The behaviour and habitat use of red deer (Cervus elaphus) in the flow country of Sutherland

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THE BEHAVIOUR AND HABITAT USE OF RED DEER (*Cervus elaphus*) IN THE FLOW COUNTRY OF SUTHERLAND.

by

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SUMMARY

1) A study was made of the behaviour of Red Deer (*Cervus elaphus*) in the flow country of Sutherland. In addition the use of this habitat by the deer was assessed through the use of a Geographic Information System (GIS). The study took place from the 20th of April to the 25th of June, 1994, covering the period in which parturition occurs.

2)Activity patterns were found to be broadly similar with those found in previous studies of Red Deer in other areas of Scotland.

3) Differences in activity budgets between the sexes were assessed. It was found that stags spent more time moving, and exhibiting vigilant or aggressive behaviour than hinds.

4) During the pre-parturition period hinds spent 79% of the time observed grazing, compared to 39%
post - partum.

5) Analysis of habitat availability and utilisation was performed using a GIS. It was found that NVC types M17 and M18 made up 27% and 35%, respectively, of the study area.

6) The combination NVC types U4 \ *Juncus*, U4 \ H9 and U4 \M15 proved to be the most heavily utilised at this time of year, relative to their abundance. The implications of this for the management of Red Deer are discussed.

Figure 1.

Male *Cervus elaphus*, on an area of semi-improved pasture, near a ruined croft on the Badanloch estate. Taken during the pre-parturition study period . Note the central animal retains his antlers, whereas the flanking stags have shed theirs. This, coupled with the heavier necks and shoulders on the stags on either side would suggest the central stag is the younger of the three.

(Photograph Courtesy D. Rees, 1994)

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1 INTRODUCTION:

The Red Deer (*Cervus elaphus* L. 1758) is the largest terrestrial mammal in Britain, and the only indigenous representative of the largest genus of deer, although *C. nippon*, (sika deer) have been introduced to Britain (Lowe 1977). Red Deer are of particular importance in the highlands of Scotland, not only as a commercial resource, but, as an integral and highly visible part of the wildlife, they represent an important tourist attraction. In addition to this, Red Deer pose a number of important conservation problems, principally due to alteration of semi-natural vegetation due to grazing pressure. (Sydes and Miller 1988).

Much of the recent work on Scottish Red Deer populations has been performed on the Island of Rhum, off the West coast of Scotland (Clutton-Brock *et al.* 1982) which has the advantage of having well studied populations with good background data, such as lineage and life histories, marked individuals and well mapped vegetation. However as an island population it may be subject to pressures such as constrained movement and a restricted range of habitat compared with mainland populations. Also, it should be noted that the flora, topography and climate are very different on Rhum to the eastern side of Scotland. (Ratcliffe and Oswald, 1988)

Previous studies of deer in mainland Scotland have included Ross-shire (Jackes 1973), Benlawers (Colquhoun 1971), Glen Fieshie (Staines 1974) and Glen Dye (Staines 1970), although none using similar techniques to this study.

1.1 The Flow Country:

The "flow country" is situated in the extreme North East of mainland Scotland, it is the largest continuous expanse of blanket bog in Britain. The area is sparsely populated by humans, but is of such importance to wildlife, in particular birds, that it has been designated a Site of Special Scientific Interest. (see section 2 STUDY SITE)

The area is a particularly important breeding ground for Arctic and sub-Arctic species, such as golden plover (*Pluvialis apricaria*), greenshank (*Tringa nebularia*) and dunlin.(*Calidris alpina*). (Ratcliffe and Oswald, 1988)

1.1.2 Red Deer in The Flow Country:

The two most important traditional land uses of the flow country are concerned with management of the habitat for herbivores. Crofting is dependant on grazing for sheep, whereas shooting estates require grazing for deer and food for grouse. The principle management tool used in maintaining these food supplies is usually burning, the full effects of which are still poorly understood. However it has been shown, through experimental burning, that this practise can increase the usage of the area by deer, (Miles, 1971), although poorly managed practises can lead to increased erosion and an increase in unpalatable sedges and grasses (McVean and Lockie 1969).

The impact of grazing on peatland vegetation is also not well known, although certain obvious effects, such as shifts in dominance and specific composition have been noted (Ratcliffe and Oswald, 1988). To the knowledge of the author, no work has been published concerning the Red Deer population of the flow country.

1.2 Distribution of Red Deer:

Red Deer are indigenous throughout the palaearctic region, between 30°-65°N, with a discontinuous distribution (Lowe 1977). Ellerman and Morrison-Scott (1955) list seventeen subspecies and races, primarily distinguished by skull morphology and antler characteristics, although this has been disputed (Lowe and Gardiner 1974).

Many authors regard *C. elaphus* and the North American/Asian *C. canadenis* (wapiti or elk) as being conspecific (Flerov 1952, Caughley 1971a). Again, this is mainly based on morphological features, although the two species have been shown to successfully hybridise both in captivity and in the wild (Flerov 1952, Gray 1972). However dissimilarities in morphology, colouration and voice are considerable (Clutton-Brock *et al.* 1982).

The British race *C. elaphus scotius* (Lonnberg 1906), is confined to Scotland, North West England and South West Ireland (Lowe and Gardiner 1974) although feral park animals are to be found throughout large areas of England. European Red Deer have been extensively translocated to Australia (Bently 1957), South America (Cresswell 1972) and the U.S.A. (Vinson 1947).

Within Britain there is frequent translocation particularly between deer parks or forests* in order to reduce inbreeding. Whitehead (1964) provides a summary of certain introductions of park (farmed) Red Deer to Scottish forest populations, up to that time.

1.3 History of Red Deer in Scotland and Population Trends:

The current Scottish populations of Red Deer inhabit open moor land whereas ancestral Scottish and existing European Red Deer are primarily a woodland mammal (Richie 1920). By the 15th and 16th centuries agricultural demands had caused extensive clearance of lowland woods, effectively restricting Red Deer to the Scottish highlands which, although predominantly moor land, retained substantial areas of forest (Pearsall 1950). Thus the deer in the highlands were relatively sheltered from over exploitation and disturbance, although the habitat was somewhat different from that inhabited by the ancestral and contemporary European populations.

Exploitation of the highlands reached a peak in the early 18th century (Anderson 1967). Intensive use of woodland for timber and charcoal combined with an increase in large scale sheep farming and general cultivation resulted in an almost total erosion of the remaining woodlands (Franklin 1952). This in turn meant the loss of the "natural" habitat of *C. elaphus* in Scotland (McArthur 1936, Adam 1960).

Due to an increase in the popularity of hunting and a decline in the profitability of sheep farming (due to wool imports) the number of managed deer forests increased from the middle of the 19th century (Mitchell *et al.* 1977). In turn the size of the Scottish populations increased, doubling in numbers between 1960 and 1989 (Red Deer Commission 1989), mainly as a result of the benefit derived from pasture improvements for sheep, and a total lack of predators apart from man

Recent changes in traditional land use in the highlands include the large areas of commercial afforestation, which has resulted in the replacement of open upland habitat with vast tracts of densely planted exotic conifers (Bunce and Barr, 1988). Changes in agricultural practise, primarily the "improvement" of marginal hill ground by draining and the application of fertilisers and pesticides, has also resulted in habitat loss, and the attendant loss in species such as birds (Bibby, 1988). Although the profitability of large scale sheep farming has declined (Mitchell *et al.* 1977), there

* The term " Deer Forest" refers to an area of land (such as a private estate) which is maintained for the stalking, and usually shooting, of Deer, rather than an area of woodland.

has still been an overall increase in sheep numbers and stocking density (Sydes and Miller, 1988), thus increasing grazing pressure on, and creating competition for, the available habitat.

A recent report from the Red Deer Commission (Red Deer Commission, 1994) proposed an increase in the cull rate to remove 100 000 animals, i.e. a third of the Scottish population. Clutton-brock and Lonergan (1994) have proposed a culling regime, based on findings from the Rhum Red Deer populations, which they speculate would provide a 30% increase in mature, good condition stags, whilst retaining a solid breeding base of good condition hinds.

1.4 Morphology of Red Deer:

The morphometric measurements of Red Deer are variable, depending primarily on habitat quality and resource availability. Mature British stags reach an average height (at withers) of 1.2-1.3m, with a nose to tail length of 2m. Hinds rarely exceed 1.1m in height, with a length of 1.8m. Weight also varies with sex, with 85kg being the average weight of a wild Scottish stag (with a range of 56-190kg) compared to hinds weighing between 38-77kg, with an average weight of approximately 58kg*. Stags in optimum conditions in Britain rarely exceed 190kg (Whitehead 1960) in contrast to those in Europe which have been recorded at 255kg (Baillie-Grohman 1896). Only stags grow antlers, developing through modified endochrondral ossification from pedicles positioned on the frontal lobes of the skull, between the ears. These begin developing in the 8-10 month old stags, although the first proper antlers are not seen before the first twelve months, usually taking the form of a single spike that may occasionally be forked (Raesfeld 1964). Thereafter the antlers are shed yearly, usually in April-May (Watson 1971) and with subsequent re growth develop into a more complex form.

Li and Suttie (1994) provide a detailed account of the initial antler development. Traditionally it was assumed that the number of points on a "head" (pair of antlers) reflected the age of the stag, however it is now known that although older, more mature stags generally have more complex "heads", the extent of growth and complexity is heavily influenced by environmental factors, probably most importantly habitat quality (Mitchell *et al.* 1977).

* All weight are "clean", i.e. minus alimentary tract (Lowe 1971)

The summer coat of *C. elaphus* is short and fine, ranging from dark brown to yellow, but predominantly a rich red. In winter a thicker more luxuriant pelage develops, usually a brown/ grey colour, although again there is a lot of variation from black to creamy white. The rump patch is usually white, below the tail, sometimes bordered with black and an orange/yellow colour above the tail (Lowe 1977, pers. obs.) The underside is usually off-white or grey, although stags in rut have a black or dark brown belly from frequent wallowing in peat/mud, (B. Lyall, pers. com.). In September, before the rut in October, stags develop a richly coloured mane which can reach magnificent proportions. This persists until the following spring (Lowe 1977).

1.5 Social Organisation and Breeding Cycle:

Breeding occurs in late September/October, a time known as "the rut". Hinds gather on areas of "short greens" (Clutton-brock *et al.* 1982), generally the same areas appear to be used every year, and are given the name "rutting grounds". Mature stags begin to congregate around the hinds, becoming increasingly intolerant of each other, and focusing more on groups of hinds. Eventually the movements of hinds are restricted as stags claim an area, creating a harem. This harem of hinds is then defended against all other stags, through a range of displays such as roaring, parallel walking and charging. This can escalate into aggressive contact involving rearing on the hind legs to strike with the front legs, scissors kicking and head butting. Clutton-Brock *et al.* (1982) provides a through description of rut interactions and the processes of mate selection.

Respective hinds are mated at the rut, and carry the foetus over winter with calving occurring in late June/early July. Single calves are the norm, although twins do occur very rarely (Mitchell *et al.* 1977).

Except for during the rut, the sexes normally live in segregated groups. Social organisation within the hind herds is a matriarchy (Lowe 1966, Clutton-brock 1974), groups comprising the matriarch and mature daughters with immature offspring of both sexes. Hinds tend to associate with relatives, with several small groups forming temporary associations. (Clutton-Brock *et al.* 1982) Once stags pass puberty, at an age of 2-3 years (Franklin *et al.* 1975) they leave the maternal herd, forming male bands which roam over a much larger area than the hind herds (Clutton-brock *et al.* 1982, Mitchell *et al.* 1977, Schreiber, Klein and Lang 1994).

