Scottish Natural Heritage

Commissioned Report 370

Is Lamb Survival in the Scottish Uplands Related to the Presence of Breeding White-Tailed Eagles (*Haliaeetus Albicilla*) as well as other Livestock Predators and Environmental Variables?

A pilot study into sea eagle predation on lambs in the Gairloch area

Final Report

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COMMISSIONED REPORT

Commissioned Report No. 370

IS LAMB SURVIVAL IN THE SCOTTISH UPLANDS RELATED TO THE PRESENCE OF BREEDING WHITE-TAILED EAGLES (*HALIAEETUS ALBICILLA*) AS WELL AS OTHER LIVESTOCK PREDATORS AND ENVIRONMENTAL VARIABLES?

A PILOT STUDY INTO SEA EAGLE PREDATION ON LAMBS IN THE GAIRLOCH AREA

Final Report

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COMMISSIONED REPORT

Summary

IS LAMB SURVIVAL IN THE SCOTTISH UPLANDS RELATED TO THE PRESENCE OF BREEDING WHITE-TAILED EAGLES (*HALIAEETUS ALBICILLA*) AS WELL AS OTHER LIVESTOCK PREDATORS AND ENVIRONMENTAL VARIABLES?

A LAMB COHORT STUDY

Commissioned Report No. 370
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Background

Farmers and crofters have reported declines in lambing performance in parts of the western Highlands & Islands of Scotland that some have linked with the spread of the re-introduced white-tailed eagle population. Whilst previous research on Mull has shown that only minimal numbers of live lambs are taken by white-tailed eagles, the applicability of this finding to other parts of Scotland has been questioned. Some crofters have suggested that levels of predation have increased markedly in recent years especially with reference to the Gairloch Peninsula.

This report presents the findings of a pilot project undertaken by the Food and Environment Research Agency that aims to validate the approach and the methods that could be employed for a larger study; principally to assess if lamb survival in the Scottish Uplands is related to the presence of breeding white-tailed eagles as well as other livestock predators and environmental variables.

Main findings

- Within the radio tracked study flocks no lambs (including both tagged and untagged individuals) were taken by white-tailed eagles during the study period.
- The five dead lambs found by FERA staff within the study areas (including two that were being scavenged by white-tailed eagles) and an additional carcass provided by a local crofter were sent for post mortem examination; additionally two signs of eagle scavenging were recorded (dense blanket areas of plucked wool), although no carcasses were located.
- Post mortem examination identified one carcass (with poor body condition), obtained from the Strath area in May, where the cause of death was due to head and neck trauma associated with puncture wounds. The wounds were consistent with being inflicted by long powerful talons. It is therefore highly likely that this lamb was killed either by a golden eagle or a white-tailed eagle.
- Fifty-eight radio tags were originally attached to lambs within the study flocks during May. However, a large number of tags were recovered that had

become detached from the lambs and therefore several re attachment sessions took place.

- In total, 167 tag attachments were carried out across the three flocks, and of these, approximately 60% subsequently fell off.
- The greatest number of active tags at any one time was 58, although this was for one day only. The lowest number, 10, was also over a single day.
- Across all three flocks, 70 – 100% of all tags were active and available for radio tracking for 64% of the study period.
- The average rate for tags detected per day during the study period was 99.93% (Cove Home 100%; Cove Hill 99.86%; Sands 99.91%).
- While only one tagged lamb died, the frequency with which tags fell off live lambs enabled some quantification of the ability to locate the tags. Tags were recovered on all 101 occasions on which mortality signals were detected.
- In total 224 vantage points were undertaken amounting to 599.1 hours of systematic observation.
- White-tailed eagle activity was recorded for less than 2% of total VP observation time but in neither Cove nor Sands in-bye, highest levels of flight activity were recorded at Cove Hill (0.87% of all observation time) with lesser levels at Melvaig (0.60 %) and Sands (0.37%).
- Cove Hill held the highest densities of both predators and prey species.
- At Cove croft of the 100 lambs put out onto the hill there were only two losses up to the end of the study period.
- At Sands croft of the 160 lambs put out on the hill only two lambs were known to have been lost up to the end of the study period.
- Outwith the immediate study flocks losses were also reported. Crofters who lost the most lambs were in the Melvaig area of the peninsula, mainly between Melvaig village and the lighthouse. However, all crofters reported few lamb losses this year than in the previous two years.

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CONTENTS

1 INTRODUCTION

This report presents the findings of a pilot project that aims to validate the approach and the methods that could be employed for a larger study to assess if lamb survival in the Scottish Uplands is related to the presence of breeding white-tailed eagles (*Haliaeetus albicilla)* as well as other livestock predators and environmental variables.

Farmers and crofters have reported declines in lambing performance in parts of the western Highlands & Islands of Scotland that some have linked with the spread of the re-introduced white-tailed eagle population. This population started breeding in Scotland in the mid-1980s and has increased to a level where there are now 46 breeding territories, mainly in the island groups of Skye, Mull and the Western Isles, but there are also small numbers of breeding territories on the smaller islands and a few breeding pairs on the mainland.

Whilst previous research on Mull (Marquiss *et al* 2001) has shown that some live lambs are taken by white-tailed eagles, the applicability of this finding to other parts of Scotland has been questioned, and some crofters have suggested that levels of predation have increased markedly in recent years.

In particular there has been a specific issue in the Gairloch area, although concerns over possible impacts of sea eagles have been raised in several geographical areas, including Skye, Western Isles and Mull, where, in spite of past research work and the current management scheme, some concern remains that sea eagles are taking significant numbers of live lambs.

2 METHODS

2.1 Background - Study area and selected crofts

The trial study took place on the Gairloch Peninsula, Wester Ross and was initially centred on three individual crofts with coverage extended during the study to accommodate emerging patterns of lamb loss and eagle activity, (approximate study area polygons are illustrated in Figure 1).

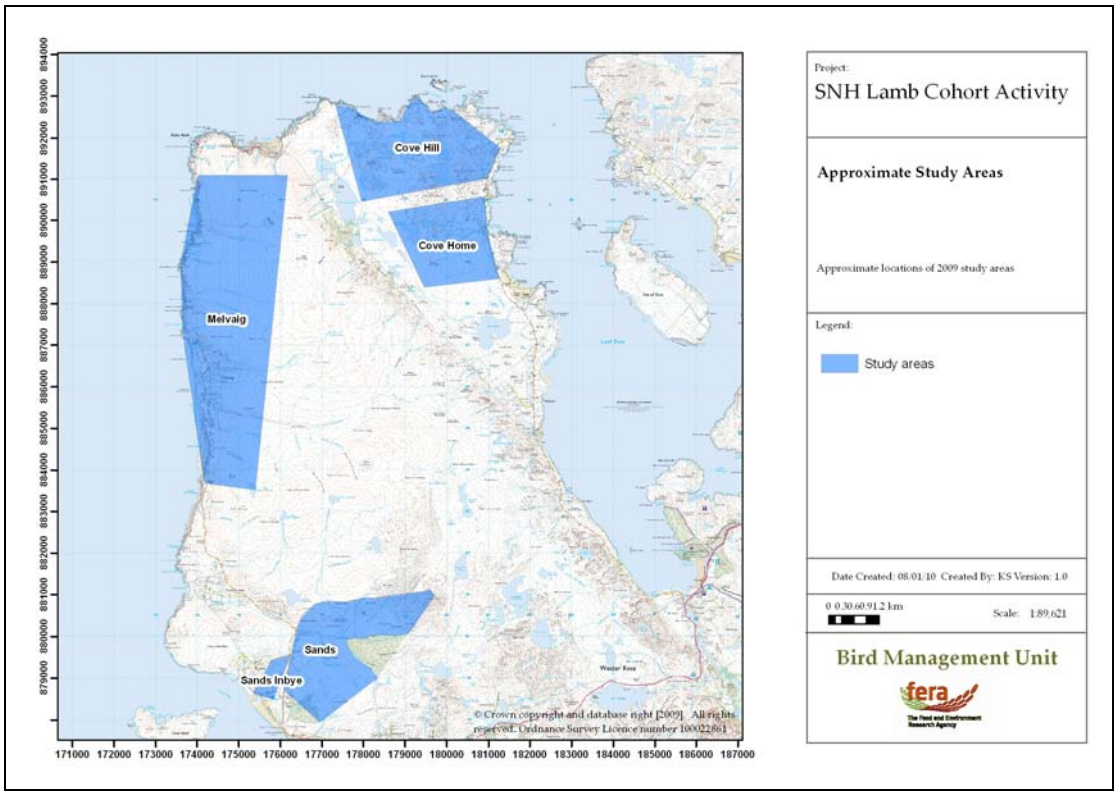

Figure 1: Gairloch Peninsula and key study areas.

2.1.1 Cove Croft

Cove croft is situated on the eastern side (and hill flock on north east tip) of the Gairloch peninsula; the flock consists of between 180 and 200 Cheviot ewes. The sheep are divided between a “home” and “hill” flock.

2.1.2 Sands Croft

Sands croft is situated on the western side of the Gairloch peninsula; the flock consists of 130 Cheviot ewes.

2.1.3 Melvaig area

The study flock in the Melvaig, in the northwest tip of the Gairloch peninsula consists of approximately 300 Blackface ewes.

2.1.4 Additional monitoring areas

Following reports of increased eagle activity from crofters and local residents, an additional study area, Strath, was added to the Vantage Point survey schedule on the 3rd June. Monitoring areas were further modified after the steering group meeting of the 16th July, with the use of locations at Strath and original VP at Melvaig being discontinued in favour of a new location centred around the single radio mast south

of Melvaig (with northerly view bearing) to monitor activity as a result of reported losses to flocks in this area.

2.2 Radio Tracking

A total of 58 tags each fitted with a mortality chip that was triggered after two hours inactivity, were attached to lambs from three flocks on two crofts. Within the two study crofts, Sands and Cove, a non-selective sample of lambs were used for the radio tracking study; tags were attached to those lambs most readily available during predetermined tagging and condition monitoring sessions. These sessions were timetabled to fit in with standard croft management practices wherever possible and practical. Additional in bye trial sessions were undertaken at Cove croft to allow field-testing of attachment methods.

The purpose of using mortality tags was to establish whether lambs could be located, and, especially when dead, within a short time of actual death.

2.2.1 Tag attachment

Concerns relating to the pre ordered tags received from Televilt Sweden were raised by the FERA study team and referred to the FERA consulting Home Office Vet. Subsequently the tags were deemed as unsuitable for mounting on lambs without modification and field trial. The unmodified radio tags were approximately 4cm x 3cm x 1.5cm rectangular boxes, (although tag size varied between individual tags) with sharp edges and 50cm long antennae. Trials of various solutions resulted in tags being adapted by the following methods (see also Figure 2):

- Slightly oversize neoprene pads were affixed to one side of each tag using Araldite©, to act as a protective cushion between lamb and tag;
- Antennae length was halved by folding back on itself and being held in place by heat-activated shrink tubing.

Pictures of adapted radio tags are included in Figure 2, which illustrated the relative size of the tags and antennae/neoprene pad adaptations.

Figure 2: Adapted radio tags.

The tag modifications were carried out at least 24 hours before being attached to lambs, in order to allow the neoprene patch to bond to the tag casing and for the Araldite to harden. Figure 3 illustrates two lambs with radio tags fitted (tags 25 and 28) and tag id numbers marked on the fleece of both lambs and their respective ewes.

