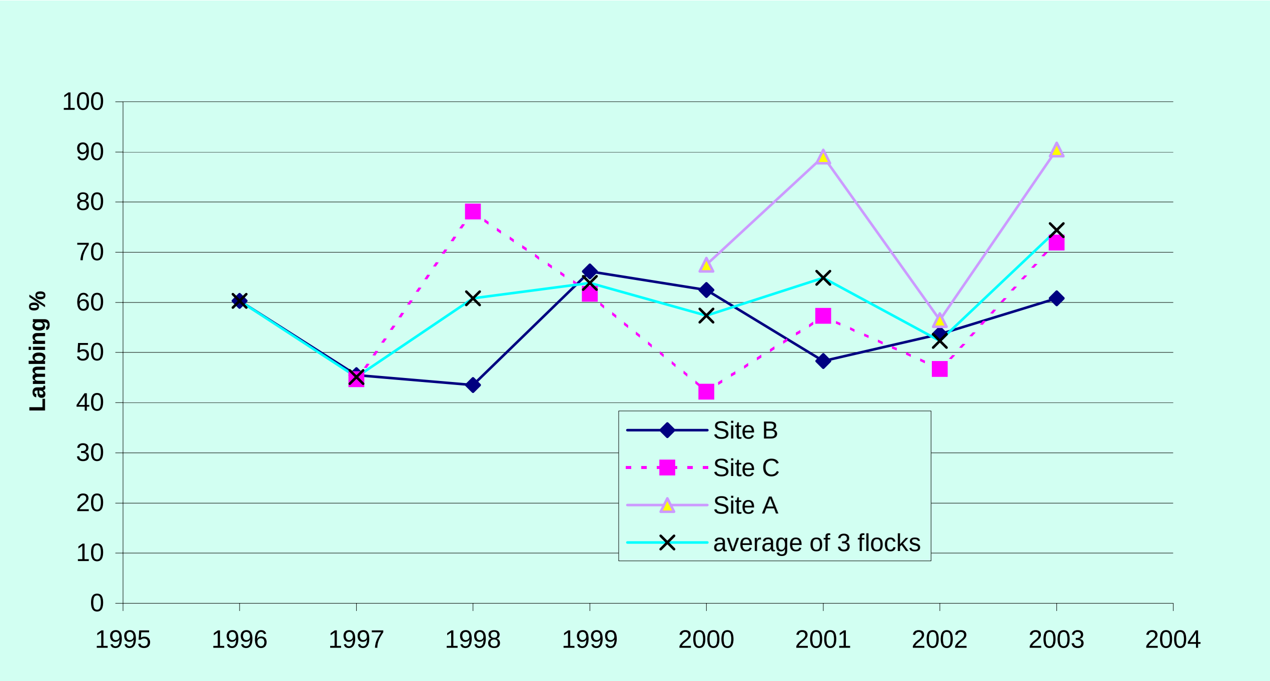
| Year | Site B | Site C | Site A | Average of sites |
|---|---|---|---|---|
| 1996 | 60.3 | | | 60.3 |
| 1997 | 45.5 | 44.7 | | 45.1 |
| 1998 | 43.5 | 78.1 | | 60.8 |
| 1999 | 66.2 | 61.7 | | 63.9 |
| 2000 | 62.5 | 42.2 | 67.5 | 57.4 |
| 2001 | 48.3 | 57.3 | 89.1 | 64.9 |
| 2002 | 53.7 | 46.7 | 56.5 | 52.3 |
| 2003 | 60.8 | 71.9 | 90.5 | 74.4 |

N.B. Data for Site D not available

In the context of the data for Scotland and the regions it is apparent that the lambing percentage at Site A in 2003 is well above the historic average one might expect on the Western Isles and the percentage achieved on Site C is about equal to the average.

The Lambing Percentages on Site B and Site D are slightly below average, although it is not possible to test whether this is statistically significant. In the case of Site D the total sample size is so small that a single lamb loss could have a large influence over the lambing percentage.

**Figure 6 Lambing percentage for flocks in 2003 and years previous to study**




### 7.4 Lambing percentage in surrounding area

Some information was gathered on lambing percentages of flocks on similar ground nearby to the study area on Benbecula. Information was sparse but in 1998 the average lambing percentage on five flocks varying in size from 30 ewes to 103 was 78% (range 75-90%). In 1999 on three of the same crofts containing flocks of 26 to 54 ewes it was also 78% (range 73-83%), and in 2000 details were only available for one flock of 119 ewes that had a lambing percentage of 59% (this flock achieved 77% in 1998).