1.6 Nutritional Requirements:

The digestive physiology and nutritional requirements of wild deer have been well documented (Pollak 1974, Staines and Crisp 1978, Kerridge and Bullock 1991, Domingue *et al.* 1991, Gordon and Illius 1994, Freundenberger *et al.* 1994.). These requirements vary depending on the age, season and reproductive status of the deer.

In the case of Red Deer late spring/early summer is a time of high energy demands. Hinds must calve and lactate sufficiently to ensure the calves survival throughout the coming winter, whilst rebuilding their own fat reserves. Stags shuck their antlers and regrow them, whilst putting on weight in preparation for the rutting season in October when over 10% of their body weight is lost in a matter of weeks. (Mitchell *et al.* 1977).

Detailed studies of feeding activity patterns in Red Deer (Colquhoun 1971, Clutton-Brock *et al.* 1982, Thouless 1990, Illius and Gordon 1990, Sherlock and Fairley 1993), show a generally diurnal trend, with peaks of grazing activity at dawn and dusk, with shorter grazing bouts occurring through the day and night. It is also proposed that local conditions, such as weather (Darling 1937, Harper *et al.* 1967) and human disturbance (Davidson 1973b, Lund-Jeppesen 1984) alter the periodicity of activity.

Red Deer will consume a wide range of plants, the principle determining factor being local availability. Mitchell *et al.* (1977) provides an excellent summary of the different methods used to assess species taken in both wild and captive animals, and points out potential problems with each method. More recently Kerridge and Bullock (1991) assessed diet composition and quality in both Red and Fallow deer (*C. elaphus* and *Dama dama*).

With regard to North East Scotland, *Calluna* and other dwarf shrubs seem to be an important resource, (Mitchell *et al.* 1977) as do sedges and grasses such as *Scirpus cespitosus* (deer sedge) and *Eriophorum* spp. (Staines 1970).

1.7 Use of Geographical Information Systems (GIS) in Ecology:

GIS, is defined by the US National Science Foundation (Walker and Muller, 1991), as a computerised database management system used for capture, storage, retrieval, analysis and display of spatial (i.e. defined by area), data. GIS represents a way of managing, using and presenting large quantities of high resolution spatially referenced numerical data, for an equally large number of variables over a theoretically infinite area. As a great deal of ecology is spatially referenced, if not spatially dependant, GIS is a tool which is ideally suited to investigating many ecological situations. This is particularly applicable at a landscape scale, where remote sensed data can very easily be incorporated into a GIS.

A GIS has a topological data structure which is created and maintained internally. This data structure takes the form of independent 'coverages' of discrete cartographic features, directly linked to associated descriptive or tabulated data. Thus a 'coverage' of roads might also contain information about the rate of accidents on each specified stretch, or the daily traffic load, at the desired spatial scale. A further coverage might contain the geographical locations of pedestrian crossing points or service stations.

At this level a GIS is no different to a computer mapping system such as UNIRAS/UNIMAP. However GIS have the additional feature of being able to overlay and combine coverages, and attendant databases, to create new, novel coverages and databases. Following the earlier example, overlaying the coverage of pedestrian crossing points with the road coverage might create a coverage showing rate of accident occurrence relative to location of pedestrian crossings, or in relation to traffic load, or both.

This is possible due to the way data are stored in a GIS. The process of locating features through relative positioning is called the coverage topology, which is a mathematical procedure for explicitly defining spatial relationships. Topology expresses different types of spatial relationships a lists of features, (ESRI, 1993).

The GIS system used in this study (Arc/Info, ESRI INC.) operates four data models: vector, TIN, lattice and raster. In a vector model data is stored either as lines (arcs), or as points (nodes). Arcs may be joined to create polygons, which have a perimeter, contain an area and may posses additional attributes set by the operator. In this study polygons represent the spatial location, and approximate spatial extent of Red Deer herds.

Each polygon possesses a unique identifier which links it to an associated database, in the case of this study the database contains information relating to herd size, composition and activity. Vector is best suited for operations on cartographic features, as was the case in this study.

In the raster data model the data is stored as an array of cells. Each cell possesses a value representing an attribute of that specific location. Raster is best suited for space filling analyses *i.e.* soil types. The third data model, TIN (triangulated irregular network) is used to convert two-dimensional contours to a three dimensional data terrain model, as was the case in this study. A lattice model is the surface interpretation of a grid, represented by equally spaced sample points referenced to a common origin, the lattice model is used in a similar way to the TIN model.

1.8 Use of GIS:

GIS's are being increasingly used for analysis and modelling of spatial ecological problems, proving to be particularly useful where changes in land use or management are being investigated. The potential of these systems for conservation management and planning is vast. For example, Environmental Systems Research Institute (ESRI), are currently working in close contact with several US coastal authorities in order to construct and maintain a Marine Spill Contingency and Resource Planing GIS, in a co-ordinated attempt to drastically reduce the likely hood and impact of marine contamination (Roper, 1993). Incorporating remote sensing, such as satellite imagery, will allow continuous updating of the system, with the real-time movements of tankers and other bulk carriers being continuously monitored within the GIS data space. This will give advance warning of potentially hazardous situations, and should a spillage occur, it could provide accurate updates on the dispersion of the contaminant. In addition, a suitably integrated and managed system may help to predict dispersion and any resulting threat to sensitive areas.

GIS has often been combined with remote sensing. For example Ormsby and Lunetta (1987) constructed resource availability maps for Whitetail deer (*Odocoileus virginia)* using thermic mapper data from Landsat 4 imagery, and Avery and Haines-Young (1990) used satellite imagery in combination with GIS to assess the impact of afforestation in Sutherland and Caithness on the internationally important breeding populations of Dunlin (*Caldris alpina*) present there.

Indeed the large data handling and geo-referencing capabilities of GIS make it an ideal compliment to remote sensed data, particularly when habitat mapping, and assessing the impact of land use changes in and around those areas. Other recent studies include habitat use in Florida scrub jays (*Aphelocoma coerulescens coerlescens)* (Breininger, Provancha and Smith, 1991), and investigating distribution and abundance of moor land birds in upland Britain (Aspinall and Veitch 1990). Recent advances in GIS capability now permit integral complex multivariate analyses, as in Clark, Dunn and Smith's (1993) study on female Black Bear (*Ursus americanus*) habitat use.

1.9 Aims of This Study:

This study comprises two parts. The first part sets out to investigate habitat use based on the composition and activity of herds relative to the vegetation classes occupied.

Due to the changing metabolic demands of Red Deer over the study period, in particular hinds calving and lactating (Arman 1974) the project not only investigates differences in stag-hind habitat use, but pre- and post-calving habitat use by hinds. Habitat selection or preference was also investigated in a comparison between the habitat available and habitat use. Work of this nature has previously been carried out on ungulates by studies of individual animals. This normally requires radio tracking or some form of individual identification which was beyond the scope of this study (Larson, Rongstad and Terbilox 1978, Krausman 1978, Clutton-brock *et al.* 1982, Carronza *et al.* 1991, Lazo *et al.* 1994). Alternatively faecal or rumen analysis can be performed to asses habitat use in fine detail, but as pointed out in Mitchell *et al.* (1977) there are limitations to the use of these methods, and again beyond the scope of this study. Here I adopt a broad, landscape scale, based on the location of herds, rather than individuals. In this part of the study I use a Geographical Information System (GIS), as these data were of a complex, spatially referenced nature and covered a large geographical area at a map scale off 1:10,000.

In the second part of this study I investigated differences in behavioural patterns between the sexes and pre/post parturition, and at different times of day using scan samples of herd activity patterns and focal animal scanning of individuals. In particular I wished to see if Red Deer in East Sutherland exhibited the same patterns in activity as on the island of Rhum, where Clutton-Brock *et al.* (1982) has provided a comprehensive view of the behaviour in both stags and hinds.

This project was carried out in association with a Scottish Natural Heritage funded project awarded to Dr. C.J.Thomas and Prof. P.R.Evans, entitled Functional Needs of Peatland Animals within Special Protection Areas. (FNPA)

2 STUDY SITE:

The study site was based on the Badanloch and Achentoul estates in East Sutherland, North East Scotland, (Figures 2, 3 & 4), this area had previously been selected to form the principle study area of the F.N.P.A. project; permission from the respective landowners had been granted and accommodation was readily available within the study site. The full extent of the F.N.P.A. study area was approximately 230 km^2 , although due to the nature of this project it was not necessary, or practical, to use the full area available.(See Methods; 3.2.1 Line Transects)

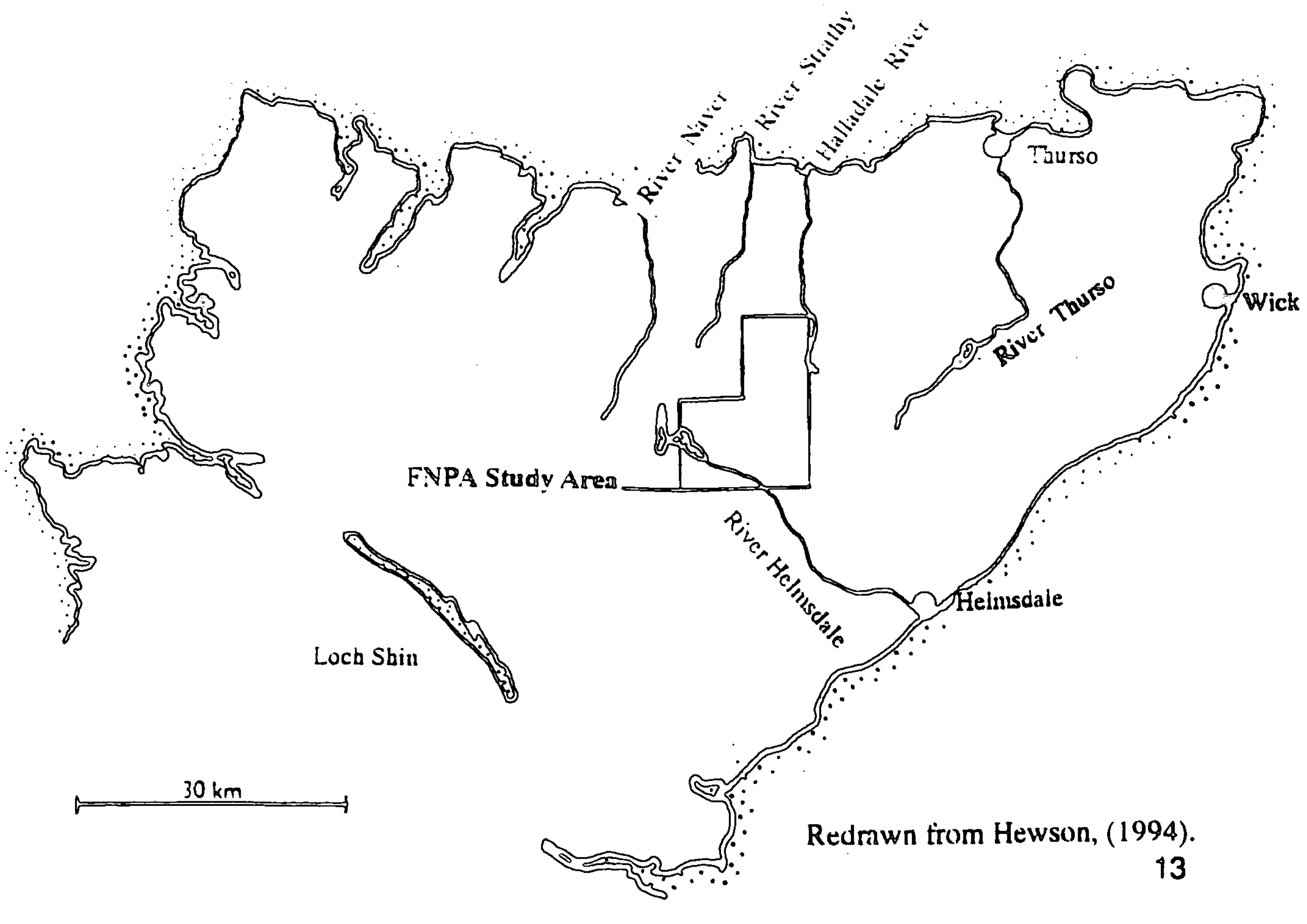
2.1 Physical Features:

This area of Scotland consists of low-lying, sometimes flat, peat moor lands broken by rugged mountainous outcrops. It is the huge expanses of almost level bog land which earned this area the name of the "flow country." The flows of Sutherland and Caithness cover an area of some 4000km^2 (Ratcliffe and Oswald, 1988) forming the largest continuous expanse of blanket bog in Britain. The study area consists mainly of raised mire, cut by water courses, lochs and dubh lochans overlooked by the two Ben Griam mountains. Ben Griam Mor, the highest of the pair, reaches an altitude of 590m a.s.l., this is contrasted by the strathy bottoms which are some 100m above sea level. (i.e. Strath of Kildonan).