Figure 3: Examples of tagged lambs and marked ewes.

During tag attachment procedures, additional information was collected from each tagged lamb:

- weight
- age
- sex
- fleece staple length
- hind foot length
- ear tag number
- ewe lambing experience

Two methods were used to attach tags to the lambs, and required the presence of three field workers (one to hold the lamb, one to clip the fleece and attach the tag, and one to record various parameters and prepare glue and tag for attachment), details of which are presented below:

2.2.1.1 Method TA1 (5th – 14th May)

On all attachments up to and including the 14th May 2009, a patch of fleece between the shoulder blades, just large enough to accommodate the neoprene pad, was clipped down to bare skin using veterinary grade clippers. Veterinary surgical glue (Vet Bond) was applied to the base of the neoprene pad and held down onto the bare skin for a period of approximately 60 seconds.

2.2.1.2 Method TA2 (15th May – 15th July)

On all attachments from the 15th May, once the patch of fleece was clipped, the skin and surrounding fleece was cleaned first with antibacterial hand cleanser and then with surgical white spirit in an attempt to remove any excess lanolin in the area of tag attachment. Once clean and dry, Vet Bond glue was applied to the treated skin patch and the underside of the radio tag before attachment. The tag was then held in place for a minimum of 60 seconds to ensure effective adhesion.

2.2.2 Radio tracking

A single fieldworker trialled two methods to monitor the three flocks that had lambs fitted with mortality tags over the course of the study.

2.2.2.1 Method RT1 (5th May – 13th June.)

Each flock was visited once per day to check for mortality signals and a visual check was undertaken on as many of the tagged animals as could be located within a 2 hour period. The day was split into four time periods (covering from dawn – dusk), which equated to the same time periods used to timetable the Visual Observation surveys (see section 2.3). Visits to each flock were rotated between the four time periods so that each flock was visited each time period once every four days. A schedule was developed so that visits by the radio tracker did not coincide with a Visual Observation survey on that croft.

2.2.2.2 Method RT2 (13th June – 13th August)

The following changes to the methods were incorporated into the radio tracking protocols:

- Number of radio tag checks per day:
  It was decided to increase the number of tag checks to three per day to ensure that any mortality signals were detected as soon as possible after they were activated.

- Daily visual observations of lambs:
  It was decided that the visual observations would no longer be carried out daily and would be undertaken as and when there was sufficient time available within the working day once the tag checks and any other higher priority work had been carried out.
- Timetabling of radio tracking visits:
  Tag checks were carried out across all periods of the day between dawn and dusk, this being achieved through a four day rolling schedule, devised so that visits did not coincide with a Visual Observation survey on that croft.

2.2.3 Field protocols

On each visit, all tag frequencies for that flock were scanned and tag signal status was recorded as follows:

- Active (signal indicating that tag was mobile in last two hours);
- Mortality (signal indicating that tag was immobile for more than two hours);
- Not found (tag signal not detected)

Full fieldwork protocols are included in Appendix 2

Once a full scan was completed, any tag frequencies giving off mortality signals were searched for until found. If attached to a dead lamb, field examination of the carcass was carried out following set protocols (see section 2.4). In addition, any lamb carcasses encountered or reported to the team whilst carrying out any work were to be processed in the same way.

Any tags giving off a mortality signal but not attached to a lamb were collected and subsequently prepared for re-attachment at a later date.

Whilst searching for tags emitting mortality signals, any frequencies not detected on the initial scan were also searched for. If no mortality signals were detected, tags identified as not found were searched for a maximum of two hours on each visit to that flock. If a tag was not detected for more than 48 hours, a wider search for the signal across the whole peninsula from vantage points and at known nest sites would be made.

2.3 Visual Monitoring

Systematic observation of several flocks (including those in the radio tracking study) took place from suitable vantage point (VP) locations throughout the study period, monitoring key bird species activity around ewes and lambs from pre-determined locations. The aim of the visual monitoring was to record any predation events and activity and behaviour of any avian predators seen during the VP. All vantage point locations are illustrated in Appendix 1 Figure A1.

All vantage point monitoring was conducted by field observers wearing muted natural colours and camouflaged in standard British Army Pattern DPM material. Vantage point locations were situated below the immediate skyline and where possible in natural cover (e.g. rock outcrops).

Vantage points were only conducted in weather that avoided poor visibility (< 3km at ground level) and heavy prolonged precipitation

2.3.1 Survey methods

For each registration the number, age, sex and flight time were recorded and flight lines were mapped for target species, namely white-tailed eagle, golden eagles

(*Aquila chrysaetos*), raven (*Corvus corax*) and greater black backed gull (*Larus marinus*). (All eagle records were aged to juvenile, immature, sub adult and adult, additionally wing tags and markings for each bird were recorded so that a pattern of movement could be established for individual birds).

Additionally, a predation score was allocated to each flight depending on the behaviour of the bird, as follows:
0 – High flying (above c 100m);
1 – Medium flying (between 20m – 100m);
2 - Low flying (below c 20m);
3 – Looking / Targeting (close observation of individual lambs, either in flight at any height or perched on a vantage point);
4 – Pursuit / Worrying (chasing / mobbing individual lambs);
5 – Scavenging (predator on or around carcass);
6 – Predation (taking of live individual).

Total counts were also recorded at regular intervals throughout each vantage point survey for all target species, plus hooded crow (*Corvus cornix*) and species from potential eagle prey species groups:
Lagomorphs (rabbits, hares);
Wader species;
Grouse;
Sea birds;
Geese;
Diver species

Various changes and refinements were made to the timings and methods of the recording protocols and these are detailed below.

2.3.1.1 Method VM1 (23rd April – 30th April)
Surveys were split between Melvaig, where the sheep had lambed on the open hill, and Cove and Sands, where lambing occurred in-bye. Two surveys were carried out each day, lasting three hours each, and were scheduled so that visits to each flock were rotated across six time periods (covering dawn – dusk) so that each flock had a visit in each time period once every six days.

2.3.1.2 Method VM2 (1st May – 19th May)
During this period, the duration of surveys changed to two hours. This meant that Visual Observation surveys at Melvaig, Cove and Sands could be covered in a single day. Additionally, the Sands flock were put out onto the open hill on the 16th May and at Cove the ewes and lambs known as the Hill flock were released onto the hill on the 15th May. The timing of the schedule was amended in order to avoid clashes with the radio tracking studies, but still covered the period from dawn to dusk.

2.3.1.3 Method VM 3 (20th May – 13th August)
During this period, the last of the study flocks, known as Cove home, went out onto the open hill on the 3rd June. In addition, following reports of increased eagle activity from crofters and local residents, a fifth location, Strath, was added to the Vantage Point survey schedule on the 3rd June, bringing the total number of study sites to five.

With all study flocks now out on the hill the duration of surveys changed back to 3-hours, and visits reverted to two sites each day, as it was felt this reduced disturbance and minimised travelling time between surveys. The timings of the schedule was again amended in order to avoid clashes with the radio tracking studies, but still covered the period from dawn to dusk.

Following the steering group meeting of the 16th July, the use of locations at Strath and original VP at Melvaig were discontinued in favour of a new location centred around the single radio mast south of Melvaig (with northerly view bearing) to monitor activity as a result of reported losses to flocks in this area. In addition, the two flocks at Cove, (home and hill) were treated as one study group, with scheduled visits alternating between the two flocks.

Example fieldwork protocols are included in Appendix 2 and vantage point locations are illustrated in Figure A1 Appendix 1

2.3.2 Radio tracking

When carrying out Visual Observation surveys at Sands and Cove Hill and Cove Home flocks, the observer scanned across all of the tag frequencies before the start of the survey period and every hour during each survey. As with the radio tracking study, tag signal status during each scan was recorded as follows:

- Active (signal indicating that tag was mobile in last two hours);
- Mortality (signal indicating that tag was immobile for more than two hours);
- Not found (tag signal not detected)

If the signals for frequencies indicated all tags were attached to live lambs, or there were one or more frequencies that were not detected the observer continued with the observation survey.

If a mortality signal was detected, and once all frequencies had been scanned, the visual observation survey was suspended and the individual carrying out the radio tracking studies for that day was contacted immediately. The observer then located the tag to ensure that the carcass remained undisturbed, and to provide a grid reference and directions for the radio tracker.

2.4 Lamb Casualty Examination and Evaluation

2.4.1 Carcass examination in the field

Any dead lamb reported or detected in the three study crofts was located and examined. The area around the carcass and the carcass itself was examined for evidence, which may point to ante or post- mortem wounds and the cause of death. During these examinations, eagle predation was only recorded as the cause of death if the examiner was absolutely sure.

2.4.2 Post mortem examination of carcass

Initially, due to practicalities of storage and transporting dead lambs, the carcasses collected for post-mortem were frozen and sent to a FERA vet for examination. The examination looked for:

- presence and location of any talon/beak injuries
- body condition e.g. body fat deposits at the time of death
- tick burden
- tick pyaemia, abscesses in joints etc.

As the carcasses were frozen, post mortem was limited in terms of distinguishing haemorrhage associated with puncture wounds from autolytic changes or freezing artefacts. Freezing the carcasses also means no histological or bacteriological tests were carried out.

From the 6th July, any carcasses recovered from the study crofts or carcasses displaying clear signs of predation from other crofts would be sent for fresh post

mortem examination. Examinations were arranged with Veterinary Labs of the Scottish Agricultural College in Inverness, provided the carcass was less that 12 to 15 hours old by the time it arrived at the lab.

2.5 Croft Management and Lamb Biometrics

Information on croft management, mammalian predator control, animal husbandry and data on ewe and lamb condition was collected for the three initial study areas: Melvaig, Sands and Cove Crofts. In addition, further flock information was made available from a number of other crofts within the study area.

2.5.1 Lamb biometric data

During the initial tagging in May and when lambs were brought in bye again at the end of June and beginning of July those lambs being tagged were weighed and the hind foot length and fleece staple length measured. These measurements were taken in order to enable analysis of general lamb condition in relation to mortality.

2.5.2 Ewe condition monitoring

Condition scoring, as described by the Scottish Agricultural College (SAC) is a method used to maintain ewes in adequate body condition, and ensures that they have sufficient body reserves to survive the winter, that they can cope with the demands of pregnancy and can manage when there may be periods of inadequate grazing.

Ewes in poor condition at lambing time (below condition score 2) are more likely to have difficulty delivering their lambs through exhaustion, show impaired maternal behaviour and have reduced production of colostrum and milk. In addition, their lambs are more likely to be light and weak at birth and slow to stand and suckle. In turn these effects mean that lambs are likely to get less passive immunity and may be more likely to succumb to infectious diseases, and are less likely to survive to weaning.

2.5.3 Fox surveys

While radio tracking and walking to and from vantage point or radio tracking scan locations details were recorded of any signs of fox (*Vulpes vulpes*) activity. The members of the Gairloch Fox Club were contacted for information regarding fox densities and sites of fox dens. The Fox Club had not found any active dens or seen any other signs of fox activity at either croft this year. Usual locations of fox dens were obtained from the Fox Club and additional surveys for active fox dens were carried out within the Cove croft area. While numerous potential den sites were seen, no active dens were located and no other signs of fox activity were detected during these surveys.

On the West side of the peninsula the Fox Club normally sees around four or five active den sites in a year between Strath and the lighthouse at Melvaig, with the population levels of foxes being fairly constant for at least the last 10 years. Fox den locations in this area are very transient and dens are usually just in hags or rough ground. Based on the information from the Fox Club and limited staff time, intensive fox surveys were not undertaken over the western side of the peninsula and preliminary surveys at Sands indicated no active den locations.