Data were also available for a single croft that was in close proximity to an eyrie containing a breeding pair of eagles (no part of the croft was more than 2 km from the nest and most of it was much closer). With a flock of 120 ewes, this croft returned lambing percentages of 67% in 2000, 68% in 2001 and 67% in 2003.

## 8. Weather conditions

### 8.1 Mean temperature, rainfall and sun

Weather conditions are one environmental factor that could potentially have a big impact on lamb survival. Under adverse conditions, the risk of death due to exposure, starvation or illness may increase. It is also possible that such conditions over the winter could result in ewes having particularly poor body condition, making lambs more vulnerable to adverse conditions. Conversely good weather conditions could create a situation where survival is higher than it would be under normal conditions.

Unfortunately, figures from a local weather station were not available. However we did obtain Meteorological Office summaries of the monthly regional weather for the period of the study and preceding months. The differences between these figures, and the average figures from 1961-1990, are shown in table 27.

**Table 27 Differences in monthly weather factors between 2003 and long term average for North Scotland region.**

| Month | Jan-03 | Feb-03 | Mar-03 | Apr-03 | May-03 | Jun-03 |
|---|---|---|---|---|---|---|
| **Sunshine (hrs)** | +2% | +50% | +44% | **+17%** | -14% | -2% |
| **Mean temp *** | +0.6 (2.6) | +1 (2.9) | +2.3 (5.7) | **+3 (8.1)** | +0.7 (8.7) | +2 (12.7) |
| **Rainfall** | +27% | -41% | -30% | **-29%** | +66% | -11% |

*shown in Centigrade, figure in brackets is actual mean temperature

It is clear from the figures that the late winter of 02-03 was milder than average and that the early spring was drier, sunnier and warmer than average, although May then went on to be considerably wetter and duller than average, although temperatures was broadly average. Figures for 2002 show similarly above average mean temperatures but heavier rainfall (table 28).

**Figure 28 Differences in monthly weather factors between 2002 and long term average for North Scotland region**

| Month | Jan-02 | Feb-02 | Mar-02 | Apr-02 | May-02 | Jun-02 |
|---|---|---|---|---|---|---|
| **Sunshine (hrs)** | -22% | -22% | +8% | +9% | +10% | +12% |
| **Mean temp** | 2.4 (4.4) | 1.1 (3) | 1.4 (4.7)% | 1.8 (7) | 1.3 (9.3) | 1.1 (11.,8) |
| **Rainfall** | 41% | 128% | 3% | 12% | 0 | 37% |

It should be noted that the effects of adverse weather are likely to be greatest on newborn lambs, which will be the most susceptible to exposure during April when the majority of lambs are born; almost 97% of the lambs on Site A and Site B were born in April. This is likely to be of less importance in two of the study flocks, Site A and Site B because the ewes are lambing on inbye land and are closely monitored, although poor weather could affect weight gain and subsequent mortality risk when lambs are put out onto the hill. However in the other flocks, where ewes are lambing untended on the hill, survival of newborns could be much more strongly affected by weather conditions.

In the period from 1999 to 2003 the mean temperature during April fluctuated from average to above average when compared with the long term (see figure 7). The hours of April sunshine increased four years in a row whereas rainfall fluctuated from above to below average levels from year to year (see figure 8).