The geology of the area is a combination of Granites and Old Red Sandstone (the "Caithness Flags"), this is overlain by deep peat deposits, which form the near continuous flows of Sutherland and Caithness. Thus the area is highly acidic, pools and dubhlochs usually have a pH of around 4 (Rees, 1994).

Figure 2: Location of FNPA Study Site in the U.K.

Figure 3: Sutherland and Caithness, Showing FNPA Study Area.



Redrawn from Hewson, (1994).

Figure 4

Observation Points shown in red

Streams and Lochs in Blue

Forestry blocks outlined in green

Roads shown in black

Scale, 15mm : 1km

The study area, based around the Badanloch and Achentoul estates, Sutherland.

2.2 Land Use:

The majority of land in both Badanloch and Achentoul estates is given over to deer forest, sheep walk and grouse moor, whilst also maintaining smaller areas of improved and semi-improved pasture around buildings, for the use of sheep, particularly during the winter.

Red Deer roam freely over the entire area; features such as roads, railways and rivers presenting little or no impediment to their movement. Indeed the only areas from which they are excluded are where deer fences have been erected. To be successful these must usually be at least 3m in height. Areas of commercial forestry plantation are usually protected in this way, as are many of the improved pastures, particularly when near houses, and private gardens.

2.3 Vegetation:

The principle vegetation assemblages in the study area are National Vegetation Classification (NVC) types M17 and M18. River and stream courses generally have an associated corridor of grassland, either NVC category M25 or the shorter sward of U4, areas of H9 and M15 also occur in the M18/M17 dominated study area. Figure 5 shows the NVC composition of the study area. A description of the principle categories is given below:

M18: Raised and blanket mire. The underlayer is dominated by sphagna, forming an extensive undulating carpet composed of irregular mosaics of differing specific or structural composition. M18 in this study area typically contains scattered or sometimes extensive pool complexes, ranging from shallow, temporary puddles to deep, shear sided, dubh lochans. The different pool types were classified according to structural and vegetation characteristics, (Twiss *et al.* 1993) and can be used to further differentiate the irregular, and often complex mosaic of M18. Usually dominated by *Erica tetralix* and *Sphagnum papillosum*, with *Calluna vulgaris* and *Eriophorum vaginatum* also common.

M17: Blanket mire. As M18, dominated by a sphagna underlayer, however M17 lacks the characteristic pool complexes of M18, and tends to be dominated by *Scirpus cespitosus* and *E. vaginatum*. In addition, *E. angustifolium* may occur in abundance.

M25: Mire. An abundance of *Molinia caerula* is the characteristic feature of this vegetation type, which contains a varied assortment of species of varying floristic nature. Its growth form ranges from extremely tussocky to an almost even sward, the most common type in the study area being a combination of the two extremes, large stools of *M.caerula* interspersed with more level areas of *Potentilla erecta*, another characteristic species of this type.

U4: Grassland. An intimate mix of grasses forming a generally smooth, short, sward dominant grasses are *Festuca ovina* and *Agrostis capillaris,* with *Galium saxatile* generally abundant.

M15: Wet Heath. A highly variable vegetation type, with a wide range of species present, and an equally wide variation in the pattern of dominance. *E.tetralix*, *C. vulgaris*, *S. cespitosus* and *M. caerula* tend to be constant species present.

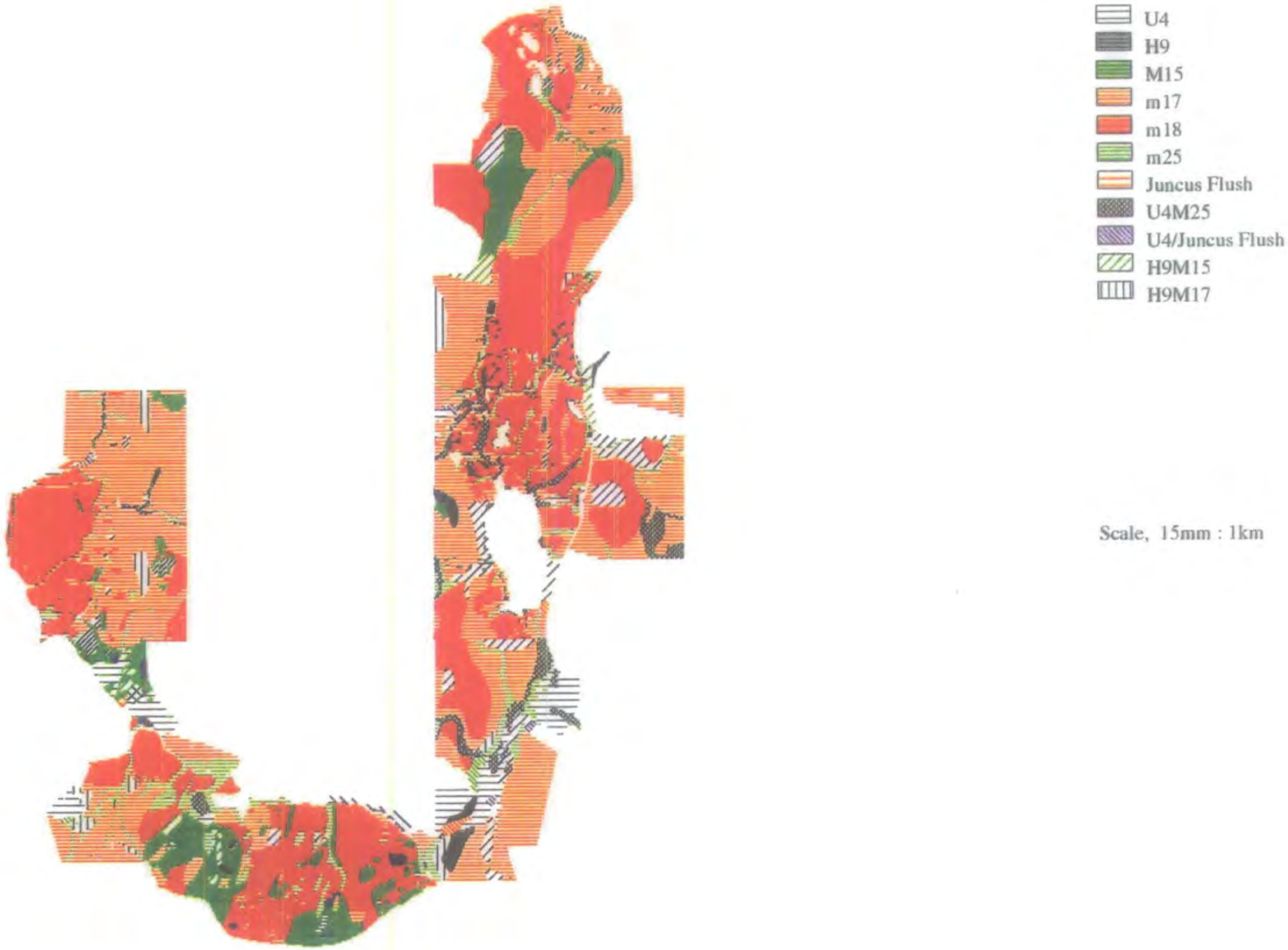
H9: Heath. Normally occurs on drier hummocks rising from the relatively moister M17/18, primarily dominated by *Calluna vulgaris*, which usually forms a low and quite open canopy, interspersed with *Vaccinium myrtillus* and tufts of *Deschampsia flexuosa.*

The entire study area was mapped according to the NVC (Rodwell, 1991) classification system by members of the FNPA team.

In an area where no clear distinction was possible between two or more NVC classes that area was classified as a "combination class". i.e. M17\H9 or M25\U4. It was normally possible to identify two dominant types in a mosaic of vegetation, thus the majority of combination classes only consist of two NVC types.

The dominant trees are those in commercial plantations, mainly sitka spruce (*Picea sitchensiss*) or lodge pole pine (*Pinus contorta*), a few isolated and stunted specimens of Birch (*Betula pubescens*) and Rowan (*Sorbus aucupana*) tend to occur only in sheltered ravines and gullies on the steeper, better drained slopes.

Figure 5



NVC Map of the Study Site.

3 METHODS:

3.1 Study Periods:

Data were collected at two periods, pre-parturition from 20th April-10th May, and post-parturition from the 6th June to 4th July. Calving occurred from approximately 1st to 25th June. Due to the wide ranging nature of the deer herds, coupled with the cryptic behaviour exhibited by young calves, it was not feasible to ascertain the actual numbers of calves born. Many days of additional fieldwork would have been required to obatain accurate data, this was not possible within the time constraints of the project.

3.2 Field Data Collection:

Data for habitat availability/utilisation analysis were collected during transects performed from a vehicle on the single track road which ran through the study area, (marked on Figure 4). The road provided good views of most of the study area and the use of a vehicle allowed large areas to be surveyed in a relatively short time, thus enabling many more repeat transects to be performed than would have been possible on foot. In addition deer were undisturbed by the presence of a vehicle (provided the doors remained closed), but usually moved at a considerable distance when approached by a person on foot. This was of particular importance when observing behaviour (see below.) Records were made of location, composition and activity of all herds visible.

Behavioural observations were also made from a vehicle on the roadside for the reasons given above. Observations were carried out using 8 x 30 Swift Belmont binoculars, a x30 fixed magnification Optoylith telescope and a variable magnification telescope both tripod mounted. Transect data were recorded directly onto 1:10,000 scale Ordinance Survey maps, and behavioural observations on tick sheets.

I attempted to make observations during all daylight hours. This varied from 6 am to 6 p.m. during the initial pre-calving period, to 4 am to 11 pm towards the end of the post calving period.

3.2.1 Line Transects:

Eleven observation points were chosen along the transect road, which offered the largest field of view , whilst being safe places in which to park, (Figure 4). The use of predetermined observation sites ensured that each transect was directly comparable with all the others, and also removed the need to attempt to locate herds whilst driving, a potentially fatal technique. The transects took between 1.5 and 3 hours to complete, depending on visibility, number of deer and weather, most importantly wind speed, as counting and sexing of deer became proportionately more difficult as wind speed increased due to increased movement of the telescope, thus increasing the time taken to characterise a herd.