3 RESULTS

3.1 Radio Tracking

3.1.1 Tag attachment

Days on which tag attachment took place are presented in Table 1. Tags were originally attached on the 5th May (Cove Hill), 7th May (Cove Home) and 14th and 15th May (Sands). However, a large number of tags were recovered that had become detached from the lambs and therefore several re attachment sessions took place.

The lambs at Sands were brought back in-bye during the day on the 25th June to be weighed as part of the Signet scheme. Ten lambs with tags still attached had the tags removed and reattached after clipping and cleaning the fleece. Two further tags were also reattached to lambs that had previously shed them.

Additionally, the lambs at Cove (both the Home and the Hill flock) were brought back in-bye within the week commencing 6th July. All tags that were still on lambs were removed, and on the 10th July tags were re attached to all available previously tagged lambs with 43 tags being reattached in total.

Table 1. Tag attachment history

	Number of tags attached		
Date	**Cove Home**	**Cove Hill**	**Sands**
5/5/2009		15	
7/5/2009	14	3	
11/5/2009	10	6	
14/5/2009			8
15/5/2009			19
19/5/2009	14	3	
22/5/2009	1	4	
28/5/2009		8	
25/6/2009			12
9/7/2009	18	26	
15/7/2009			6
Total	**57**	**65**	**45**

In total, 167 tag attachments were carried out across the three flocks, and of these, approximately 60% subsequently fell off (Table 3). The shortest period of time that a tag remained attached to a lamb before falling off was one day, whilst the longest lasted for 73 days. By the end of the project (13th August 2009), 41 tags remained attached to lambs. Of the two tag attachment methods, method TA2 improved the rate at which tags remained attached to lambs (from 4.5% to 52.5%) (Table 2).

Table 2. Tag attachment performance by attachment method

	% of tags that fell off	% of tags removed	% of tags still attached on 13th August 2009
Method TA1	95.5	4.5	0.0
Method TA2	47.6	37.7	14.7

Table 3. Tag attachment performance

	Total number attached	Total number detached (%)	Min – Max length attached (days)	Total number removed for re attachment (%)	Min – Max length attached (days)	Total number remaining attached**	Min – Max length attached (days)
Cove Home *	57	32 (56)	1 – 48	7 (12)	46 – 62	16	33 – 35
Cove Hill	65	34 (52)	1 – 47	10 (15)	39 – 47	21	33 – 35
Sands	45	35 (78)	1 – 73	6 (13)	41 – 41	4	29 – 49
All sites	**167**	**101 (60)**	**1 – 73**	**23 (14)**	**39 – 62**	**41 (25)**	**29 – 49**

* 1 found on dead lamb in bog / 1 unaccounted for
** tags still attached on 13th August 2209

The number of tags attached to lambs and available for radio tracking varied regularly as a result of the rate that tags fell off and were re-attached (as illustrated in Figure 4).

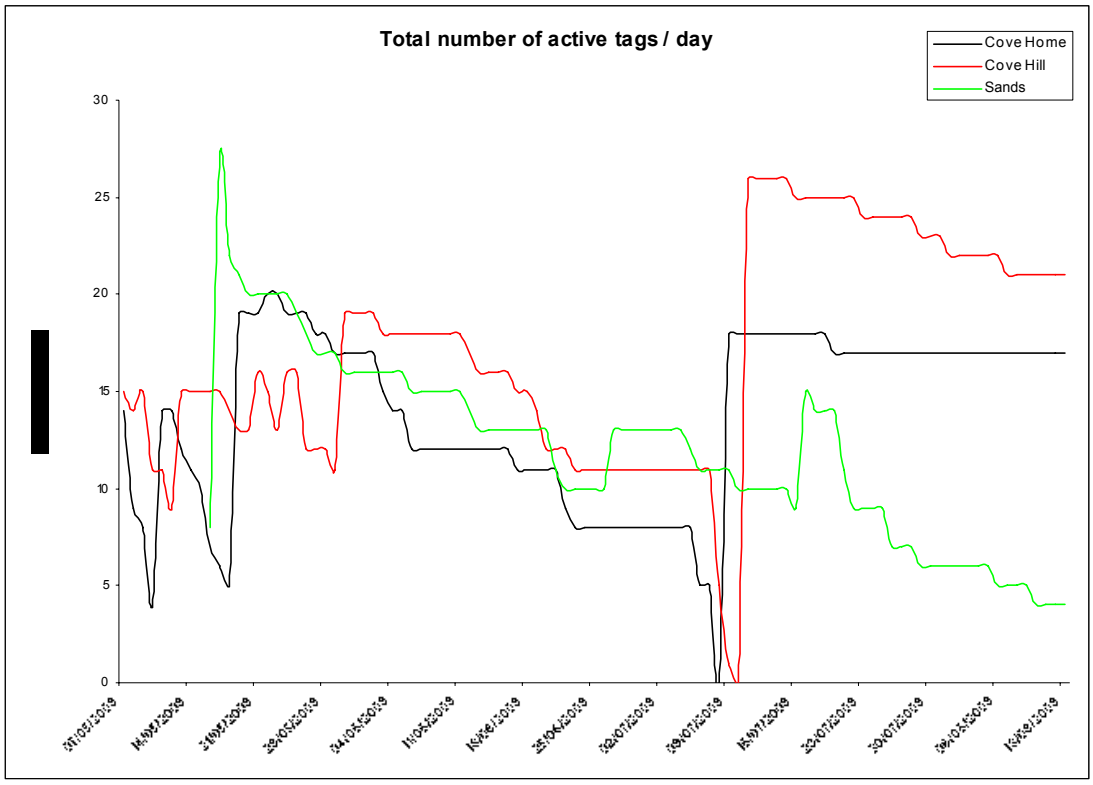

Figure 4: Total number of active tags over the study period

Across all three flocks, the greatest number of active tags at any one time was 58, although this was for one day only. The lowest number, 10, was also over a single day. Across all three flocks, 70 – 100% of all tags were active and available for radio tracking for 64% of the study period.

3.1.2 Radio tracking

Radio tracking start dates and duration of fieldwork are shown in Table 4. The average rate for tags detected per day during the study period was 99.93% (Cove Home 100%; Cove Hill 99.86%; Sands 99.91%). Two tags failed in the field and were, therefore, unable to be recovered. In both cases the lambs that had been tagged were observed without their tags within 24 hours of the signals failing.

Table 4. Radio tracking start / finish dates

	Croft			
	Cove Home	Cove Hill	Sands	Overall
Start date	8/5/2009	5/5/2009	15/5/2009	5/5/2009
Finish date	13/8/2009	13/8/2009	13/8/2009	13/8/2009
Total number days radio tracking	96	98	89	100

One of the main purposes of this study was to establish whether lambs could be located, especially when dead, within a short time of actual death. While only one lamb died, the frequency with which tags fell off live lambs enabled some quantification of the ability to locate the tags. Tags were recovered on all 83 occasions on which mortality signals were detected. While data were not systematically recorded on the length of time between detection of a mortality signal and recovery of the tag (or in one case lamb), anecdotally, in the majority of cases tags were found within 30 minutes to an hour. Therefore, use of radio tags with mortality sensors would be a suitable method of quickly finding lamb carcasses.

3.2 Vantage Point Monitoring

In total 224 vantage points were undertaken amounting to 599.1 hours of systematic observation (locations and associated viewsheds used for further site by site analysis are shown in Figure 5)

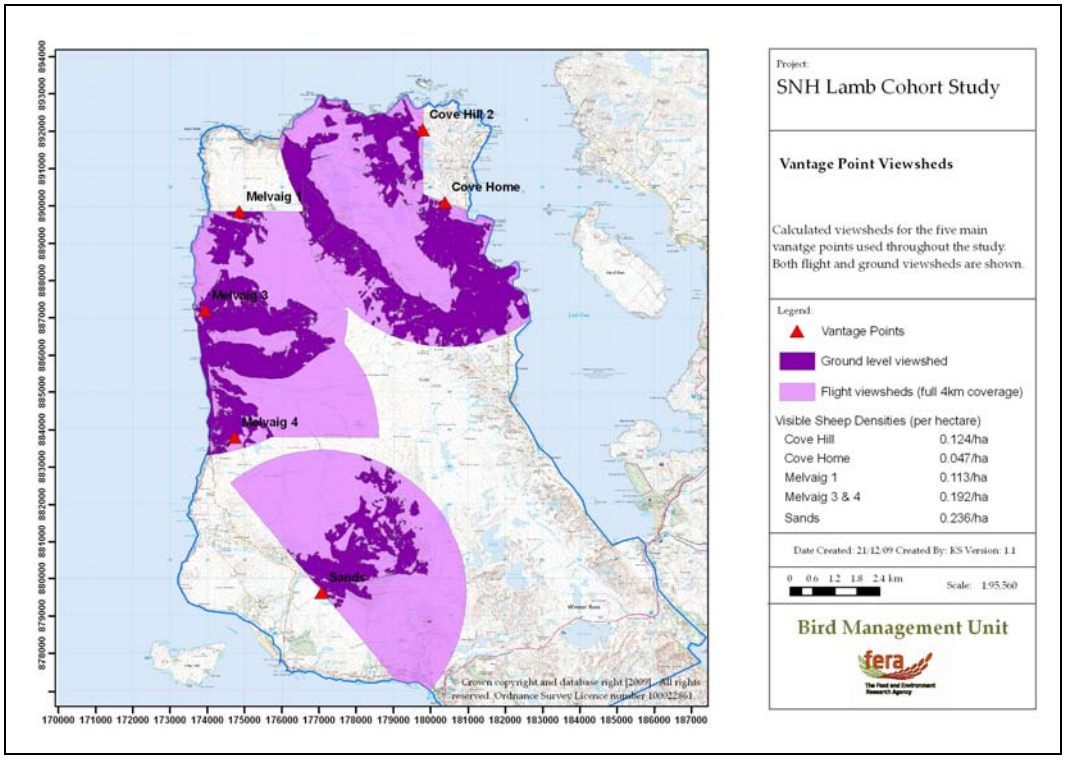

Figure 5: Vantage Point viewsheds used in further analysis.

Vantage point coverage for each of the study areas and associated changes in methodology are further broken down in Table 5 in terms of actual visits and Table 6 as observational hours. Figure 6 illustrates the spread of vantage point coverage over the daylight hours.