**Figure 7 Plot of April mean temperature per year (North of Scotland Met office data)**

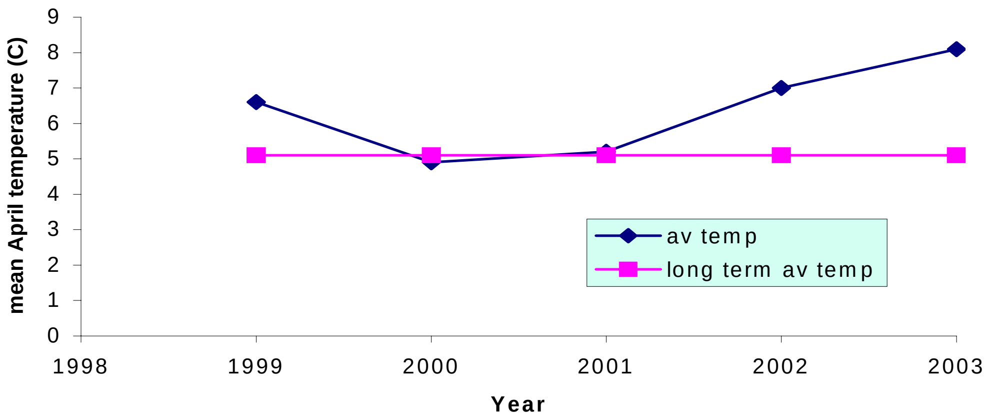
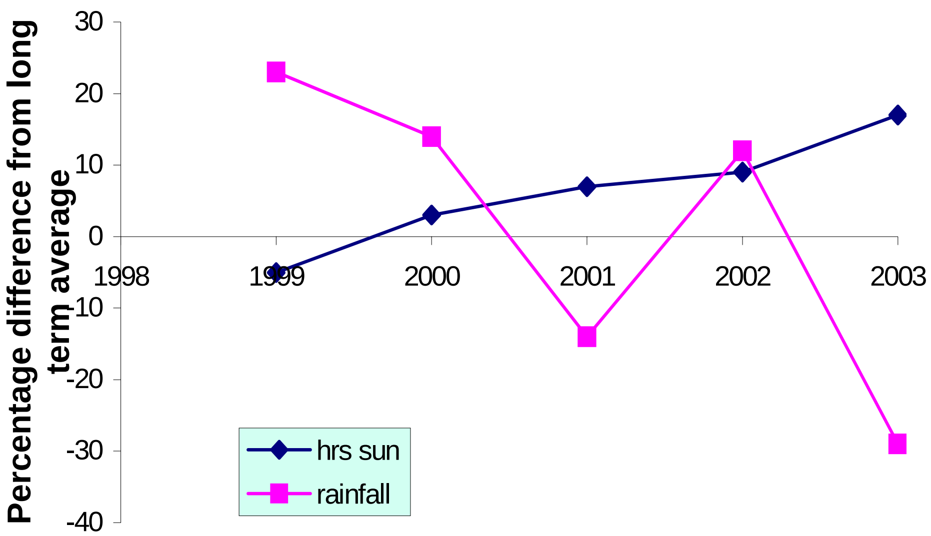



**Figure 8 Plot of percentage difference in April rainfall and hours of sunshine compared to long term average (0 on y-axis)**




**8.2 Discussion**

During April, which is the main lambing month on the study area, (approximately 97% of inbye lambs born this month) the conditions in 2003 were considerably drier and much warmer than average. In 2002 conditions were also milder than average, but not to the extent of 2003. However in 2003, May was much wetter than average, whereas the previous years' rainfall was in line with the average. There were still apparently significant numbers of lambs being born on Site C during May, and therefore, the possibility exists that weather may have had a greater impact on survival there.

When compared to the lambing percentages provided by crofters for the period 1999 to 2003, there is little evidence of a direct link between weather and production. In the most recent four years, there is a suggestion of an inverse relationship between rainfall and lambing percentage for Site C and Site A flocks (i.e. higher lambing percentage in years with lower rainfall), although in 1999 when mean rainfall was at its highest, Site C achieved a higher lambing percentage than in some following years. Also, although there is no weather data for 1998, the Meteorological office summarised April 1998 as "*Very wet. Colder than March. This has been the wettest April since 1818 and the third wettest April since records began in 1766. It has been the coldest April since 1989*. ", and yet Site C recorded relatively high lambing percentages (higher, in fact, than 2003).

Since poor weather could affect survival both directly and in many indirect ways, then other factors will be involved and it may not be possible to identify a true relationship with the small sample size, limited variables and limited time series data available. Individual weather factors such as rainfall and temperature are likely to have greater combined effects, for example high rainfall during mild conditions may be less adverse than moderate rainfall in colder and windier conditions.

# 9. Eagles and Eagle Diet

## 9. 1 Eagle presence and activity

Observations of the study area were occasionally undertaken from a high vantage point outside of the study area using a high quality 80mm flourite observation scope fitted with a 20-60x magnification eyepiece. Casual observations of eagles were made using the scope, high quality 10x40 binoculars and the naked eye during the course of other activities.