At the beginning of each transect a "working visibility" was recorded, that being the maximum distance at which I felt it was possible to reliably sex a deer . Initial binocular scans were made from each observation point followed up by the use of a telescope to sex/age individuals if necessary. The location and extent of each herd was then marked on a 1 : 10 000 scale map as accurately as possible, and assigned an individual code number which corresponded with the notebook data entry of number, ages, sex and activity.

3.2.2 Behavioural Observations :

Behavioural observations usually took place before or after a transect was performed. I attempted to observe equal numbers of herds of both stags and hinds at all times of day in order to obtain directly comparable data. To this end, before an observation bout, a suitable herd, of the required sex, had to be located. Additional constraints were the position of the herd, i.e. near enough to clearly differentiate the different behaviours, and the weather. The weather not only influenced visibility when poor, but warm, sunny weather caused a severe heat haze, occasionally making observation at any distance extremely difficult. Two behavioural sampling regimes were adopted, scan sampling and focal animal sampling.

3.2.2.1 Scans:

This method of sampling allows the activities of a large number of individuals to be recorded almost simultaneously, within a group (Altman 1974). The subject herd was scanned every 5 minutes and the behaviour of each individual was recorded on a tick sheet.

This gives a measure of overall group behavioural patterns. A group is considered to be more than one individual and membership of a group was determined by nearest neighbour distance, i.e. within 20m (after Clutton-Brock *et al.* 1982).

Ideally, the activity of all group members would be recorded instantaneously, thus providing a snap shot image during each scan. Unfortunately this was impossible to achieve with a group size of more than one, as it took time to locate the next individual in the group. Therefore the activity of each individual at the moment of observation was recorded, and the next target located as quickly as possible. The time taken to scan a herd depended primarily on the number of individuals, degree of dispersion and weather conditions. A standard observation period of 30 minutes was used, giving a total of seven herd scans per observation period. (First scan commenced at 0 mins, final scan commenced at 30 mins)

3.2.2.2 Focal Animal Sampling:

An individual animal (the focal animal) was continuously observed and at the end of every minute the activity exhibited (at that precise moment) was recorded on a tick sheet (See below for activity types). In addition counts of bites per minute were recorded when the clarity of view, primarily affected by weather and/or distance from the observation point, permitted. Standard time spent per focal animal was 30 mins.
As with scan sampling it was attempted to sample equivalent numbers of stags and hinds, at the same times of day. Where possible the focal animal chosen had a physical attribute (normally coloration/patterning) which was unique within the herd being observed. This was to ensure that if the animal moved momentarily out of sight, it could be distinguished from others when it reappeared.

3.2.2.3 <u>Activity Types:</u>

In order to simplify data recording and due to the distance at which some observations were taken, seven broad categories of easily distinguishable and mutually exclusive behaviour were used.

1) Grazing:	Any feeding activity performed whilst in a standing position, including moving with head down in a grazing position.
2)Resting/lying:	Individual recumbent or moving to or from a recumbent position.
3)Moving:	Walking with head up, trotting and running.
4)Vigilant:	Adoption of a vigilant posture, i.e. head erect, ears forward scanning for disturbance or focusing on obvious disturbance. An animal may assume a vigilant posture whilst resting or lying, this is then scored as resting.
5)Scratching:	Any form of grooming including licking, nipping with teeth, scratching with front or hind legs, rubbing with head or rubbing against an object e.g. fence post.
6)Aggression:	Threatening behaviours such as eye rolling, scissors kicking, rearing, butting, biting or chasing.
7)Out of Sight:	Individual out of view.

In addition to the seven categories of behaviour individuals were placed into one of five age/sex categories:

3.2.2.4 Age/Sex categories:

1) Stag: Mature males, distinguishable by the presence of antlers, during the first study period. Once antlers had been shed (Second period) stags were still readily distinguishable as they are heavier set than hinds, have thicker necks, blunter foreheads and a distinctive way of moving.

2)Hind: Mature females generally smaller than males, with a more rounded forehead and face. General body structure and movements more delicate than males.

3)Yearling: Young deer of indeterminable sex, only found in hind herds, smaller than adult females, often accompanying a mature hind.

4)Young stags: Young males, often with the maternal herd, but distinguishable from yearlings by the presence of one or two tined "spike" antlers. After shedding of antlers, young stags remained distinguishable due to differences in body size and shape.

5) Calf: Offspring produced this season of indeterminable sex.

3.3 Data Analysis Methods:

3.3.1 Computer Equipment/Packages Used:

For manipulation and analysis of habitat availability/utilisation data two versions of the ARC/INFO Geographical Information System, (GIS), produced by Environmental Research Systems Institute (California) was used. One version (ARC/INFO PC) running on MS-DOS, supported on a Gateway 2000 P5-60 Pentium Processor PC, the other (Rev 6.0) on the University of Durham UNIX network, accessed through the "XWINDOWS" windowing system on Hewlett-Packard "Apollo 700" workstations. Databases associated with the GIS coverage's on PC were accessed through the Ashton-Tate "dbase" package.

Statistical analysis of both transect and observational data were performed on Microsoft Excel for windows, and SPSS for windows on the University of Durham NOVELL network, and a Gateway 2000 P5-60. Microsoft Excel for Macintosh was also used running on a Macintosh Classic II.

3.3.2 Transects:

3.3.2.1 GIS Data Layers:

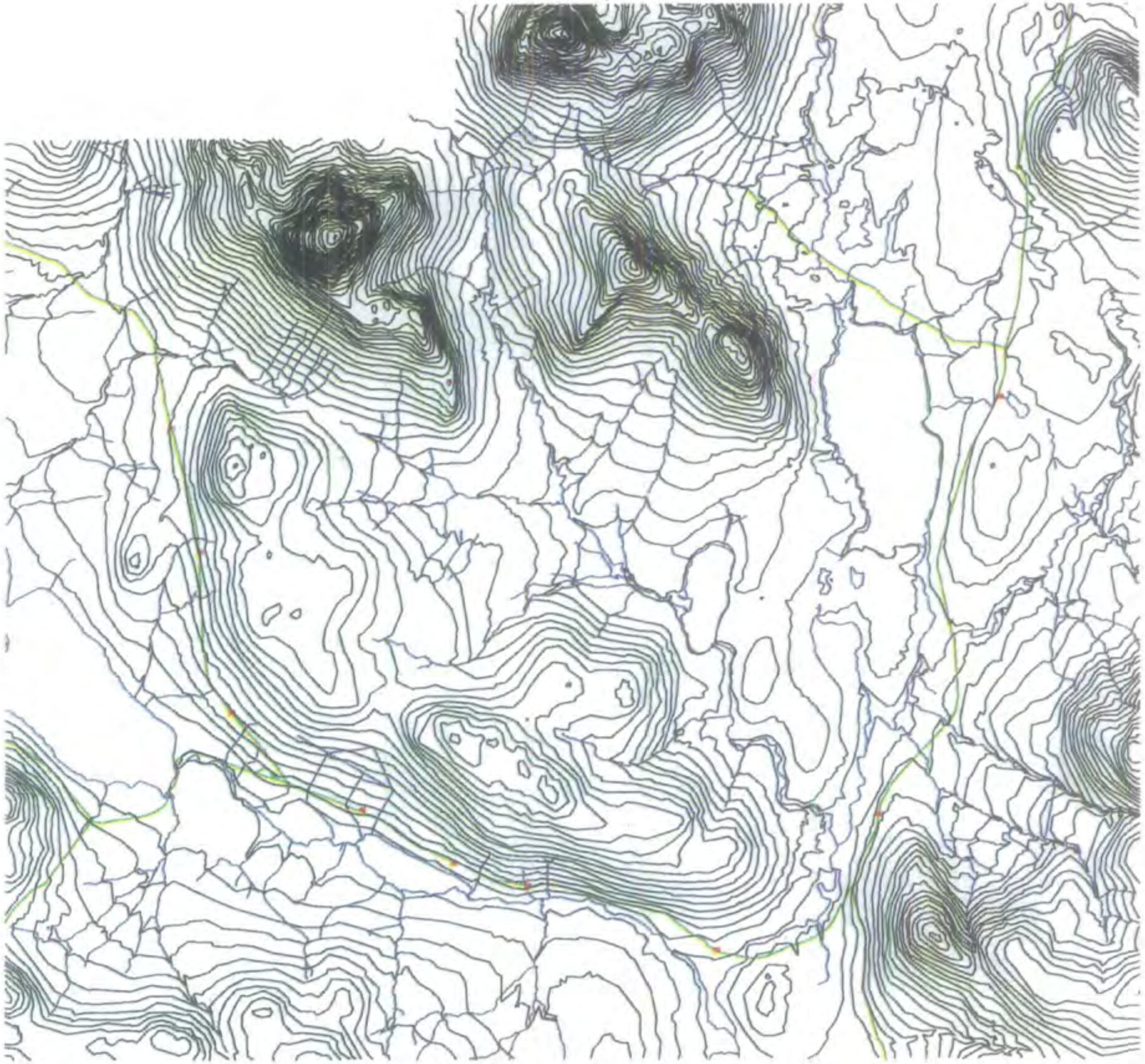
The NVC maps, and the transect maps were digitised, using a "Summagraphics summasketch II professional" digitising table and processed to form a coverage in PC ARC/INFO, supported on the Gateway 2000 P5-60.

Geographical features of the study site, such as water courses, lochs, roads and contours, were made available to me as ARC/INFO coverage's (Twiss *et al.* 1993). These along with the NVC maps of the area provided a data base representing the physical and vegetational structure of the study area.

3.3.2.2 Measurement of Habitat Sampled Using Viewfield Analysis Within the GIS

Using the maximum visibility distances recorded at the beginning of each transect and a three-dimensional Data Terrain Model (DTM) constructed from the study area contours, using the ARC/INFO T.I.N. (Triangulated Irregular Network) procedure, a visual field analysis was performed for each transect. A contour map of the study area, and a view from the resulting DTM are shown in Figures 6 and 7. This was necessary to provide accurate availability values for the different habitats (vegetation classes) as the total area seen, and therefore sampled differed for each transect due differences in working visibility. This processes was performed using the Arc/Info command VIEW FIELD, with an observer height of 1.5m, a 360° field of view and a maximum visual limit as recorded at the beginning of each transect. A coverage containing the 11 observation points was used to set the observer positions.