Table 5: Vantage Point Visits: divided into study areas and observational methods

Method	Cove Inbye	Cove Home	Cove Hill	Croft Sands Inbye	Sands	Strath	Melvaig
VM 1 23rd April-30th April	5			5			4
VM 2 1st May–19th May	13		4	14	3		17
VM 3 20th May-13th Aug		30	29		39	8	53
Total	18	30	33	19	42	8	74

Table 6: Vantage Point Hours: divided into study areas and observational methods

Method	Cove in bye	Cove Home	Cove Hill	Croft Sands in bye	Sands	Strath	Melvaig
VM1 23rd April – 30th April	15			14.5			12
VM 2 1st May – 19th May	26		8	28	6		34
VM 3 20th May – 13th Aug		89	86.25		118.5	16	145.85
Total	41	89	94.25	42.5	124.5	16	191.85

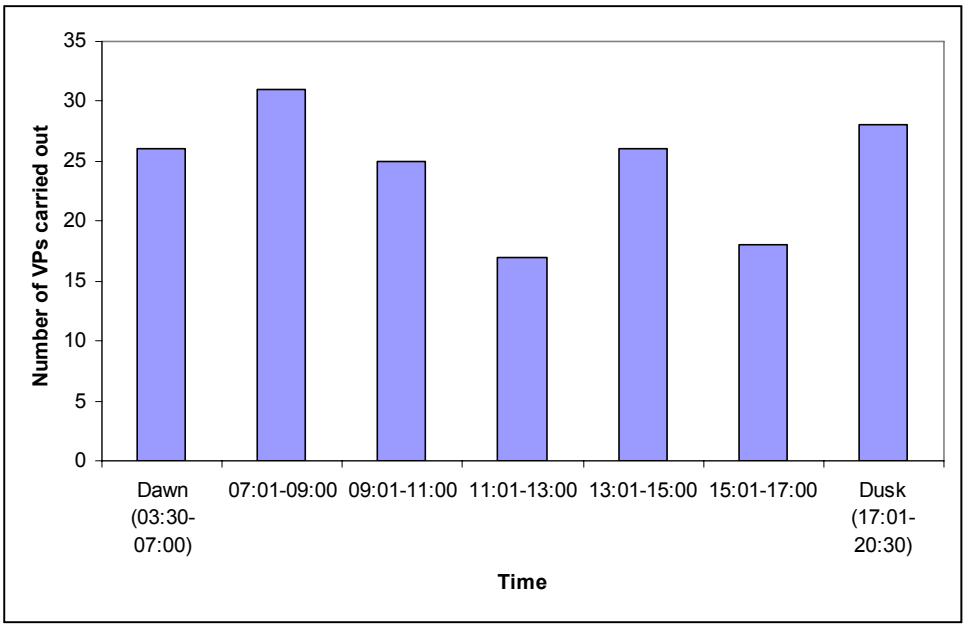

Figure 6: Vantage Point coverage during daylight hours.
(VPs assigned to time based on VP start time. Only includes VPs for Cove Home, Cove Hill, Melvaig 1, Melvaig 3 & 4 and Sands).

3.2.1 Key species overview

Flight lines recorded from field observations are illustrated in Appendix 1: Figure A2-White-tailed eagle; Figure A3-Golden eagle; Figure A4-Raven and Figure A5-Greater black-backed gull.

The cumulative flight time (uncorrected for land parcel area or vantage point viewshed area) for each of the 4 key target species is detailed for each study croft in Table 7. White-tailed eagles were recorded in all of the hill areas but in neither Cove nor Sands in bye, highest levels of flight activity were recorded at Cove Hill (50 minutes 59 seconds in 94 hours 15 minutes of observations) with lesser levels at Sands (28minutes 40 seconds in 124 hours 30 minutes of observations) and Melvaig (32 minutes 50 seconds in 191 hours 51 minutes).

Table 7: Observed flight activity for four key target species in hours, minutes and seconds

Species	Croft						
	Cove Inbye	Cove Home	Cove Hill	Sands Inbye	Sands	Strath	Melvaig
White-tailed eagle	0	3m 45 s	50m 59s	0	28m 40s	0	32m 50s
Golden eagle	0	4m 43s	0	0	0	0	0
Greater black backed gull	10m 5s	13m 52s	6h 11m 14s	21m 30s	47m 5s	3m 44s	58m 35s
Raven	12m 58s	7m 34s	14m 36s	3m 22s	3h 52m 6s	2m 6s	4h 16m 40s

3.2.2 Sheep Densities

Observed sheep densities recorded during VP observations ranged from 0.047/ha at Cove Home to 0.236/ha at Sands (Figure 7).

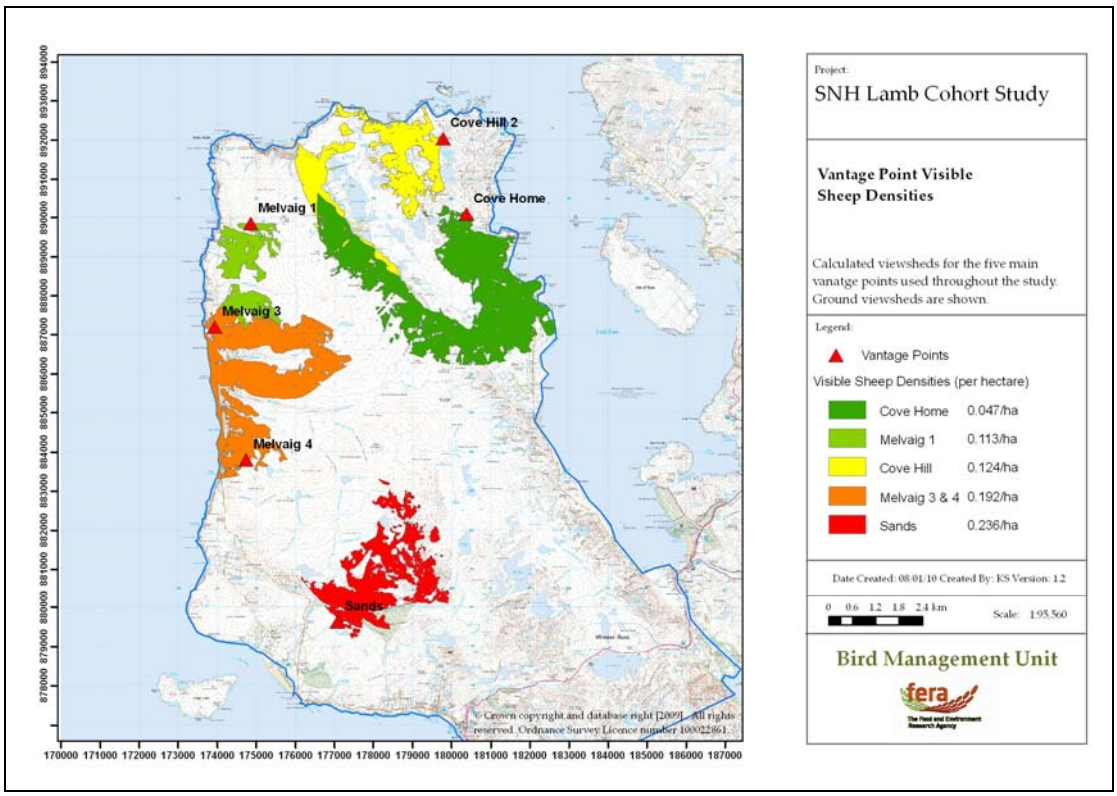

Figure 7: Sheep densities recorded during VP surveys.

3.2.3 White-tailed Eagle Activity

White-tailed eagle activity was recorded for less than 2% of total VP observation time, with the greatest level, 0.87%, observed across the Cove Hill area (Table 8). Lowest levels of observed activity were recorded across the adjacent Cove Home area. Figure 8 displays this activity as bird flight seconds per hectare per hour.

Table 8. Activity of white-tailed eagles separated by age and observation site. Activity is recorded as percentage of time flying of total observation time.

	Age of Birds Observed						
Site	**Adults**	**Adult and Juveniles**	**Adults and Immatures**	**Juveniles**	**Immatures**	**Unknown**	**Total**
Cove Hill	0.87						**0.87**
Cove Home	0.07						**0.07**
Melvaig 1	0.14						**0.14**
Melvaig 3 & 4	0.46			0.04			**0.50**
Sands	0.37					0.01	**0.38**
Total	**1.91**	**0.00**	**0.00**	**0.04**	**0.00**	**0.01**	**1.96**

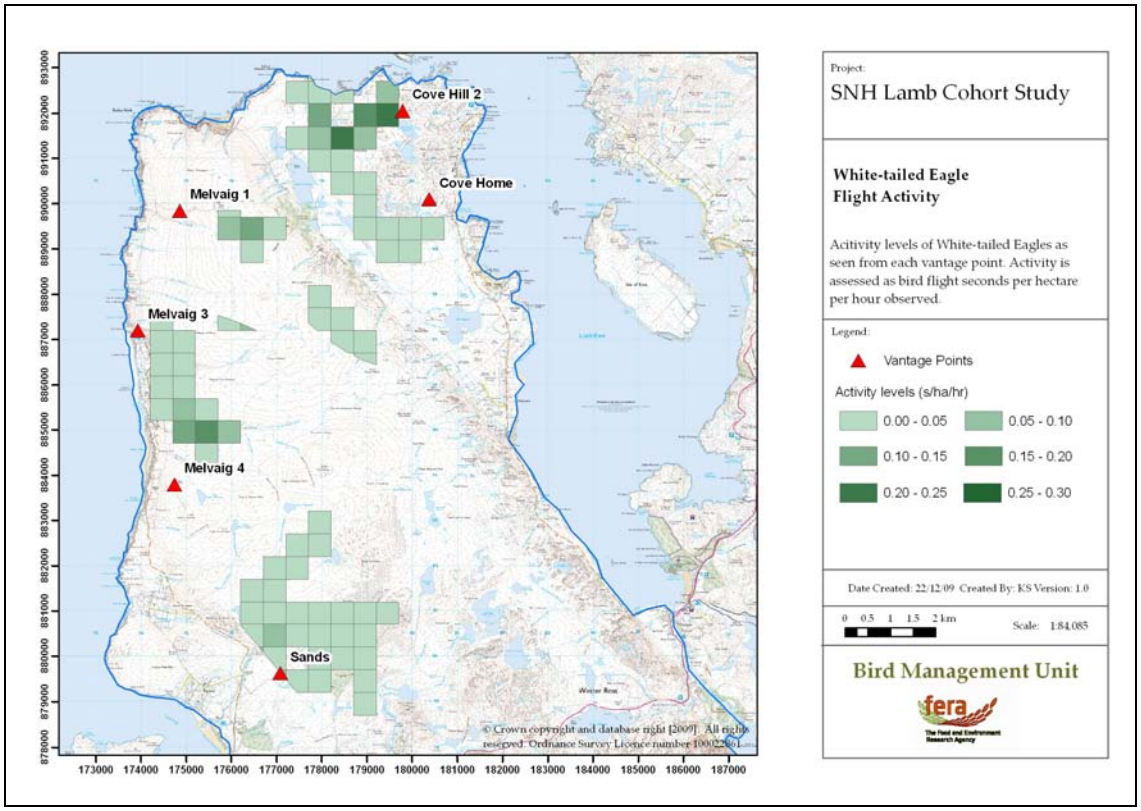

Figure 8: White-tailed eagle standardised activity levels (flight seconds per hour of observation).

3.2.4 Other Target Species

Activity of other target species were recorded for over 45% of total VP observation time, with the greatest level recorded across the Cove Hill area (Table 9). Lowest levels of activity were again recorded across the adjacent Cove Home area.

Golden eagles were only observed at Cove Home, contributing 0.09% of the total VP observation time. Greater black-backed gulls were recorded across all areas, although the greatest amount of activity was observed across the Cove Hill area. Raven were also recorded across all areas, with the greatest level of activity observed across the Melvaig area.

Figures 9, 10 and 11 display these activity levels as bird flight seconds per hectare per hour, to enable standardised comparison of species and sites.

Table 9. Activity of other target species (golden eagle, raven and greater black-backed gull) separated by site. Activity is recorded as percentage of time flying of total observation time.