There were a pair of eagles that centered their activity around the southern half of the study area, one of the birds in this pair was a sub-adult. This pair maintained an eyrie but did not produce an egg, possibly because of the immature status of one of the pair. The birds were often observed flying low over parts of the study area, and also to the North West and South and Southwest of the study area. Roosting and perching sites could be identified when birds were seen sitting (pellets were recovered from some of these).

Another pair of eagles nested in an eyrie 6 to 7 km to the south of the study area; this pair had an eyrie and raised a chick. It is not possible to say whether these birds visited the study area to hunt but on balance it would seem unlikely that they would do so with any degree of regularity, because of the pair that were apparently resident in the area, and also because of the distance. Although eagles can bring prey to eyries from distances as great as 13-16km, it is likely to be much shorter distances in most circumstances. Also, eagles observed on the study area were not seen to fly off in the direction of this active nest. Another active nest was known to be about 7km to the North but again there was no obvious indication of any birds arriving from or flying off in that direction; we do not know whether this nest held any chicks.

## 9.2 Pellets

A number of pellets were collected from sites where golden eagles had been seen sitting or where there was evidence of the presence of eagles. These included the vicinity of the closest known active eyrie to the study area, from close to lamb carcasses, and also from roosts and perches on the study sites.

Pellets were collected on over 17 occasions, and were sent for analysis to CEH; at the time of writing the pellets were still awaiting processing.

Many of the pellets contained sheeps wool and a proportion of them were made up of feathers. A BTO metal bird ring was recovered from one pellet prior to being sent for analysis, and was later confirmed as belonging to a grey heron that had been rung the previous year on one of the study sites.

## 9.3 Prey remains at eyrie

In addition to the pellets, prey remains were also collected from around the eyrie containing an eagle chick 7 km south of the study area, both from the nest itself and from within approximately 50m of it. Any fresh uneaten remains in the eyrie were noted but not removed. Old remains that were obviously from a previous nesting season were not collected. It is likely that the remains of larger items of prey have a much greater chance of surviving and being found in this sort of collection. Small items may be completely eaten, or discarded parts may easily be lost in vegetation and between rocks, and would be numerically under-represented in this collection.

The remains were identified as follows:

In eyrie:

- herring gull chick -fresh and intact;
- meadow pipit -fresh and intact;
- shelduck -wing feathers & skull base;
- lamb - upper leg bone, vertebrae and bit of skull cap, one pair of forelegs.

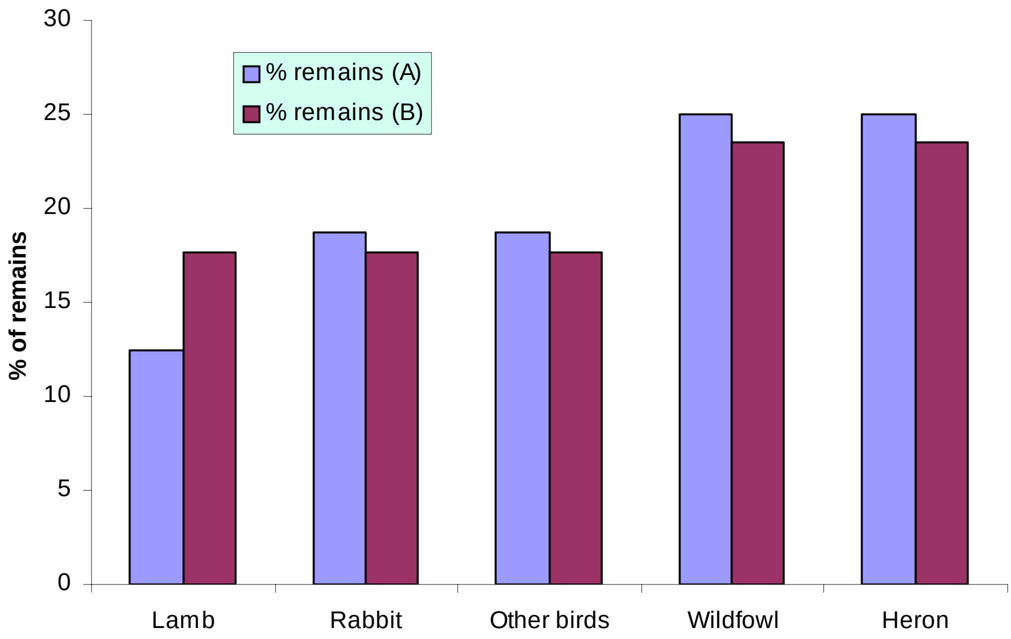
Adjacent to eyrie:

- 3 rabbits (2 full grown and 1 juvenile);
- fragment of lamb skull (same as above?);
- 1 lamb leg;
- 4 herons (3 full grown and one nestling);
- 2 greylag geese;
- female mallard duck;
- red grouse.