Figure 6



Observation Points shown in red

Roads shown in green

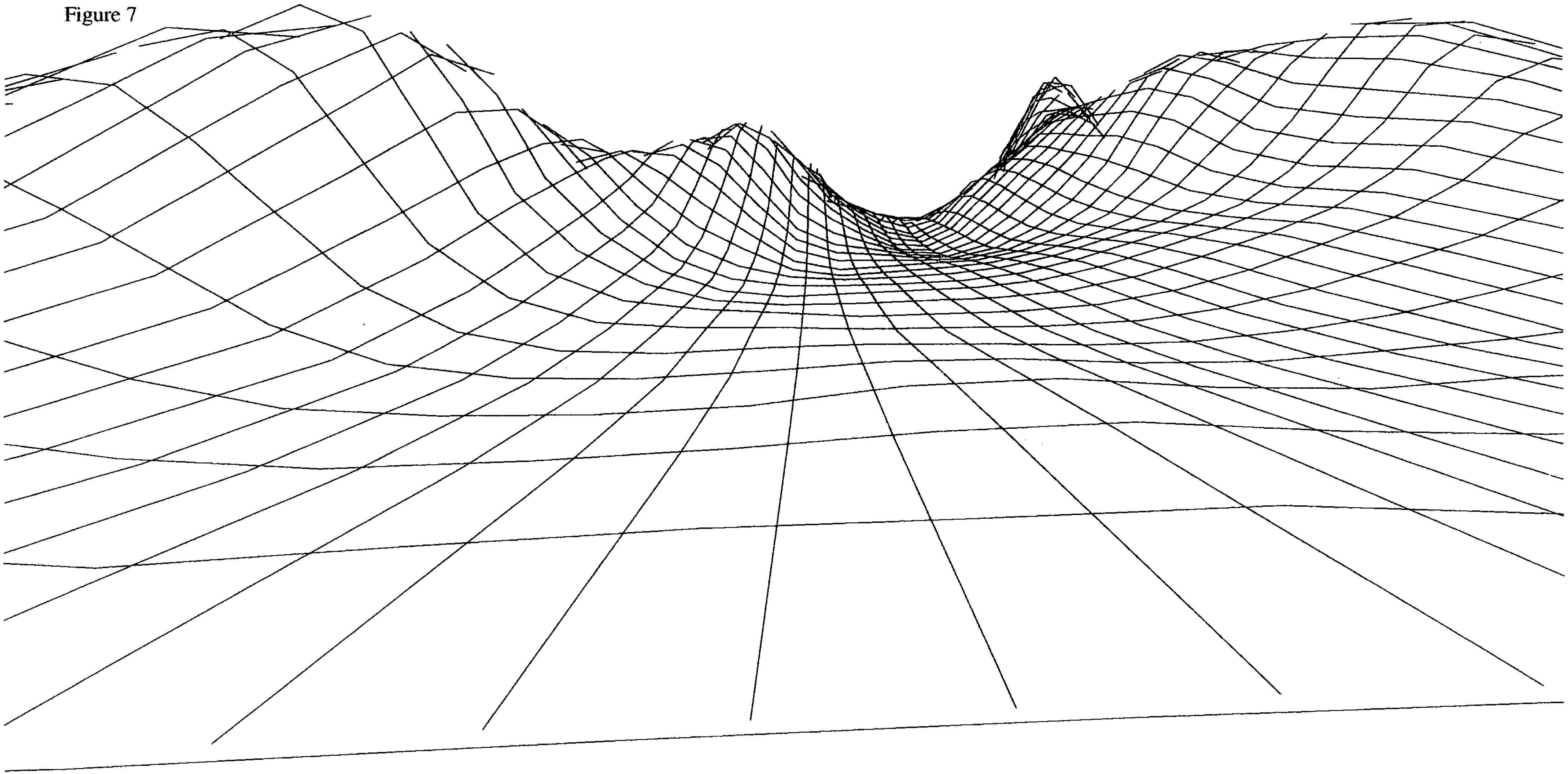
Streams and lochs shown in blue

Contours at 50m intervals

Scale, 15mm : 1km

Contour map of the study area, showing terrain features for reference.

Figure 7



The digital terrain model, viewed west from the final observation point.

Overlooking The Gremachary croft, at the foot of Meall a' Bhuirich.

This produced a visibility polygon giving the area visible from each observation point, including areas of overlap and areas excluded from view due to physical features, i.e. hills. This was then edited using the RESELECT command in order to produce a single visibility polygon defining the maximum visual extent, and a further coverage containing all the non visible areas within this. These coverage's were then used as "cookie-cutters" on the NVC map of the study site, through use of the CLIP command. This produced a coverage containing the total areas of each individual NVC type visible, and therefore available, when the relevant transect was performed, Figure 8 is an example of such a coverage, and shows the area sampled during transect 4.

3.3.2.3 Measuring Habitat Used by Herds Using Overlay Tools Within the GIS:

A similar process was performed using the G.I.S. coverage's created from the transect records. This involved using the herd coverages, as cutters on the NVC map through the CLIP command, to create new coverages showing the areas of the individual NVC classes occupied by Red Deer for each transect ("Occupancy coverages"). Then, through the RESELECT command, the stag herd polygons were extracted from the initial herd coverage's and used first to ERASE their corresponding polygons in the occupancy coverages, and then as CLIP coverage's on the full NVC map.

This process creates coverages showing the total areas of the individual NVC classes occupied by sexed herds. An Example of a coverage resulting from this procedure is are shown in Figure 9 (Occupancy by sex for transect 4).

The Polygon Attribute Tables (PAT), for these occupancy polygons, which contained the area values were then sorted and processed in SPSS, using RECODE and AGGREGATE functions. This provided an accurate measure of habitat utilisation in the form of area (m^2) of each NVC class occupied. This was then split into utilisation by sex over both study periods, hinds in period one and period two.

Figure 8

Observation Points shown in red

Roads shown in black

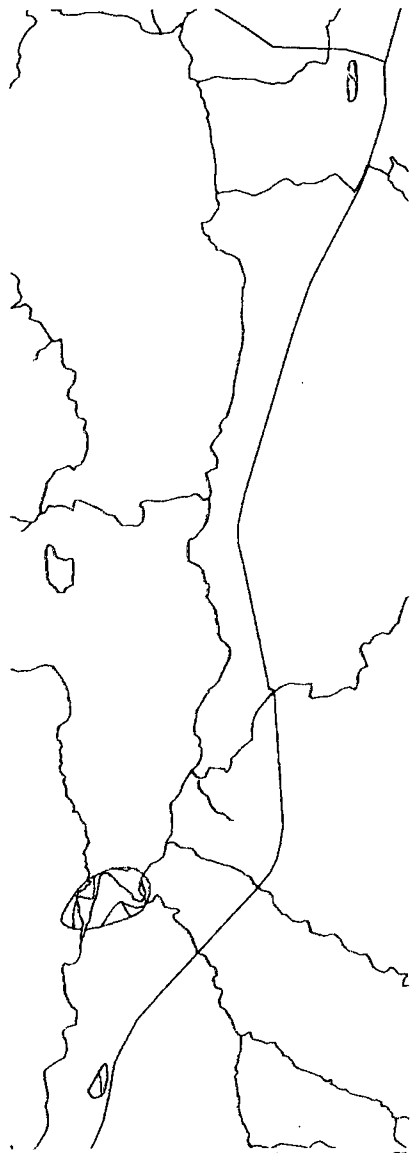
Lochs shown in blue

NVC classes delimited in green

Scale, 15mm : 1km

NVC map of the study area, 'clipped' to show area sampled (visible) during transect four.

Figure 9



Roads shown in black

Lochs and streams shown in blue

Stag herds shown in red

Hind herds shown in green

Scale, 3cm : 1km

Position and extent of Red deer herds, showing NVC classes occupied, during transect four.

Thus a range of different habitat utilisation values with corresponding habitat availability values were extracted from the data set. These values were then ranked and used to evaluate resource preference using the method first described by Johnson (1980). This method is a rank comparison, based on the difference between the rank of availability and the rank of usage for each habitat type.

Once the differences in ranks have been calculated for each dataset, in this case stags/ hinds and pre/post parturient hinds, the rank differences are tested to determine any difference between the paired sets. In this study, the test suggested by Johnson (1980), Hotellings T (Morrison 1976) is used. Hotellings T is a multi- variate paired t-test used to assess the significance of any differences which exist in the respective data sets. Should the F value obtained from this test show a significant degree of variation between the datasets, then a multiple range comparison can be used to identify which variables differ, and the extent of that dissimilarity. Johnson (1980) suggests the test described by Waller and Duncan (1969).

Alldredge and Ratti (1992) provide a review and comparison of four techniques for the analysis of resource selection, including a worked example of the Johnson (1980) method, which proved very useful when performing the analysis.

3.3.3 Behavioural Data:

3.3.3.1 Scan Samples:

During the analysis, "out of sight" animals were removed from the analysis (Clutton-Brock *et al.*). I inspected histograms of the total occurrences of each behaviour type, by sex and period, to note the gross differences, if any, in the dataset. The counts from the herd scans were then tabulated to provide the data table shown as Table 1 (Appendix 1). This was then analysed using SPSS Hierarchical Log Linear Multiway Frequency analysis.

This method constructs an interaction model using the full data set to account for all the interaction variables present in the data set. It then tests each possible grouping of interactions, (e.g. sex x activity; sex x activity x time), and eliminates those which are not found to significantly influence the data set.

It was used to identify the principle interactions among the four variables of sex, sample period, time of day and activity. In order to satisfy the requirements of this test the data had to be grouped as follows:

Time of day: Grouped in two equal time periods:
6 am to 2 pm: morning
2 pm to 10 pm: evening

Due to the infrequent occurrence of certain activities, such as scratching, aggression and vigilance only the three primary activities of grazing, resting and moving were included in the hiloglinear procedure.

The principal interactions identified from the multiway frequency analysis were then further investigated through SPSS crosstabs, using the chi-squared test option.

3.3.3.2 Focal Animal Sampling:

Mean bite rates per minute for stags (overall) and hinds pre/post parturition were calculated. The remaining data set from this sampling using this technique was not analysed due to time constraints.

4 **RESULTS:**

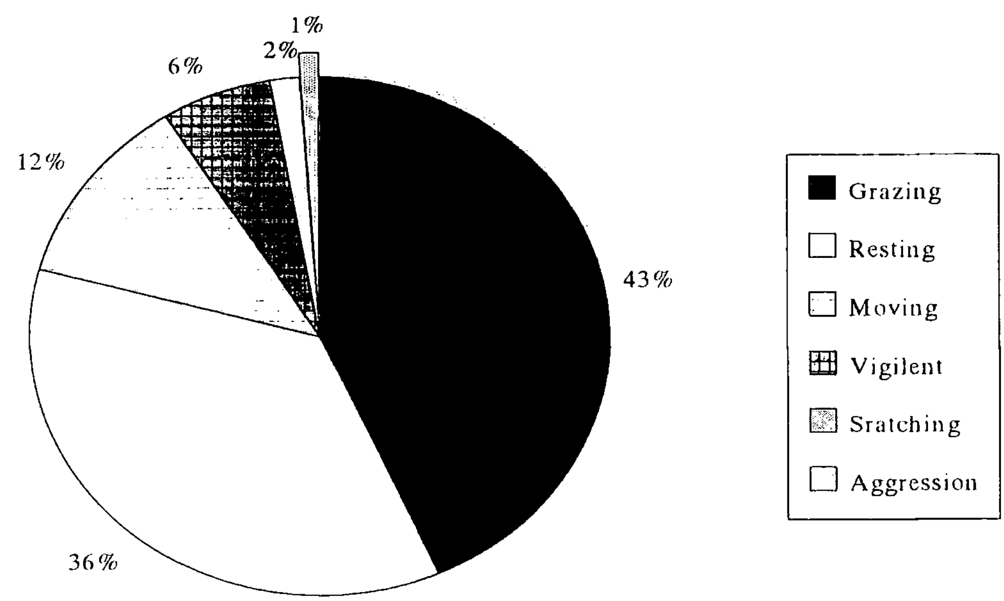
4.1 Behavioural Observations:

Observation sessions (according to 3.2.2 Behavioural Observations) usually occurred before or after a transect also herds under observation were normally within the area covered by the transects. Opportunistic sightings, and subsequent observation of herds fulfilling the required conditions (see 3.2.2) did occur outside the direct study site, and at non-scheduled times. Herds sampled ranged in size from one to forty individual animals, stag herds usually numbering less than hind herds.