Site	Golden eagle	Greater black-backed gull	Raven	**Total**
Cove Hill		22.57	0.36	**22.92**
Cove Home	0.09	0.23	0.24	**0.56**
Melvaig 1		0.43	14.35	**14.78**
Melvaig 3 & 4		0.61	1.33	**1.93**
Sands		0.85	4.26	**5.11**
Total	**0.09**	**24.69**	**20.53**	**45.31**

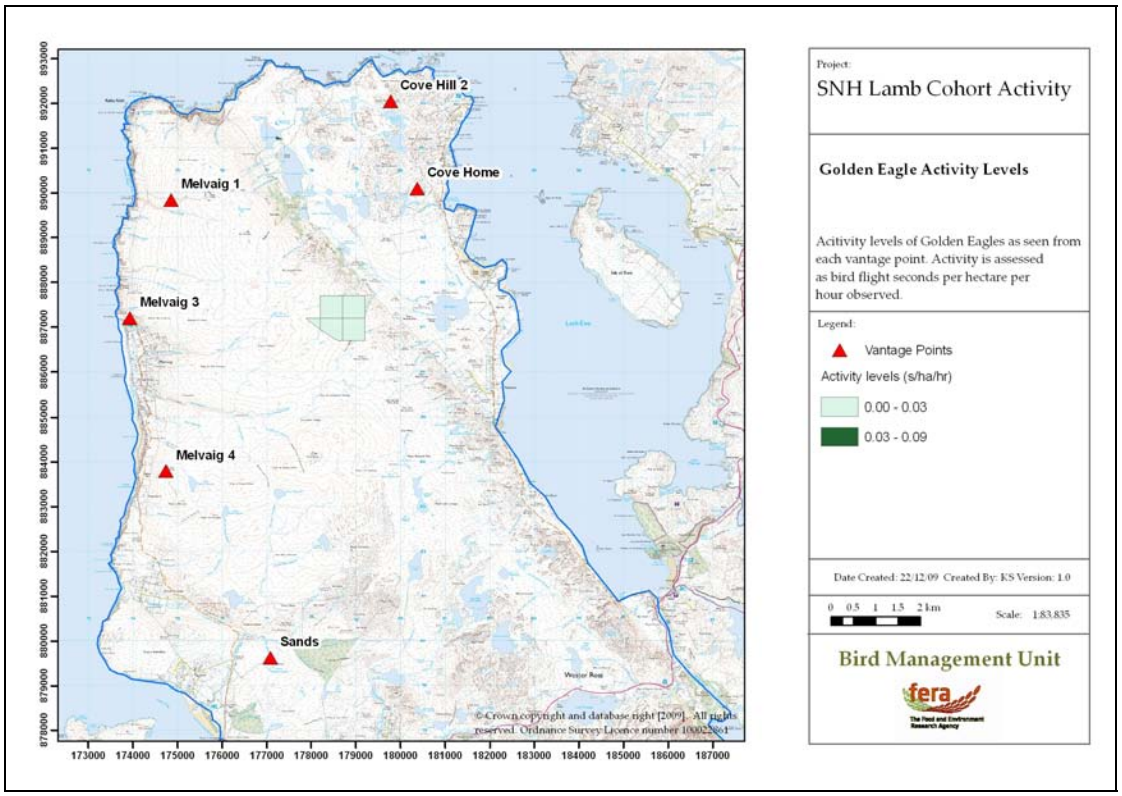

Figure 9: Golden eagle standardised activity levels (flight seconds per hour of observation)

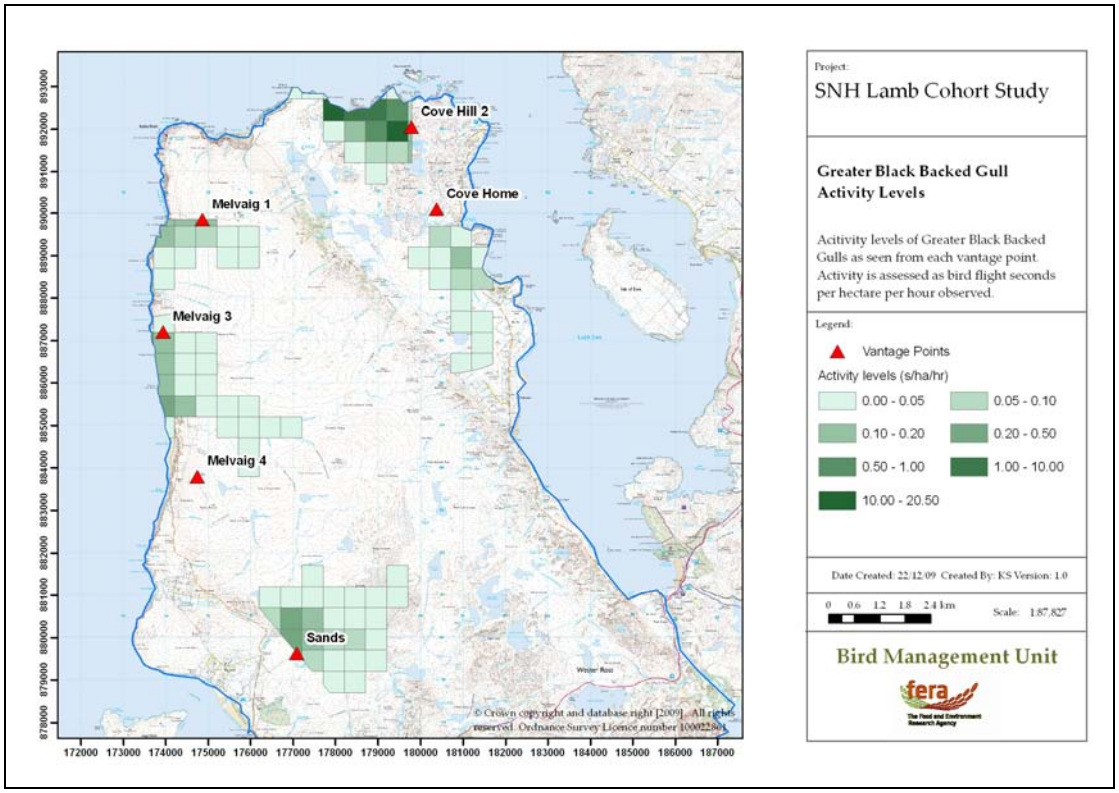

Figure 10: Greater black-backed gull standardised activity levels (flight seconds per hour of observation)

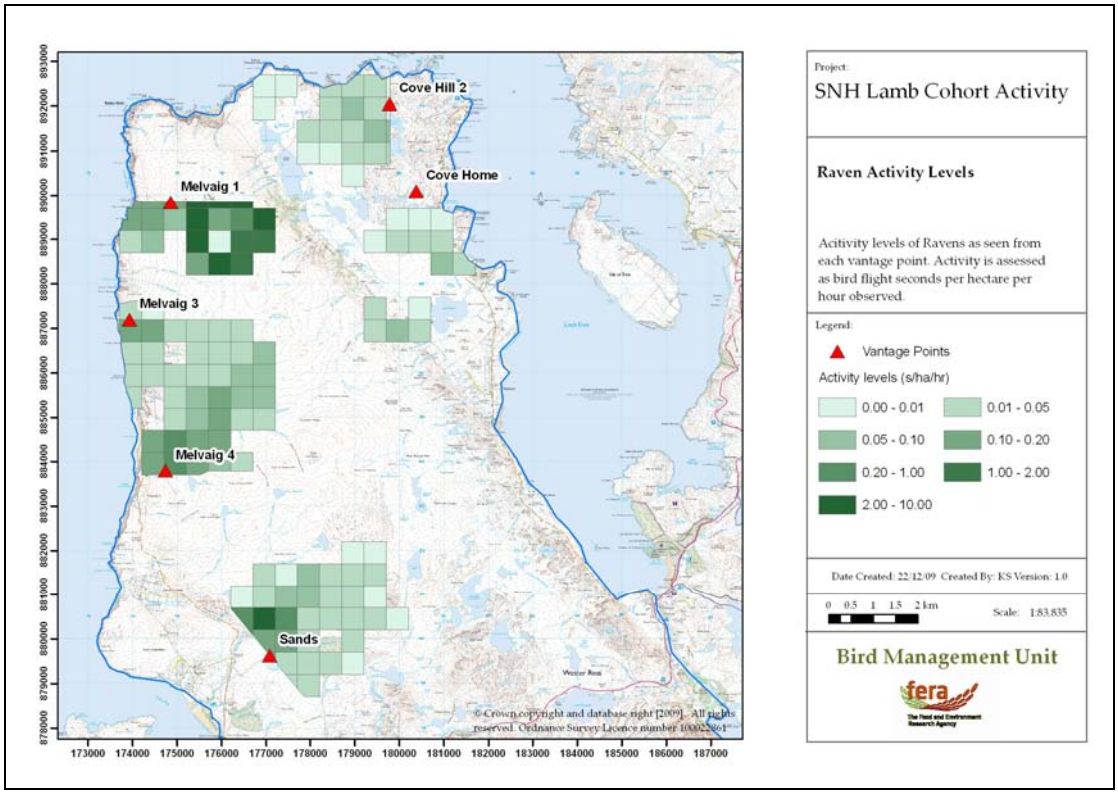

Figure 11: Raven standardised activity levels (flight seconds per hour of observation)

3.2.5 White-tailed eagle predation activity

No instances of actual predation were recorded, whilst scavenging of existing carcasses took place three times (0.03% of total observation time). Birds were seen observing individual lambs twice (0.06% of total observation time). The greatest proportion of White-tailed Eagle activity falls within the non-predatory behaviour classes of high, medium or low flying (Tables 10 & 11).

Adults accounted for 41 recorded flights, with only 2 juvenile flight records.

Table 10. Activity of White-tailed Eagles separated by age and predation score. Activity is recorded as percentage of time flying of total observation time.

	Age of Birds Observed						
Predation Score	**Adults**	**Adult and Juveniles**	**Adults and Immatures**	**Juveniles**	**Immatures**	**Unknown**	**Total**
0	0.20						**0.20**
1	0.87			0.04		0.01	**0.92**
2	0.75						**0.75**
3	0.06						**0.06**
4							**0.00**
5	0.03						**0.03**
Total	**1.91**	**0.00**	**0.00**	**0.04**	**0.00**	**0.01**	**1.96**

Table 11. Number of White-tailed Eagle flights recorded, segregated by predation score and age

	Age of Birds Observed				
Predation Score	**Adults**	**Juveniles**	**Immatures**	**Unknown**	**Total**
0	2				**2**
1	4	1		1	**6**
2	29	1			**30**
3	2				**2**
5	3				**3**
Unknown	1				**1**
Total	**41**	**2**	**0**	**1**	**44**

3.2.6 Other target species activity by predation score

No predation events were recorded from the other three target species (Table 12). Scavenging by adult Greater Black-backed Gull was observed three times, or 0.01% of total observation time (Tables 12 & 13).

Adult Ravens were observed mobbing individual lambs on four different occasions, equivalent to 0.04% of total observation time (Tables 12 & 14).

Greater Black-backed Gulls were seen observing individual lambs twice.

A total of just two Golden Eagle flights were recorded, falling into the non predatory behaviour class of medium height flying (Tables 12 & 15).

Table 12. Activity of other target species separated by predation score. Activity is recorded as percentage of time flying of total observation time.