In practice it is difficult to be certain how many individual lambs made up the remains found; they could all have come from one lamb, but it is more likely that they originated from two, perhaps three, animals. This would indicate that between 12 and 17% of the prey items found were lamb.

Numerically the majority (approximately 65%), of the prey items recovered were birds, dominated by species found on and around water; almost 50% of items were wildfowl or herons. Rabbits and other birds (gull chick, pipit and grouse) accounted for around 18% each, and lambs accounted for between 13 and 18% (depending on whether the remains were from 2 or 3 individuals) (see Figure 8).

**Figure 8 Relative percentages of prey remains found in or near Eyrie**




Note: '% remains (A)' is calculated on the basis of the lamb remains being from two individuals, '% remains (B)' assumes three individuals.

## 9.4 Available prey species

On the study area, and in the nearby vicinity, there are a wide range of available prey species. Due to time and manpower constraints, detailed surveys were not conducted, although notes were made of species seen and numbers of individuals counted on visits to individual study sites. The species present are typical of moorland and coastal habitats.

It is worth noting that within a 7 km distance of the study area are large tracts of machair and blackland where high numbers of rabbits, waders and waterfowl can be found. While it is unlikely that eagles would return with heavy prey items from these sorts of distances they could easily return from this far and beyond with lighter prey items, or after feeding themselves rather than bringing food for their chicks. Therefore the prey available in and adjacent to the study area is by no means the only food source available, although it may be an important element of it.

### 9.4.1 Birds

Waterfowl are common, Greylag geese are nesting on and around the study area; red-breasted mergansers, shelduck and eiders are common around the coast; mallard also occur on some freshwater lochans. Herons are very common around the coastal areas and there is a reasonably sized heronry in the study area (30+ birds counted on occasions).

Waders are common and along the coast with reasonable numbers of oystercatcher and redshank. Lapwing are present on expanses of short, better quality grass on three of the study sites, and snipe are common on the wetter areas of ground. Golden plover, ringed plover and common sandpiper occur in small numbers and other species occur on passage or when flying in from outside the area to feed on large sand/mud flats which are exposed at low tide.

Gulls are plentiful on and around the study area, common gulls and herring gulls in particular. There are many nesting on islands adjacent to the study area. Great black-backed gulls also nest and lesser black-backs also occur. Arctic terns are present and may be nesting nearby. A few pairs of arctic skua nest on moorland in the study area.

Small passerines are fairly abundant, skylark and meadow pipits are common throughout the study area. Other species such as stonechat, wheatear, blackbird, song thrush, dunnock, linnet and twite all occur. Starlings can be found around the various ruined buildings on and around the study sites. Hooded crow and ravens are also found, some of which are nesting.

Other bird species breeding or feeding in the study area and its immediate vicinity include hen harrier, buzzard, short-eared owl, rock dove, diver species, buzzard, kestrel, red grouse, mute swan and cormorant, all of which have been known to be preyed upon by golden eagles (Watson 1997, Sulkava *et.al.* 1999).

### 9.4.2 Mammals

Rabbits occur on the study area at low density, but have apparently been present in greater numbers in the past. It is possible that myxomatosis is responsible for reducing the population recently. Field voles are present across the study area and rats are also present. Mink may be present in very low numbers although efforts are underway to eradicate them. Otters are common throughout the study area with two active holts identified on the area and probably more.

### 9.4.3 Carrion

Large numbers of sheep are distributed across the study area and in the surrounding land. A small proportion of the stock are likely to die over the winter period, the ewes that do not survive often remain unburied and provide a potential source of carrion. Ewes can also occasionally die in spring and summer, again proving a source of carrion. During this study, Eagles were seen feeding on the carcass of a ewe about 500m from one study site and during the course of the study three ewes died on the study area with a fourth being bogged down and rescued only to die later. In the natural course of events, stillborn and weak lambs can be expected to add to available carrion, as will other forms of death such as illness. Red deer are present at low densities in the surrounding area and these too, may on occasion, be a source of carrion, although their low numbers may make this a rare occurrence.