4.1.1 Pie Charts showing total occurrence of activity types, subdivided by sex and study period are given in Figures 10 - 14.

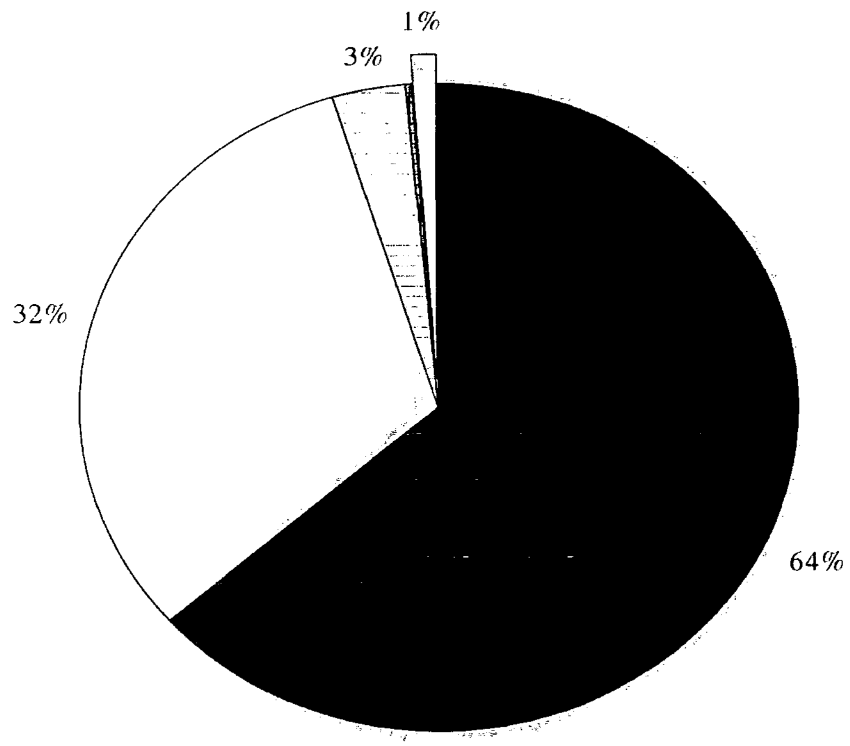
From Figure 10 it can be seen that the most frequently observed activity by stags was grazing, which occurred 43% of the time observed. Resting was the next most frequently observed activity, occupying 36% of the study period, with movement, vigilance, scratching and aggression making up the remaining time at 12%, 6%, 2% and 1% respectively.

Figure 10 Total Activity Exhibited By Stags Over The Full Study Period



In contrast Figure 11 shows the activity exhibited by hinds during the study period. As observed with stag herds, it can be seen that the most predominant activity observed was grazing, occupying 64% of the total observation time. The next most frequent activity observed was resting at 32% of the total observed time, followed by moving, vigilance and scratching at 3%, 1% and 1% respectively. The substantial difference in the amount of time spent in vigilant activities between stags and hinds is also interesting. Although this activity is not predominant in either sex, it is found far more frequently in stags than in hinds.

Figure 11 Total Activity Exhibited By Hinds Over The Full Study Period.

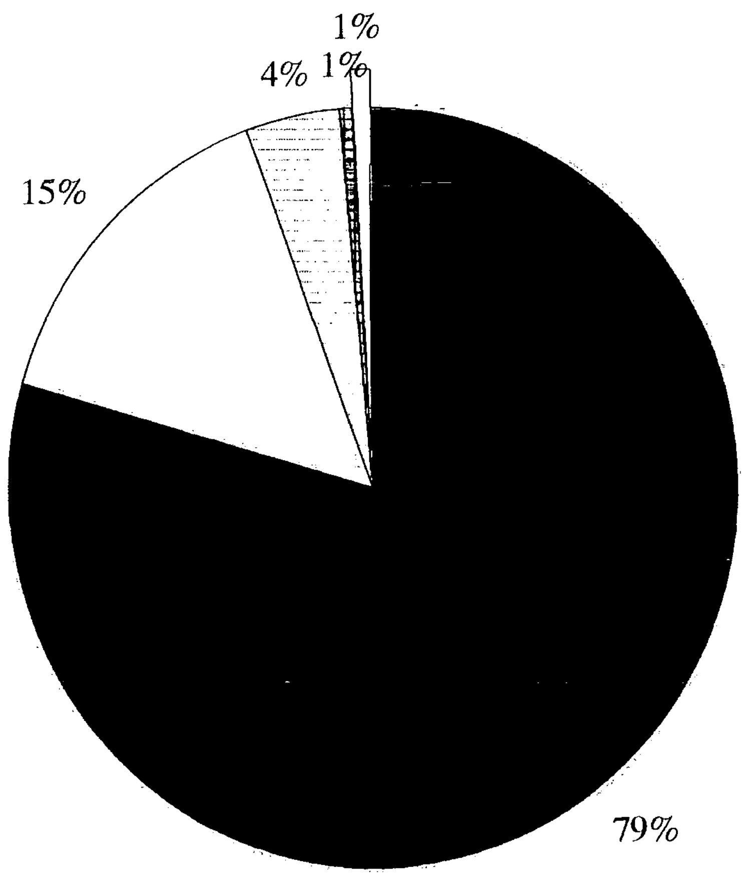


Refer to Figure 10 for key.

Figures 12 and 13 show activity observed in hinds pre- and post-partum.

The most striking feature of feature of Figure 12 is the time spent grazing, occupying 79% of the time pre-parturient hinds were observed. Resting occupied 15% of the remaining time, with moving and scratching taking up 4%, and 1% respectively. As in Figure 11, vigilance is an infrequent activity, also occupying only 1% of the activity observed.

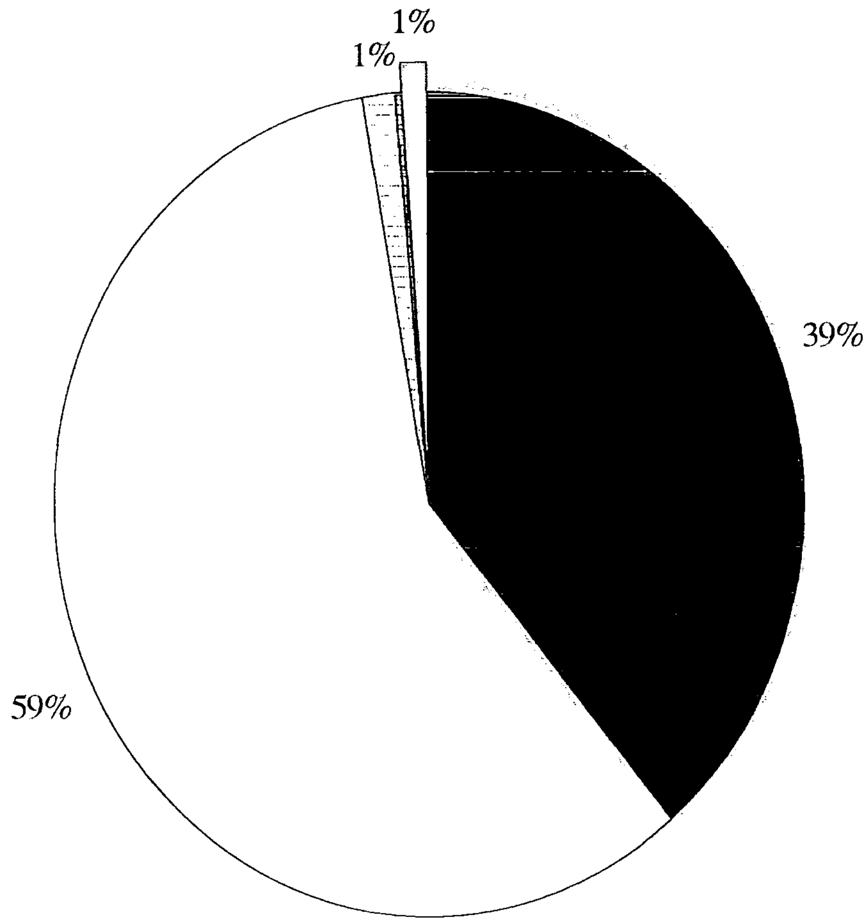
Figure 12 Total Activity Exhibited By Hinds Pre-Partum.



Key as in Figure 10

It can be seen in figure 13, that during the post calving sampling period, the most frequently observed activity is resting/lying down, which occurs 59% of the time observed. Grazing (39%) occupies the majority of the remaining time, with moving and scratching occupying 1% of the time each. During the post-partum period one might expect to see a rise in the amount of time spent vigilant by hinds, however this is not the case.

Figure 13 Total Activity Exhibited By Hinds Post-Partum.



Key as in Figure 10.

4.1.2 Multi-way frequency analysis:

Table 2 shows the significance of the multiple variable interactions. All levels of interaction are significant at the P=0.05 Probability level.

Table 2: Hierarchical Log Linear Analysis of The Multiple Interactions Occurring Between Sex, Period, Time and Activity

K	DF	Pearson χ^2	Probability
1	5	2823.6	0.001
2	9	1983.7	0.001
3	7	124.3	0.001
4	2	10.4	0.0055

Key: DF = Degrees of freedom

K = number of interacting variables i.e. Sex * Activity is a two-way interaction.

Table 3 shows the probability tests of the partial associations between the variables. It can be seen that all interactions are of Significance when tested (P = < 0.01), however interactions such as Period*Sex, Period*Time and Sex*Time have no direct relevance to activity patterns and so are not investigated further. As there is only one fourway interaction (sex x period x activity x time), and this was shown to be a significant interaction term, (Table 2), it has been excluded from Table 3, (which shows only partial, three way or less, interactions).

Table 3: Showing Partial Associations Between Variables.

Interaction	DF	Partial χ^2	Probability
Activity*Period*Sex	2	21.5	0.001
Activity*Period*Time	2	8.3	0.0162
Activity*Sex*Time	2	60.2	0.001
Period*Sex*Time	1	70.8	0.001
Activity*Period	2	289.1	0.001
Activity*Sex	2	81.6	0.001
Period*Sex	1	11.7	0.0006
Activity*Time	2	460.4	0.001
Period*Time	1	17.2	0.001.
Sex*Time	2	350.9	0.001

4.1.3 χ^2 Tables:

Tables 4 to 9 show the Chi-square tests applied to individual variable interactions. The observed and expected values are given (expected values in *parenthesis*), as is the Chi-square value, degrees of freedom and the probability of the result being due to chance.

Table 4 shows there is a statistically highly significant association between sex and the activity during both periods ($P < 0.01$).There are positive associations between stags and moving during the first period of observation, contrasted with negative associations between the amount of grazing and resting activity exhibited by stags in the same period. Hinds in period one show the opposite activity patterns.

During the second sampling period, hinds showed a negative association with regards to grazing and moving, correspondingly the time spent resting increased. For the same study period, stags spent a greater proportion of time grazing and moving and, as in period one, resting was shown to be less.

Table 4:

Activity by Sex, controlled for Period

ACTIVITY	STAG	HIND
Grazing	558 (607.3)	1140 (1090.7)
Resting	165 (199.9)	394 (359.1)
Moving	173 (88.7)	75 (159.3)

First Period

$\chi^2 = 140.46$

Df = 2

Probability < 0.01

ACTIVITY	STAG	HIND
Grazing	141 (120.4)	348 (368.6)
Resting	145 (175.6)	568 (537.4)
Moving	27 (17.0)	42 (52.0)

Second Period

$\chi^2 = 19.55$

Df =2

Probability < 0.01

From Table 5 it can be seen that the differences in the number of occurrences of the principal activities are significant ($P < 0.01$), when the time of day is considered as a factor.