	Species			
Predation Score	**Golden Eagle**	**Greater Black-backed Gull**	**Raven**	**Total**
0		7.74	13.87	**21.61**
1	0.09	15.47	2.11	**17.67**
2		1.46	4.51	**5.97**
3		0.02		**0.02**
4			0.04	**0.04**
5		0.01		**0.01**
Total	**0.09**	**24.69**	**20.53**	**45.31**

Table 13. Number of Great Black-Backed Gull flights recorded, segregated by predation score and age.

	Age of Birds Observed			
Predation Score	**Adults**	**Adults and Immatures**	**Immatures**	**Unknown**
0	14			
1	47	14	9	3
2	44		5	1
3	2			
5	3			
Unknown	17		1	
Total	127	14	5	4

Table 14. Number of Raven flights recorded, segregated by age and predation score.

	Age of Birds Observed			
Predation Score	**Adults**	**Juveniles**	**Unknown**	**Total**
0	9			**9**
1	59	6	19	**84**
2	61	14	37	**112**
4	4			**4**
Unknown	2	2	2	**6**
Total	**135**	**22**	**58**	**215**

Table 15. Number of Golden Eagle flights recorded, segregated by predation score and age.

	Age of Birds Observed						
Predation Score	**Adults**	**Adult and Juveniles**	**Adults and Immatures**	**Juveniles**	**Immatures**	**Unknown**	**Total**
0							**0**
1	2						**2**
2							**0**
3							**0**
4							**0**
Unknown							**0**
Total	**2**	**0**	**0**	**0**	**0**	**0**	**2**

3.2.7 Distribution of additional target species

Further information on the wider avian community within the study areas was recorded during vantage point watches and key species were classified into general groups, for all sites large gulls (including skuas) were the most numerous group. Large gulls, waders, crows and, to a lesser extent, waterfowl accounted for the highest activity levels across all sites (Figure 12). Further site-by-site breakdown of activity levels are included in tabulated and graphical form in Appendix 4 section 4.4.

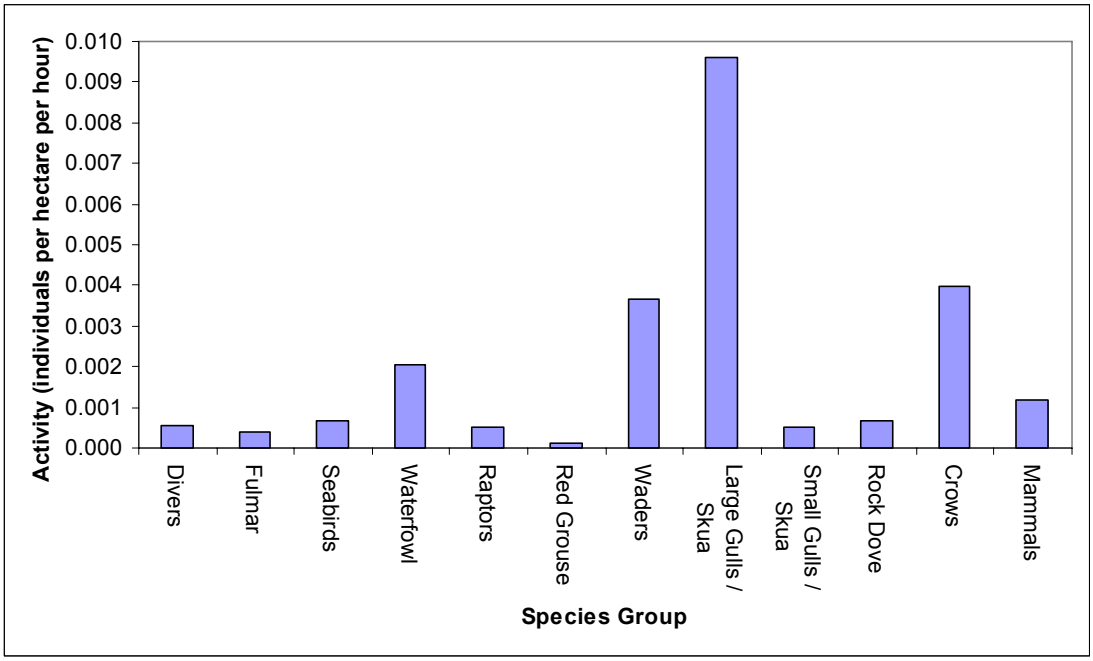

Figure 12: Total number of individuals seen per hectare per hour of observation within specific species groups for all sites.

For all species, crows were the predominant group at Cove Home and Melvaig 3 & 4, whereas large gulls/skuas were recorded in highest densities at Cove Hill and Melvaig 1.

Cove hill held the highest densities of large gulls, waders and waterfowl

The 12 species groups are amalgamated into either prey (for white-tailed eagle) or predator/scavenger (for lambs) species. Standardised prey species activity levels are highest at Cove Hill followed by Sands with lowest levels at Cove Home and Melvaig respectively (Figure 13).

Cove Hill, and to a lesser extent Cove Home, also held the highest densities of predator/scavenger species, with the lowest densities recorded at Sands and Melvaig 1 (Figure 14)

Within the study areas Cove Hill held the highest numbers of combined possible prey species and additional predator species, these levels need to be considered solely as indicators for site comparability and not in terms of overall distribution throughout the peninsular wide area. Local white-tailed eagles would be expected to forage over the

whole of the local area and would obtain significant amounts of food outwith the study areas.

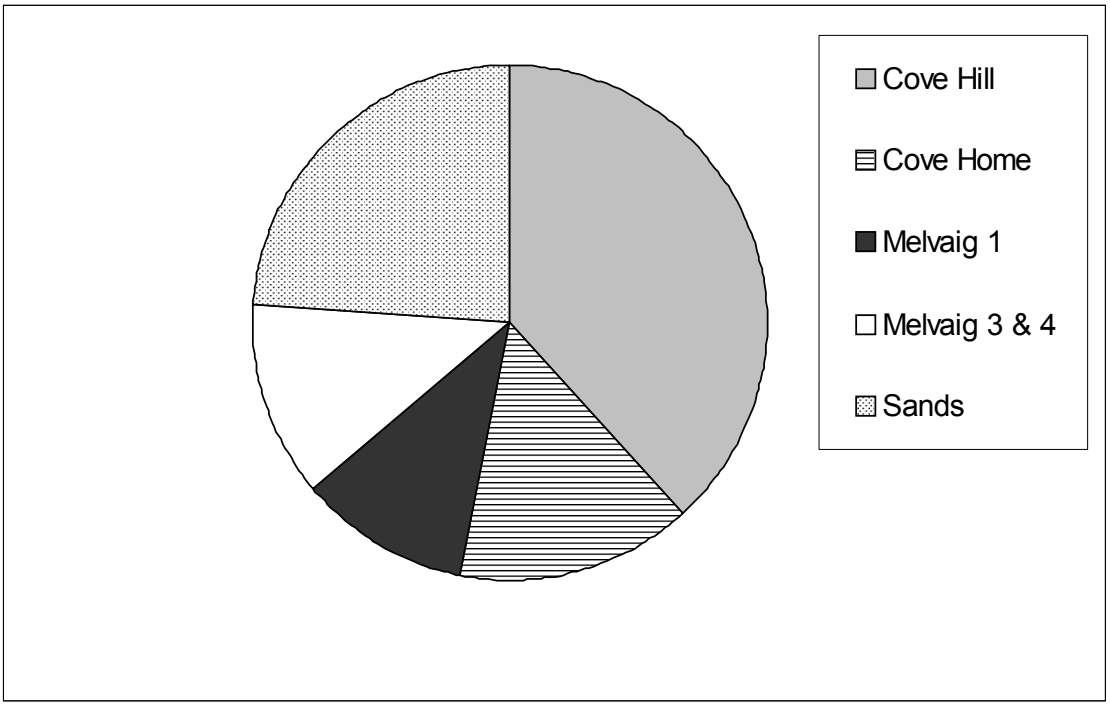

Figure 13: Relative percentage of the total number of prey species seen per hectare per hour per site

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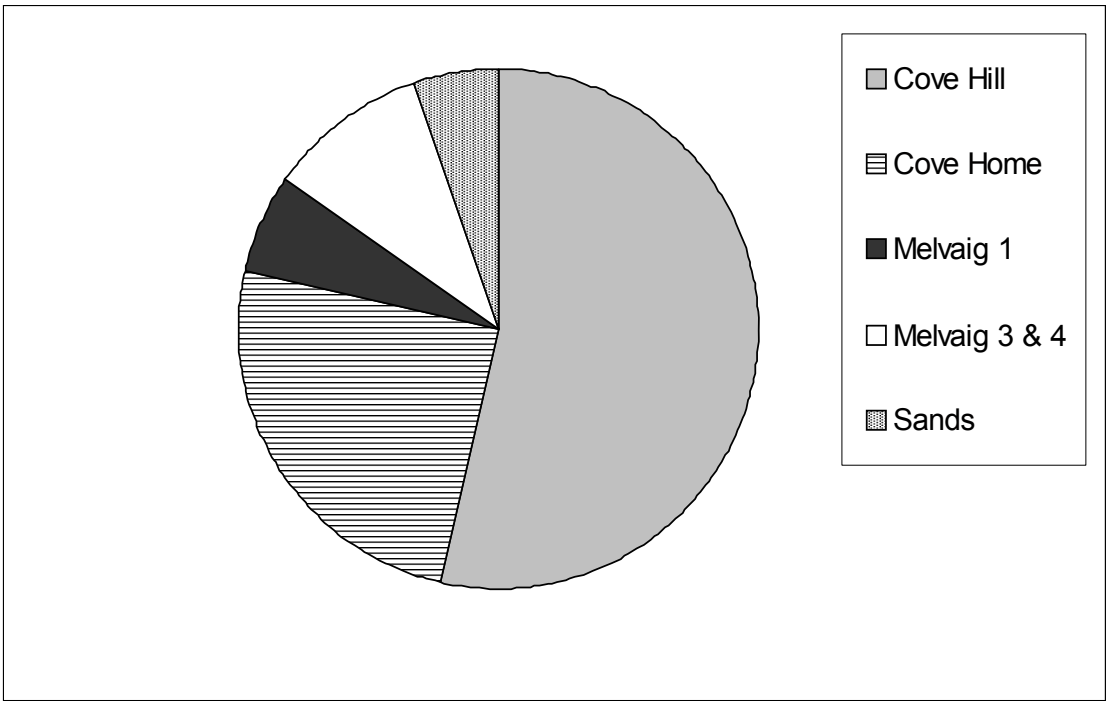

Figure 14: Relative percentage of the total number of additional predator species seen per hectare per hour per site

3.2.8 Further statistical analysis

All statistical analyses were carried out in SPSS 15.0 for Windows®. Activity rates were calculated as seconds of activity per hour of observation per hectare observed and summed across the study sites for each day. Tag detachments were taken to be the number of tags detached per day. The majority of the weather data came from field observations. However, Maximum air temperature, minimum air temperature, minimum grass temperature and rainfall data, came from Inverewe Gardens (National Trust for Scotland) meteorological recording station.

The 'Kolmogorov-Smirnov' test was used to test the data's conformation to the normal distribution. All tests for species activity and tag detachments showed the data was not normally distributed (Table 4.2.1 & 4.2.2). The data could not be transformed to meet the normal distribution (i.e. meet the requirements of parametric tests) and therefore, non-parametric 'Spearman's Rank' correlations were used to test the association of recorded variables.