## 10. Discussion

### 10.1 Lamb production

This investigation has shown that the survival of lambs to mid June for two of the four study flocks is around or slightly greater than the average for the Western Isles. For the other two flocks it is slightly below the average. It is not possible to say whether these figures deviate significantly from the average, but it is likely that there is a considerable spread around the average lambing percentage and therefore all of these flocks probably fall within the range that would be expected. When compared with lambing figures from other studies in the West of Scotland under similar environmental conditions they do not appear unusual. The combined lambing percentage for the study area was around 75% which falls well within the range of percentages quoted for similar areas by Brown and Watson (1964), Lockie (1964), Hewson (1981) and Leitch (1986). Even the lowest recorded value for the individual flocks under investigation (60%) falls within the lower range of figures previous studies have quoted. Although the data show that average lambing percentages in the Western Isles and Scotland as a whole have increased since many of these other studies were carried out; this is most likely due to changes in management practices. Therefore on crofts where management practices are broadly similar to those of 20 or 30 years ago it would not be unreasonable to expect similar production figures. So although lamb production is very low, it is not necessarily unusually low for a flock on poor ground and with relatively low intensity management.

It is also worth noting that a flock of ewes which have been kept in close proximity to a breeding eagle pair in very similar conditions to the area under study (similar vegetation, topography and minimal management) has returned lambing percentages of around 67% in three of the last four years. Percentages from flocks on the study sites have fluctuated more dramatically in that time.

### 10.2 Cause of death

We estimate that 1% of lambs in one flock were killed by eagles and 3% in another flock were possibly killed by eagles. When all flocks are combined, then this figure is less than 1.5% of lambs killed or possibly killed by eagles (bearing in mind that for two flocks we don't know precisely how many lambs were born, only an estimate of ewes pregnant). This figure is close to previously quoted losses, such as the minimum of 1% quoted by Hewson (1984), and that of 1.8% reported by Leitch (1986). Weir (1973) estimated that a maximum of 2% of lambs were taken by eagles (including those scavenged). In contrast with losses from eagle kills, losses to other known causes were responsible for approximately 7% of lambs lost for one flock and 21% of lambs lost for the other. Unknown causes accounted for approximately 5% and 11% of the lamb flock respectively.

As a proportion of total lambs born, death due to birth problems including stillborn lambs account for 2% and 6% of lambs from sites A and B (for which we have accurate information on lamb numbers), this is equivalent to 15% and 16% of deaths respectively. On sites C and D birth problems account for 27% and 50% of deaths in carcasses recovered. Illness and disease account for the loss of 4% and 10% of lambs born on sites A and B, this is equivalent to 31% and 28% of deaths for sites A and B respectively. Illness and disease was responsible for 27% of dead lambs found on one of the other flocks. The fourth flock had no dead lambs found due to illness or disease, but this could be an effect of the very small sample size for that flock.

Henderson (1997) cites figures from ADAS that indicate birth problems being responsible for 35% of lamb deaths in hill flocks, and disease and genetic defects responsible for 12.4%. Wiener *et al.* (1983) found that birth problems accounted for 21% of dead lambs, and that diseases and congenital defects were responsible for 40% of deaths in an upland grassland flock in the Borders. Houston (1977) found that stillborn lambs accounted for 22% of lambs found dead (a further 5% had died shortly after birth and never walked), and that disease was responsible for 9%.

Hendersons' (1997) losses due to misadventure are combined with those for predation (16.1%). In our investigation we estimate misadventure alone accounting for between 7 and 24% of deaths depending on the flock. Wiener *et al*. (1983) listed 'environmental mishap' as being a factor in around 2% of losses. It is worth however, noting that in the Wiener study, the flock involved was closely shepherded at all times, which may help to explain the low mishap losses, since this is a factor where frequent shepherding could make a significant difference.