Table 5:

Activity by Sex, controlled for Time

Morning

ACTIVITY	STAG	HIND
Grazing	96 (133.9)	737 (699.1)
Resting	195 (157.7)	786 (823.3)
Moving	10 (9.5)	49 (49.5)

$\chi^2 = 23.33$
Df = 2
Probability < 0.01

Afternoon

ACTIVITY	STAG	HIND
Grazing	603 (646.0)	751 (708.0)
Resting	115 (138.8)	176 (152.2)
Moving	190 (123.1)	68 (134.9)

$\chi^2 = 82.84$
Df =2
Probability < 0.01

Table 6 (over leaf) shows the effect of time on the relationship between activity exhibited and the study period. These differences are also shown to be significant at the $P < 0.01$ level.

Table 6: Period by Activity, controlled for Time

Morning

ACTIVITY	PRE-	POST-
Grazing	586 (469.6)	247 (363.4)
Resting	432 (553.1)	549 (427.9)
Moving	38 (33.3	21 (25.7)

$\chi^2 = 128.41$
Df = 2
Probability < 0.01

Afternoon

ACTIVITY	PRE-	POST-
Grazing	1112 (1031.0)	242 (323.0)
Resting	127 (221.6)	164 (69.4)
Moving	210 (196.4)	48 (61.6)

$\chi^2 = 199.82$
Df =2
Probability < 0.01

Table 7 shows the differences in activity exhibited by both sexes, differentiated by period, to be statistically significant (P< 0.01).

Table 7: Period by Activity, Sexes combined

PERIOD	GRAZE	REST	MOVE
Pre -	1698 (1450.9)	559 (843.8)	248 (210.3)
Post -	480 (736.1)	713 (428.2	69 (106.7)

$\chi^2 = 430.80$
Df = 2
Probability < 0.00

In Table 8 the differences in activity exhibited by the different sexes are shown to be significant when taken over the full study period. The differences in the occurrence of resting and moving behaviours are of particular interest.

Table 8:

Sex by Activity, Periods combined

SEX	GRAZE	REST	MOVE
Stag	699 (100.2)	310 (407.3)	200 (101.5)
Hind	1488 (1486.8)	962 (864.7)	117 (215.5)

$\chi^2 = 174.79$
Df = 2
Probability < 0.01

Table 9 shows the relationship between occurrence of activity, (combined over both sexes) and the time of day. The differences proved to be significant at the P< 0.01 level.

Table 9:

Activity by Time, Sexes combined

TIME	GRAZE	REST	MOVE
Morning	833 (1084.8)	981 (630.9)	59 (157.2)
Afternoon	1354 (1102.2)	291 (641.1)	258 (159.8)

$\chi^2 = 623.13$
Df = 2
Probability < 0.01

It can be seen from table 10 that the average bite rate per minute (BRPM) increased substantially in hinds after parturition. This is particularly interesting when the decrease in time spent grazing in the post- partum period is considered.

Table 10:

Mean Bite Rates Per Minute

Period	Sex	Mean Bite Rate per Minute	Number of Samples (minutes)
Pre	Stag	44	60
Post	Stag	40	25
Pre	Hind	59	50
Post	Hind	67.9	36

4.2 Habitat Availability/ Utilisation:

A total of 36 transects were performed, 21 during the first study period, and 15 in the second. Each transect comprised maps, showing position and extent of each herd seen, and a data table recording the composition (age and sex), and overall activity of those herds.

Herd size ranged from one to over one hundred individual animals. Herds of hinds were usually consistently larger than stag herds. The transect had a length of 11km. and was consistently driven from the western-most point. The area surveyed varied according to visibility, average visibility was 1.25km, resulting in a total area of 4017 km^2 being sampled. An average of 5 herds was seen on each transect, although this varied with time of day and visibility.

4.2.1 Total Area Comparison:

The values in the following tables show the total areas, available and utilised, of each habitat type, over the full thirty six transects.

Figure 14 shows the total availability of each NVC class expressed as percentages of the entire area surveyed. It can be seen that M18 and M17 to be the most abundant categories over the study site, comprising 35% and 30%, respectively, of the study site. Also abundant are the M25, U4 and M15 types.

Figure 14:

Total Areas of Individual Habitat Types Expressed as Percentages of the Total Area Surveyed, Over the Entire Study Period

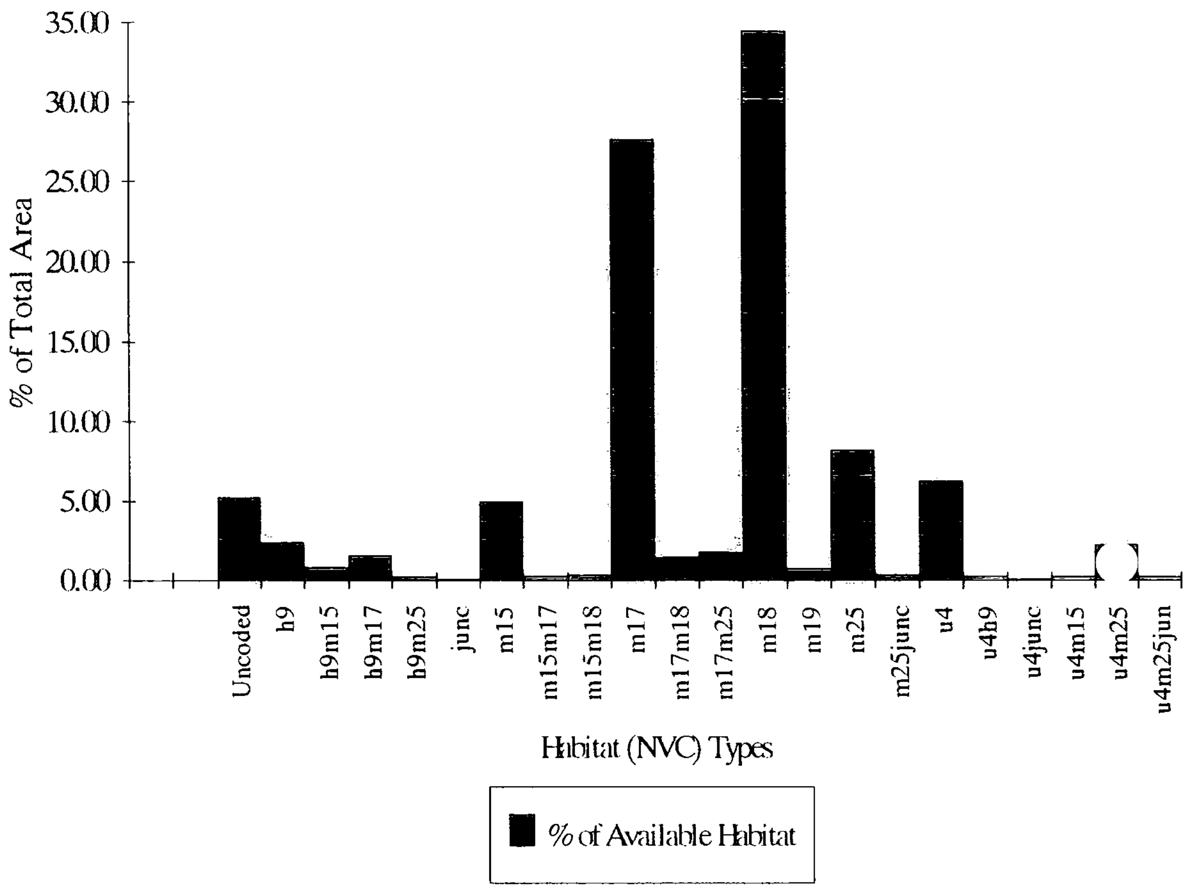


Figure 15 shows the area of each NVC type occupied, totalled over the 36 transects performed. This value is shown as a percentage of the total area occupied. From this it can be seen that the largest area occupied was NVC type M18, with 25% of all herds recorded during the transects occurring in that class. M15, M17 and M25 were also occupied to a considerable extent.

Figure 15:

Total Area of Each Habitat Type Utilised by Red Deer over the Full Study Period, Expressed as a Percentage of The Total Area Occupied