Two groups of variables were tested:

i) 'Test' variables (tag detachment rates [for methods 1 and 2], White-tailed Eagle & Raven activity levels)

ii) Weather variables (including temperature, rainfall, wind speed, cloud cover and visibility). The results of the correlations, associated tables and statistically significant correlation graphs are included in Appendix 4.

Statistically significant correlations were found between the following variables:

- Significant positive correlation between White-tailed Eagle and Raven flight activity
- Significant negative correlation between tag detachment (using method 1 attachment) and maximum air temperature
- Significant positive correlation between White-tailed Eagle flight activity and minimum grass temperature.
- White-tailed Eagle activity was also significantly correlated with maximum and minimum air temperatures
- Significant positive correlation between Raven flight activity and minimum grass temperature.
- Raven activity was also significantly correlated with minimum air temperature
- Significant positive correlation between Raven flight activity and rainfall

3.3 Livestock Management

3.3.1 Key Study Crofts

Detailed records were obtained for Sands and Cove Crofts and to a lesser extent Melvaig. Full details are included within Appendix 6, the Confidential Annex.

3.3.2 Peninsula wide area

A telephone survey was undertaken of the other crofters in the wider area regarding their husbandry and lamb losses this year (results are tabulated in the Confidential Annex, Appendix 6, Table 1). Although further information regarding flock numbers and losses throughout the study period was requested by the Steering Group, results were not available for inclusion within this report.

3.3.3 Ewe condition scoring

Condition scoring was carried out on both the Cove flocks, including both Home and Hill flocks, and Sands crofts on the 9th April by the Auctioneer from the Dingwall Agricultural Mart. A summary of the scores for the whole flock and for those ewes whose lambs were radio-tagged are given in Tables 16 and 17.

Table 16: Number of sheep in each flock with condition score for the whole flocks.

		Condition score								
Croft	N	0.5	1	1.5	2	2.5	3	3.5	4	4.5
Cove	166	0	5	18	48	42	36	12	4	3
Sands	158	0	5	38	52	41	21	1	0	0

Table 17: Number of sheep in each flock with condition score for those with radio tagged lambs.

		Condition score								
Croft	N	0.5	1	1.5	2	2.5	3	3.5	4	4.5
Cove Hill	38	0	0	2	8	20	5	3	0	0
Cove Home	15	0	0	0	5	4	5	0	1	0
Sands	20	0	0	5	6	7	2	0	0	0

Data not available for 2 ewes at Cove Hill, 5 at Cove Home & 8 at Sands

3.3.4 Livestock losses

3.3.4.1 Cove Croft

Of the 100 or so lambs put out onto the hill there have only been two known losses this year. The crofter mentioned that there had been no incidence of yellowses (photosensitization due to liver damage associated with eating toxic plants) this year, which usually badly affects 3 or 4 lambs per year. No lambs kept in-bye died since lambing finished.

3.3.4.2 Sands Croft

Of the 160 lambs put out on the hill only two lamb losses were recorded up to the end of the study period. Neither of these was thought, by the crofter, to have been predated upon. Of the hogs only four were missing, one of which is known to have died, the crofter considered this to be a normal level of loss for the hogs.

3.3.4.3 Melvaig area

As the lambs are born on the hill there is no accurate record of the number of lambs born or those stillborn or died within the first few hours. It is thought that the majority of the 300 ewes were pregnant in March, but as they were not scanned it is not known how many had had twins. The crofter stated that some of his lambs were gradually disappearing, especially in the area between his sheep pens and the TV tower road in Melvaig. He also states that it is the younger lambs that were disappearing, but he was not seeing any dead lambs, “they just go missing”. He did think that he had lost fewer lambs than last year.

3.3.4.4 Peninsula wide area

A telephone survey was undertaken of the other crofters in the wider area regarding their lamb losses this year (results are tabulated in Appendix 6, the confidential annex). The crofters who lost the most lambs were in the Melvaig area of the peninsula, mainly between Melvaig village and the lighthouse. However, all crofters reported fewer lamb losses this year than in the previous two years.

3.4 Post Mortem Examination

Six dead lambs were collected and sent for post mortem examination; additionally two signs of eagle scavenging were recorded (dense blanket areas of plucked wool), although no carcasses were located and a single very old ewe carcass was also recoded but not returned for post mortem. Of the six sent for post mortem, two were observed being scavenged upon by sea eagles, one is thought to have been a road traffic accident and the others appeared to have died from other causes with extensive scavenging damage. The locations of all collected carcasses are illustrated in Appendix 1 Figure A6.

Post mortem examination identified one carcass with cranial damage deemed to relate to eagle predation.

3.4.1 Post mortem summary findings

3.4.1.1 Lamb carcass recovered on 11th May 2009

This lamb carcass was passed on to FERA staff by a crofter in the Strath area of Gairloch Peninsula and frozen on day of death. This extensively scavenged lamb carcass was in poor body condition although it had suckled recently. There were several skin punctures over the head with deep penetration of two of the punctures through the skull and blood in the fleece over the head and neck. There were multiple punctures over the dorsal and lateral neck with deep penetration into underlying soft tissues. There was extensive haemorrhage, oedema and soft tissue and skeletal tissue trauma of the head and neck, including subluxation at the atlas/C1 and C1/C2 junctions.

The cause of death was probably due to head and neck trauma associated with the puncture wounds. The wounds are consistent with being inflicted by long powerful talons. It is therefore highly likely that this lamb was killed either by a golden eagle or a white-tailed sea eagle.

3.4.1.2 Lamb carcass recovered on 12th May 2009

There was no evidence of live predation around the head and neck of this lamb carcass which was found by FERA staff at Melvaig. The rear of the carcass had, however been extensively scavenged. Body condition as far as it could be assessed was poor. There was a heavy tick burden and soft tissues appeared pale, but it was not possible to determine the cause of death.

3.4.1.3 Lamb carcass recovered on 4th June 2009

This carcass was found and recovered by FERA field staff within a bog at Cove Hill and initial cause of death was thought to be drowning. There was no evidence of live predation in this lamb carcass. Body condition was good and the lungs were inflated with no evidence of the lamb having drowned as suggested by the history. The cause of death was not determined although there was some evidence of tricuspid valve endocarditis.

3.4.1.4 Lamb carcass recovered on 11h June 2009

This individual was found by FERA staff at Melvaig, there was no evidence of live predation in this autolysed lamb carcass. The carcass had been scavenged and the cause of death was not possible to determine, although, based on the good subcutaneous and visceral fat deposits, it had been in reasonable body condition immediately prior to death.

3.4.1.5 Lamb carcasses recovered on 29th June and 3rd July 2009

Both of these carcasses were collected by FERA staff after white-tailed eagles were observed scavenging on the remains. These previously frozen lamb carcasses had been extensively scavenged. There was, however, no evidence of live predation with no signs of haemorrhage or soft tissue trauma associated with the skin and skull wounds. It is likely that these wounds were inflicted post-mortem. It was not possible to determine the cause of death for either of these lambs.

3.4.2 Evaluating carcass handling, storage and examination factors

The six post-mortem examinations carried out for this project were on carcasses that had been frozen as soon as practical following discovery in the field. Whether carcasses are examined fresh or after being frozen, it is clearly advantageous for carcasses to be found and chilled or frozen as soon as possible after death to minimise scavenging and to minimise autolytic changes, especially as projects such as this are invariably carried out during the summer months when ambient temperatures are relatively high. The advantages and disadvantages of fresh versus frozen carcasses are highlighted in the following sections.

There are practical and financial advantages associated with frozen carcasses over fresh carcasses. Transport can be arranged for several frozen carcasses together, with just the use of cool boxes and freezer blocks, instead of rapid and thus more costly transport having to be arranged for each carcass as it is found. Similarly the examinations can be arranged for several carcasses at one time, rather than having to respond on demand as fresh carcasses arrive.

There are, however, some disadvantages of examining carcasses that have been previously frozen over fresh carcasses, but the significance of these will be weighted by the desired objectives of the post-mortem examinations.

3.4.2.1 Primary objectives

If the primary objective is to determine the cause of death, fresh carcasses are almost certainly a necessity, ensuring maximum diagnostic value from the gross appearance of tissues (assuming carcasses are indeed fresh and are examined as soon as practicable), and ensuring maximum value from further diagnostic tests such as histology and bacteriology. It is probable that artefactual changes in tissues associated with freezing and the reduction in value of further diagnostic tests on previously frozen tissues would significantly reduce the likelihood of determining actual cause of death.

If, however, the primary objective is to determine whether death was caused by live eagle predation, then these disadvantages may become less significant.

Determination of whether wounds were inflicted ante-mortem or post-mortem is a key factor in differentiating between live predation and post-mortem scavenging. Live eagle predation is characterised by large, deep puncture wounds, predominantly on the dorsal surfaces and most commonly over the head and neck (Wiley and Bolen 1971). In addition, wounds inflicted ante-mortem are associated with subcutaneous and/or musculo-skeletal tissue oedema and haemorrhage underlying the skin wounds. Talon wounds inflicted post-mortem are not associated with oedema and haemorrhage.

Assessing presence or absence of puncture wounds should not, theoretically, be any different whether the carcass has been frozen or is fresh. Assessing the appearance of such wounds for the presence of haemorrhage and/or oedema, however may be compromised by the effects of prior freezing. It is unknown to what extent this might affect the ability to determine timing of wound infliction and it is not something that can be easily measured since examination of subcutaneous tissues is by nature, destructive and changes gross tissue appearance per se.

Wound age determination is an important subject in human forensic pathology. Collagens, cytokines and growth factors are potential candidates for immune-histochemistry to determine if wounds were inflicted ante-mortem or post-mortem (Kondo 2007). However, for these techniques to have any application in this context, it would be necessary for chemical changes to be detectable in wounds inflicted immediately prior to death (Raekallio 1972). Further evaluation of the value of these techniques was outside the scope of this project, but may warrant future investigation.

3.4.2.2 Secondary objectives

Assessment of body condition is also an important piece of secondary information. Lambs in poor body condition are likely to be more susceptible to live predation (Wiley and Bolen 1971), and such a finding could be supportive evidence if puncture wounds were also consistent with live predation. The proportion of live predation kills in poor condition, and potentially at risk of dying from some other cause, may also be a relevant factor for stakeholders assessing the impact of eagle predation on lamb production. Theoretically, the assessment of body condition should not be affected by prior freezing of the carcass. The effects of scavenging however, may seriously affect assessment of body condition.

3.5 Nest Contents Searches

3.5.1 2009 breeding season overview

For several years, the RSPB has undertaken analysis of the prey remains found in a selection of sea eagle nests annually after chicks have fledged as part of the ongoing monitoring of the re-establishing sea eagle population. In 2009, Scottish Natural Heritage (SNH) commissioned RSPB to carry out additional analysis in conjunction with the lamb cohort study. The interim RSPB nest contents report, which is paraphrased here, is included within Appendix 7.

Three of the four territories established in Wester Ross were successful in 2009 each fledging two chicks. Of the successful nests, the Gruinard nest was deemed unsafe to access due to its precarious location. However, prey collections were made at the two remaining successful nests at Gairloch and Loch Maree.

77 and 56 items were collected from Gairloch and Loch Maree respectively. All remains could be identified to species with the exception of four nestling birds found at Loch Maree. At both Gairloch and Loch Maree, fulmar was the most common prey item making up 80% and 58% of items identified at each site respectively.