Starvation was an additional major cause of mortality in other studies; Henderson (1997) cites hypothermia and starvation as responsible for 34.2% of deaths, and Weiner *et al*. report a figure of 25% (Weiner includes 'weakly lamb' in this total; in this study 'weakly lamb' was included in the disease total). Houston (1977) determined that starvation accounted for 48% of dead lambs found. In our investigation starvation came out quite low, it was not identified in two flocks, although one lamb that went missing after the ewe died can be assumed to have starved. Starvation was responsible for 9% and 50% of losses from the remaining two flocks, although again the high percentage for one flock was due to small sample sizes rather than many starving lambs.

### 10.3 Missing lambs

From each flock there was a large proportion of lambs that were never recovered, and the cause of death for these lambs cannot be determined. The size and terrain of the sites inevitably meant that our carcass searching was not 100% efficient and therefore it is not surprising that some lambs were never located. It is also possible that some lambs were not recovered because they fell in holes or ditches or the sea, thus making them difficult, or impossible, to find. Furthermore, some lambs went missing between the end of the study in mid-June and gathering at the end of June. The size of the lambs at this stage makes them highly unlikely to have died of eagle predation.

Given that the eagles that were most often present on the study area were a local non-breeding pair, then there was little reason to suspect they carried large prey items such as lambs away out of the study area. Without eggs to incubate, or young to feed there was no need to take food to the eyrie and therefore little reason to expend energy moving heavy food items more than a short distance. No prey remains were found in the eyrie and only a few relatively old decayed prey remains (probably from the previous year) were found around a vantage point about 20 meters from the eyrie. If the birds did move a carcass, due to the weight they would probably not have moved it far and it would therefore still be likely to be found. Matchett and O'Gara (1987) state that golden eagles carry more small (<2 kg) items to nests and that even under ideal conditions it would not be possible for an eagle to carry lambs of over 4 kg to an nest. Sulkava *et al*. (1998) cites the maximum weight that an eagle can carry to be equal to its weight (3.8 kg for a male and 5.3 kg for a female). However under favourable circumstances (e.g. on a hillside with a strong updraft) it may be possible for a bird to lift heavier weights, but such conditions are unlikely to occur on the relatively flat and low lying study area. The greater the weight an eagle lifts then the shorter the distance it is likely to be able to move the object, lifting weights close to the limit that they are capable of would suggest that the distances involved are likely to be relatively short. The average weight of day old lambs from the Site A and B flocks was 3.95 Kg, but by the time they went to the hill, most weighed in excess of 5 Kg, and some double that. The birth weight of lambs from the Site C and D flocks is not known, but it is possible that a carcass could have been lifted by an eagle and moved. However, it is worth noting that all carcasses that were found, including several newborn lambs, some of which had very recently died, were still present at the end of the study period. It is therefore most likely that lambs killed on the study area would be eaten *in situ* or only carried a short distance, and hence the remains would still have a chance of being located. Hewson (1984) states that there is a "strong bias in favour of finding predated lambs" compared with other carcasses.

### 10.4 Susceptibility of lambs

It has been shown in other studies that certain lambs can be more susceptible to some forms of mortality than other lambs. For example, Hewson and Verkaik (1981) noted that lambs born to gimmers had lower survival than those born to older ewes. This effect was not due to lower pregnancy rates or poorer condition but was thought to be due to poorer maternal care. It is also often suggested that smaller or poorly lambs may be more likely to suffer from the adverse effects of weather or be more vunerable to predation. In this study it appears that lambs born small or light may have had a slightly lower chance of survival but it was unlikely to be related to predation. We examined whether there was a relationship between survival and birth weight or hind foot length (indicative of size). There was some evidence that smaller or lighter lambs were more likely to die than others within the same flock. However there were also significant differences in the average weight of lambs between the two flocks so any relationship between weight and survival was not absolute, but relative to other factors for each flock, such as management.

We looked to see if the age of the mother, the mothers' condition or her maternal behaviour were related to lamb survival. Only one of these factors showed a significant relationship with the subsequent fate of individual lambs and only for one flock. Lambs born to Gimmers from the Site B flock died more often than those born to older ewes. There was an indication that the higher the average body condition scores for a flock, the higher the lamb survival. However this was thought not to be a direct effect, i.e. other factors that were responsible for the increased survival may also have been responsible for the higher condition scores.

General weather conditions may have helped survival, of the three flocks where we have data, survival was higher than in 2002 while rainfall was much lower. And there was some inconclusive indication that there may be a relationship with rainfall going back for several years.