Sheep, in terms of black-faced lambs, accounted for 15% (minimum 11 individuals) and 4% (2 individuals) respectively of the Gairloch and Loch Maree nest site contents.

3.5.2 Inter year comparison

At Loch Maree, where two chicks fledged in each of the years 2006, 2008 & 2009, the number and composition of prey remains was very similar in each year. Between two and four lambs were recorded each year making up between 4% and 7% of the total number of items identified. Fulmar was consistently the most common item making up between 58% and 64% of items. Rabbits, geese and herons were other prey species that were delivered to the nest in each year.

At Gairloch, where single chicks fledged in 2007 & 2008 and twins fledged in 2009, there was a large variation in the total number of items recorded between years. Over twice as many items were recorded in 2009 compared with 2007 & 2008. This may be partly due to the difference in the way in which the prey was collected. When only a single prey collection is made at the end of the season, some prey may be overlooked, broken down, or removed. However, it is also likely that in 2009 when two chicks fledged more prey deliveries were made than in previous years when single chicks fledged. Despite differences in the total number of items recorded at Gairloch, there was little variation in dietary composition between years. Fulmars and lambs were the most common items each year, fulmars making up between 68% and 80% of items and lambs between 14% and 16%.

4 DISCUSSION AND RECOMMENDATIONS

4.1 Lamb Losses

Within the radio tracked study flocks no lambs (including both tagged and untagged individuals) were taken by white-tailed eagles during the study period. Post mortem examination of the six dead lambs recovered by FERA staff within the study areas identified one carcass (with poor body condition), where the cause of death was due to head and neck trauma associated with puncture wounds. The wounds were consistent with being inflicted by long powerful talons. It is therefore highly likely that this lamb was killed either by a golden eagle or a white-tailed eagle.

There was no evidence to substantiate eagle predation for any other lamb carcasses or remains, although four of the examined carcasses did show sighs of avian scavenger activity (white-tailed eagles were recorded scavenging on two of these carcasses).

During 2009 study period, reported losses within the Gairloch area were much lower compared to previous years and anecdotal evidence from the crofting community indicated a general pattern of less white-tailed and raven activity than in previous years.

Marquiss *et al* (2003) found that 75% of lamb carcasses diagnosed during their five-year study were scavenged as opposed to being killed. A similar percentage was recorded during this study in carcasses taken for post mortem examination (67%) although the sample size in this case is very small.

Lamb carcasses identified from the two nearest nests (see sections 3.5 and 4.2) amounted to a minimum of 13 individuals, all blackface sheep, although whether these lambs were predated or scavenged could not be determined. An arbitrary predation rate of 17% was calculated from sample of carcasses checked for cause of death, which is half the proportion of carcasses predated by all pairs (34%) during the Mull 1999-2002 study (Marquiss *et al* 2003), although the sample size in this study is significantly lower.

Assuming the predation rate of 17% to be representative of actual losses, the total number of losses to eagles recorded by this study (extrapolated from nest searches and actual post mortem analysis) amounted to 3 lambs, all blackface breed. The lambs found in the immediate vicinity of the Gairloch nest and in the key radio tracked study flocks are all Cheviots, which lambed under supervision inbye, while blackface lambs formed the basis of the Melvaig study flocks which lambed out on the open hill.

4.2 Nest Contents (RSPB Report)

Fulmar dominated species composition of prey collections made at Gairloch and Loch Maree in 2009. This is consistent with previous collections made at these sites and data collected at other white-tailed eagle nest sites throughout North West Scotland over the past 10 years. Whilst lamb remains were found at all sites sampled in 2009 and in each prey collection made in Wester Ross since 2006, the numbers of lambs represented, and their percentage of the items found were consistently small. This pattern is consistent with that found in a more intensive study carried out in Mull during 1998-2002 (Marquiss *et al*. 2003), where some lamb

remains were found in most nests but the number represented in each nest was small.

Four out of the five nests examined in northwest Scotland in 2009 contained remains of one or two lambs, while at Gairloch a minimum of 11 individuals were identified. Nine of those were delivered to the nest during the first half of the nestling period (before the end of May) and all remains were identified as blackface breed.

At Loch Maree the remains of two lambs were recorded from the first half of the nestling period and none were subsequently recorded. The timing of lamb deliveries found in this study is consistent with the results from Mull (Marquiss *et al* 2003), where most lambs were delivered to nests in late April and May with very few delivered in June, July and August.

Dietary composition at Gairloch and Loch Maree in 2009 was very similar to that recorded in previous years at these sites. However, whilst the total number of items recovered at Loch Maree was similar to previous years, the number of items recovered at Gairloch in 2009 was much greater than in 2007 & 2008. Although this may be explained by the greater number of prey collections made in 2009, Marquiss & Madders (2003) found that the number of items found when carrying out weekly visits was similar to the number found in a single post-season collection. Therefore, the greater number of items recorded at Gairloch in 2009 is likely to reflect a higher delivery rate to the brood of two chicks compared to previous years when single chicks fledged. The number of items recovered at Gruinard 2006-2008 also varied according to eagle brood size.

4.3 Post Mortem Examination

4.3.1 Cause of death

In five of the six lamb carcasses examined, it was not possible to determine the cause of death. Several carcasses had been extensively scavenged with few visceral remains. Freezing artefact and autolysis affected the gross appearance of tissues and further diagnostic tests would have been unlikely to yield information of significant value in the context of the project.

If the primary objective of post-mortem examination is to determine cause of death, carcasses should be examined as fresh as possible and be as intact as possible, with further diagnostic tests forming part of any investigation.

4.3.2 Live predation as cause of death

Skin punctures with penetration into underlying tissue were present in several of the six carcasses. In three of the carcasses, the size and location of these punctures could have been considered consistent with the wounds being inflicted by large talons. However, in one case only were these wounds associated with any visible haemorrhage or oedema. In addition, the depth and extent of the wounds in this one carcass were far more extensive than in any of the other carcasses, consistent with the wounds not only being inflicted ante-mortem, but also consistent with the wounds being the actual cause of death. In the other two carcasses, there was no evidence consistent with wounds being inflicted ante-mortem, or the wounds being a possible cause of death.

Even in previously frozen carcasses it is possible to assess the presence/absence, appearance, and in particular the timing of wound infliction with some confidence. However, as alluded to above, no direct comparison of confidence in assessment in

previously frozen versus fresh carcasses was possible due to the destructive nature of the post-mortem examinations.

4.3.3 Body condition

Two of the six lambs appeared to be in reasonable body condition with good subcutaneous and/or visceral fat deposits. Body condition assessment was not possible in two carcasses due to extensive scavenging. Two lambs were in poor body condition, one of which also had findings consistent with live predation by a large raptor.

Although valuable information relating to body condition can be collected just as well from frozen, as fresh carcasses, the consequences of scavenging are more likely to be a limiting factor.

4.4 Radio Tags and Radio Tracking

Fifty-eight radio tags were originally attached to lambs within the study flocks during May. However, a large number of tags were recovered that had become detached from the lambs and therefore several re-attachment sessions took place.

The key issues associated with tag attachment and subsequent retention were directly related to tag type/size and resulting attachment problems. Large square radio tags with sharp corners are not ideal when species to be tagged are active young animals within rough habitats and wet climate. Furthermore the overall shape, dimensions and weight were far from ideal in terms of tag retention when attached directly to the study animal.

Key difficulties in utilising these tags in the study environment manifested themselves in the very labour intensive attachment and reattachment issues. Not only were the actual methods of attachment labour intensive but gathering in more animals to reattach dislodged tags involved not only excessive amount of the study team's time but also further time from the crofting community. Without the unprecedented help from key crofters, the radio tagging and tracking would not have been possible.

An issue raised by members of the steering group concerned the visual impact the tags might have had on predator behaviour. As can be seen in Figure 3, the attached tags only cover a small proportion of the lamb's back and with fleece staple growth were less visible over time. In comparison with the additional lettering and numbers sprayed on the animals as a normal part of flock management the visual intrusion of the tags was taken to be minimal.

Although the radio tracking was very effective in locating tags with mortality signals (due to the number of tags falling off the lambs and then remaining inactive long enough for the mortality signal to be activated), there was a significant proportion of effort directed to travelling between each of the study sites each day.

4.5 Vantage Point Monitoring

Low levels of white-tailed eagle activity were recorded from vantage points especially given the amount of effort directed at vantage point monitoring, 2% of 600 observational hours. However this is more likely to be a function of low levels of sea eagle activity rather than inappropriate methods. Standardised vantage point monitoring is commonly used within Ecological Impact Assessments for wind farm developments and provides adequate sampling of raptor flight activity. Key locations for vantage points were identified that allowed unrestricted views of the study areas; this in combination with the size and flight behaviour of the key study species

enabled an accurate picture of flight activity to be recorded. Although activity levels of eagles on the ground were under recorded especially when eagles remain perched on low rock outcrops for extended periods of time (as recoded occasionally during field work).

Comparable levels of radio tag detection were obtained from both the vantage point and focussed radio tracking.

Due to the unforeseen complications resulting from tag design and associated attachment complications, time and budgetary shortfalls did not allow further analysis of vantage point records in terms of detection function decay with distance from vantage point, weather/observational visibility and species characteristics. In future studies of this nature it may therefore be appropriate to adopt refinement of the Vantage Point methodology to account for lower detection probability with distant birds (and possibly according to weather conditions)

4.6 Statistical Relationships

Statistically significant correlations were found between a number of variables. However, all but raven activity/rainfall and raven activity/white-tailed eagle activity were a function of the study progressing over the summer period (increasing temperature) and breeding season (increasing bird activity).

Although it is problematic to establish cause or causation between raven flight activity and rainfall levels beyond a general effect of rainfall on foraging conditions, the correlation between white-tailed eagle and raven activity could be explained by the scavenging habits exhibited by both species. With both species feeding on carrion and more specifically sheep carcasses it would be expected that in certain conditions activity of both species would have similar ecological drivers. An alternative explanation could be associated with the scavenging activity of one species in relation to feeding activity of the other either on a predated or scavenged carcass.

4.7 Recommendations

Overall this initial pilot study met with a number of methodological challenges, specifically:

- Pre study consultation requirement that the tags were not attached with collars
- The size and construction of the tags
- The small sample sizes of tagged lambs
- Too much emphasis was placed on specific flocks
- The recorded predatory/scavenging events occurring outwith the tagged sample flocks
- During the study period there were low lamb losses compared to claimed losses of previous years
- This short termed study was not able to take account of annual variations (e.g. 2008 was a very dry year, and poor year for fulmar/seabird productivity)

To overcome a number of the challenges faced by the study we would recommend the following:

- The key objective should be to find carcasses for analysis.
- For establishing cause of death by eagle predation post mortem of frozen carcasses is practical and cost effective.
- A better rationale for selecting study flocks should be employed.

- Effort should be concentrated in key areas; these key areas would be determined by eagle activity from systematic survey work and crofter feedback and combined to a lesser extent with the areas of greatest lamb losses from previous years.
- For flocks lambing out on the hill monitoring should consist of vantage points for visually monitoring flocks and predator activity combined with walked daily checks across selected areas of the hill looking for carcasses
- For crofts where lambing occurs in-bye,
    - Radio tag attachment should be by neck collar rather than direct gluing and pen trials on tag suitability should be conducted before full field deployments
    - Monitoring methods should include an observer recording a single study flock for whole daylight periods (e.g. a day in the life of that flock)
    - The visual monitoring and radio tracking could be carried out by same fieldworker

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