**10.5 Eagle prey**

Although to a casual observer the study area may appear to be relatively poor in potential eagle prey this is not the case. Eagles have large home ranges and can easily travel several kilometres to hunt. This is particularly true of non-breeding birds, which have no need to carry prey back to a nest. Therefore, the eagles present in the study area could be obtaining their food over an area much larger than that being investigated. However, even within the study area there was a reasonable availability of prey other than lambs. Observations showed that most the species that were found in a neighbouring eyrie, also occurred with reasonable abundance within, or in close proximity to, the study area.

**10.6 Management**

Lambing percentages vary considerably between the four flocks on the study area. Environmental factors such as weather are likely to be the same across all sites but other factors vary markedly between flocks, such as the intensity of management. This could partially explain the difference between the flocks.

Lambs from the Site A flock had a notably higher survival than the other flocks in the study. There was some indirect evidence to suggest that lamb survival increased with body condition score of the ewes, and the Site A flock had higher and more consistent body condition scores than the other flocks. This was likely to be due to several factors, such as supplementary feeding of the Site A ewes over the winter and spring, and the use of fertilizer to improve the grass on some fields. Lamb survival may also have been increased by the presence of stockproof fencing to confine the animals to an area where they can be easily monitored, the covering of all holes and ditches within these fields to reduce the chance of lambs becoming trapped, and medical treatment of sick lambs.

In addition to these management practices, the Site A flock was the only flock that had a significant number of blackface-Swaledale crosses. Unfortunately we had incomplete information on which lambs were crosses. There exists the possibility that the crossbred lambs were hardier than the purebred blackface, following the concept of 'hybrid vigour'. This would be particularly true if the pure stocks of blackface they were compared with, had a high degree of inbreeding. Certainly there is evidence of increased lamb survival from crossbred ewes (Wiener *et al*. 1983, Barker *et al.* 1985).

The practice of moving the ewes to inbye land for lambing and closely monitoring them in the first weeks is also likely to improve survival. However, this same practice occurred for the Site B flock where survival was comparatively low. Once on the hill though, Site B is a extensive area containing many hazards, and the presence of tidal islands that are often favoured by the sheep, make it difficult to check on all the animals regularly. The area is also only partially fenced, so sheep can wander well beyond the area of the site; one ewe for example wandered all the way back to the inbye fields.

It is possible that the higher lambing figures at Site C, despite the ewes lambing untended, could be due to the existence of relatively good quality grass in areas larger than any of the other sites except Site A. A large proportion of the flock spent most of its time on these areas and this may also be true for the overwinter period, possibly explaining the relatively higher condition scores on Site C.

Site D had the least intensive management of all of the flocks. The high number of wedders on the site may also be competing with ewes for resources, such as the better quality grass found around the coast and on some islets.

### 10.7 Conclusion

The data provides evidence that causes, other than eagle predation, are responsible for the majority of lamb mortalities on the study area, and that golden eagle predation levels are broadly similar to those found in other investigations in Scotland, at between 1 and 3% of the lamb flock. Action taken to prevent eagle predation is likely to result in relatively minor gains in lamb survival. For some flocks however, changes to management practices may produce substantial improvements in lamb survival.

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10th June 2004

# Annex
## Copy of questionaire form sent to reviewers of carcass photographs

A copy of the following form was sent to reviewers for each of the 11 sets of carcass photographs that they reviewed:

**LAMB CARCASS 1**

From your experience, what species do you think may have caused all or part of the damage seen? Please circle the species and state why you reached this conclusion.

| | |
|---|---|
| Eagle | |
| Corvid (raven, crow) | |
| Gull species | |
| Buzzard | |
| Mustelid (otter, mink) | |
| Other (please state) | |

In your opinion, do you think the lamb was ***killed*** by an eagle (please circle)?

| | | | | |
|---|---|---|---|---|
| YES | NO | POSSIBLE | UNLIKELY | UNCLEAR |

Any other comments?

| |
|---|
| |

**List of independent reviewers**

| | |
|---|---|
| Mick Marquiss | Center for Ecology and Hydrology, Banchory |
| Tony Patterson | SAC Veterinary Services, Inverness |
| Ranald Munro | Veterinary Laboratories Agency, Lasswade |
| Alan Leitch | SNH, Dalkeith |
| Alan Stewart | Wildlife Liaison Coordinator, Perth |