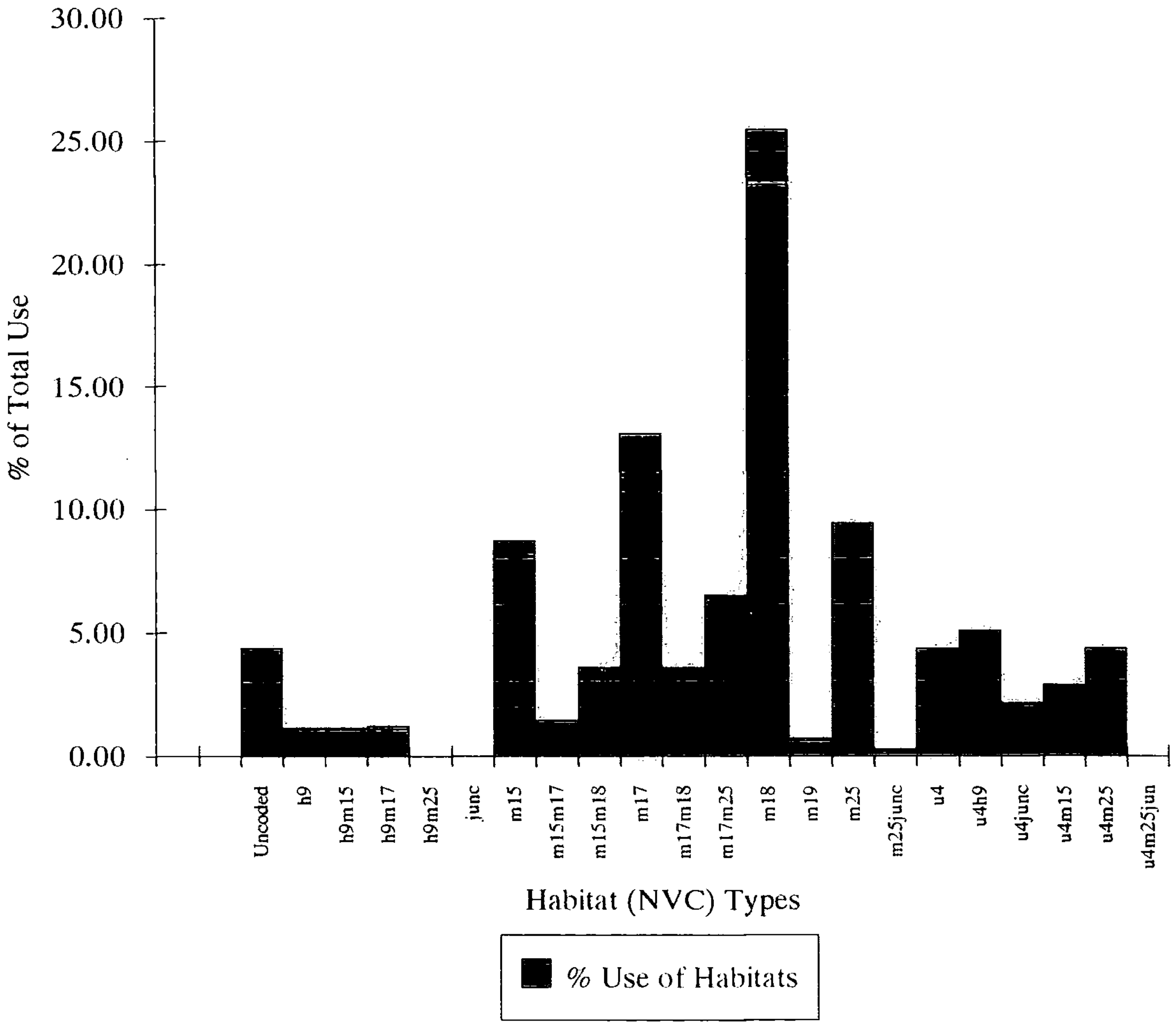
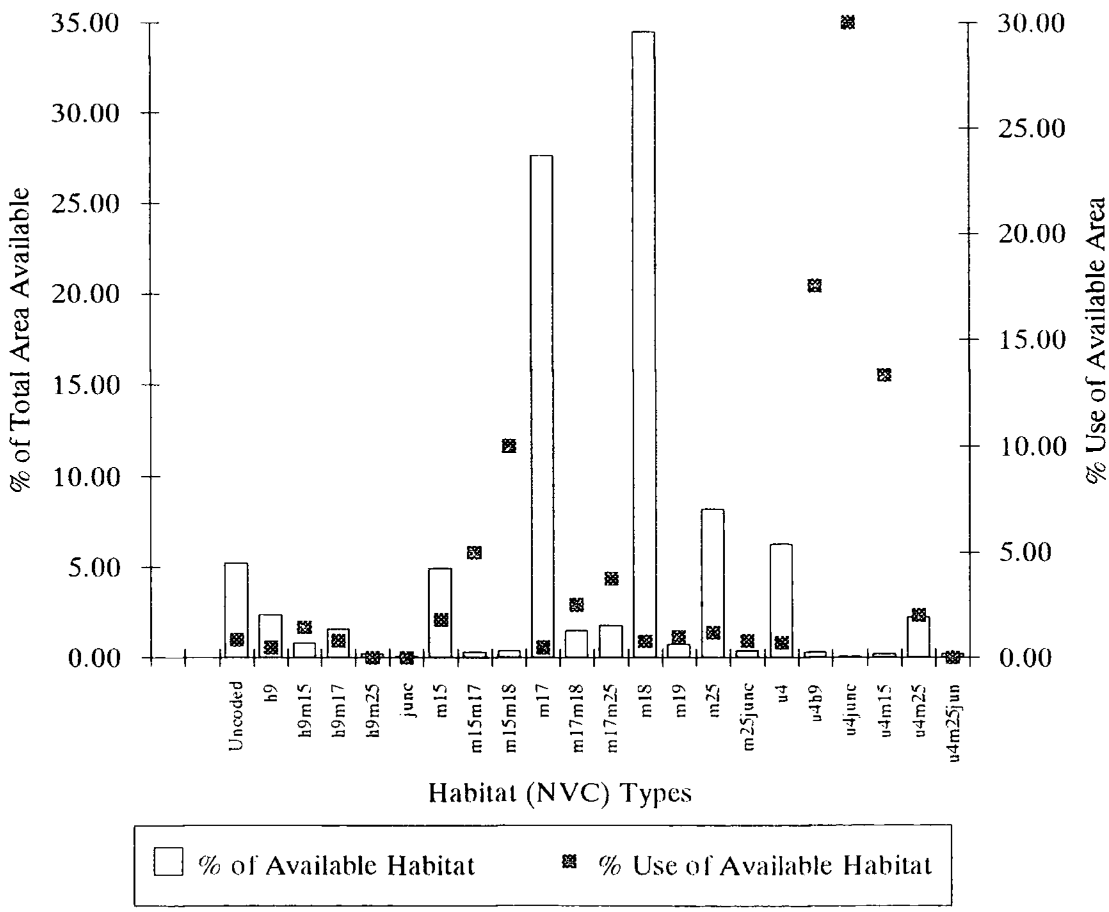


Figure 16 shows the total; area available of each habitat type, expressed as a percentage of the total area surveyed, overlain by the area of each habitat used as a percentage of the respective habitat type availability. This shows that, relative to abundance, types U4/H9, U4/Juncus and U4/M15 are the most utilised NVC classes. The most plentiful categories (M17 and M18) show very little usage, relative to their abundance in the study site.

As these values are essentially both proportions of the total area available, statistical analysis of this data was not possible within the time constraints of this project. However, through use of the GIS grid technique it would be possible to generate a frequency count of the different habitat types, both available and utilised, which would be ideally suited to application of Bonferroni type analysis.(Neu *et al.* 1974)

Figure 16

Comparison of Area Available, as a Percentage of Total Area, and Percentage of Available Habitat Used



4.2.2 Rank Comparison of Differences in Availability and Utilisation Ranks:

Table 11 (Appendix 2) shows the differences in ranked availability (km^2) and utilisation (area of each NVC type occupied) values extracted from the area occupied/ area available coverages in the GIS, combined over all the transects performed to provide a comparison between habitat use by stags and hinds, over the full period, and hinds pre against hind post-parturition.

The comparison of habitat utilisation by stags and hinds proved to be non-significant ($F = 0.00076$, $P = 0.999$), as did the comparison of hinds pre- and post-partum, ($F = 0.80496$, $P = 0.461$).

5 DISCUSSION:

5.1 Behaviour Of Red Deer:

Taking an overall view of the full study period and both sexes (Table 9), it appears that more time is spent resting during the morning category, with an increase in grazing and moving (which are complementary activities) during the afternoon.

The unexpectedly high degree of time spent resting during the morning is likely to be the result of an unobserved pre-dawn grazing period, which is common in Red Deer (Georgii, 1981). The increase in moving and grazing in the afternoon is indicative of one or more daytime grazing bouts. Anecdotal information and observation experience suggests a short midday and a longer early evening grazing period. However, splitting the data set into three or four time bands would result in compromising various statistical assumptions and requirements. A larger data set requiring more field work would be necessary to explore this aspect further.

On comparing the activity patterns between the sexes, over the full study period (Table 8, and Figures 10 and 11), it can be seen that in general hinds spend proportionately less time moving than stags, and more time resting is also observed. However it should be noted that these figures are relative to the other activities exhibited. Although stags spend a greater proportion of the time resting, when compared to hinds, stags spend less time resting than would be expected when the three principle activities are considered, within the sex, (Table 8). Table 8 also shows that the hinds are resting for a greater relative proportion of time than would be expected. This may be due to stags being under less harsh energetic constraints than the hinds during the period of study.

Whilst both sexes are rebuilding reserves post-winter, the hinds are rapidly approaching and undergoing parturition and resulting lactation, a period of high energetic cost, (Arman, 1974). In contrast, the main energetic challenge to the stags occurs during the rut, which usually begins in October, (Mitchell, McCowan and Nicholson, 1976, Lincoln 1971a, Bober, Perzanowski and Weiner, 1990), and hence a reversal in behavioural patterns may be observed during this time. Unfortunately the time constraints of the project restricted further observations at this later time.

On several observation sessions of stag herds during the study period, activities of "energetically wasteful" behaviour were recorded, suggesting that at the time of study the energetic requirements of the stags were somewhat less than that of the hinds. For example, a herd of seven young stags (4-5 years old) which were resting at the start of the observation period, were recorded to stand up, (some twenty minutes after observation began), and proceed through a shake, urinate, stretch and defecate routine, which commonly occurs after any recumbent period, (pers. obs.). The stags were then observed to chase one particular individual, which initially appeared to be an antagonistic/hierarchical display, until it was noted that the individual being chased changed frequently whilst the herd ran in circles around an area of ca. $1km^2$. This activity continues for approximately 11 minutes.

The herd then returned to the area in which they had been previously resting, spent some two minutes stretching and shaking and then resumed recumbent positions until the observation period ended, a further 20-30 minutes later. Although antagonistic behaviour was observed, whilst this activity was occurring it never occurred consistently i.e. with the same individual initiating or being the recipient of such behaviour. Similar activity was observed on several occasions during the period of study, but was only noted in herds of stags, and never in herds of hinds.

Introducing the time of day as a factor adds another dimension which is both complicating and revealing. As can be seen from table 5, hinds in general spend a disproportionate amount of time resting and this tends to occur during the afternoon, with grazing occurring equally throughout the day. In contrast the reverse was observed for resting by stags. This suggests a temporal differentiation in foraging patterns. This has not been reported in any previous study.

A gross comparison of activity and study period (pre/post partum) can be seen in table 9, with table 6 breaking this down into time categories. It is clear that more grazing and moving occurs during the pre-calving period, with a correspondingly larger amount of time spent resting during the post calving period. This pattern holds true when the aspect of time of day is introduced, (Table 6).

Table 4 provides more detail with regard to sexual differentiation in activity patterns in the different study periods at different times of day. It can be seen that the proportion of time spent moving by hinds was significantly less than would be expected during both study periods, with the difference in time being spent grazing and resting.

It was observed that hinds spent more time grazing pre-calving, presumably to build up fat and energy stores for the subsequent lactating period, and spent more time resting post-partum. One may expect that hinds would spend more time grazing post-parturition, as it has been postulated that lactation carried a higher metabolic demand than gestation (Arman 1974) this, however, was not observed.

There are a number of factors which are pertinent here. At the time when calving occurs, usually June, there is also a period of vegetation bloom resulting in more abundant, higher quality forage. This rapid growth is illustrated clearly in Figures 17 and 18. These show U4/Juncus type NVC areas during the pre-calving (17) and the post-calving (18) periods. This suggests that although hinds spent less time grazing post-calving, the actual time is more energetically profitable due to the higher food quality.

Rate of ingestion may also be worth considering. Table 10 shows the bite rate per minute, (BRPM) of stags vs. hinds during both periods of study, and hinds pre- vs. post-parturition. Although bite size was impossible to measure, using BRPM as an indicator of the rate of ingestion these figures show an increase in intake of food by hinds during the post-parturition period. This may be connected with an increase in habitat quality, it becomes possible to feed at a faster rate when a higher quality of food is available, as the need for selective feeding is diminished. Further observations on herds with and without plentiful food sources post-partum would provide additional information regarding this issue.

During the 12-24 hours directly prior to giving birth, the expectant hinds were observed to move to the edge of the herd group, spending the majority of time recumbent. Identification of such individuals during this time is aided by observing that the tail is usually continually erect during this period, even when recumbent (pers. comm. B. Lyall). Directly post-partum, the calf "goes to ground" laying in concealing vegetation, usually a tuft of *Juncus* or *Deschampsia*. They are remarkably cryptically coloured and remain motionless if approached stealthily. Mothers leave their new-born, rejoining the herd but returning 2-3 times daily to suckle the calf.

Figure 17.

An Area of NVC Type U4\Juncus
During the Pre-parturition Study Period.

NVC type U4\Juncus is shown in the fore-ground of the picture.

Note the dull colouration and general lack of vigour in the vegetation.

(Photograph Courtesy S.Twiss, 1994)

Figure 18.

An Area of NVC Type U4\Juncus
During the Post- Parturition Study Period

Figure 18 shows a similer area of U4\Juncus, during the post-partum study period, some four - five weeks later. Note the difference in both colour and height of the vegetation, when compared to Figure 17. This is indicative of a flush of growth, a similar flush was observed in all vegetation classes, however it was most noticable in the U4 and U4 combination types.

Both Figure 17 and 18 were taken on the same camera, using the same film.

(Photograph Courtesy S. Twiss, 1994)

When the calf is more mobile, usually within 3-5 days, it too joins the matrilineal herd, moving with them, but returning "to ground" when resting. The range of the maternal/matrilineal herd becomes greatly reduced, (Clutton-Brock and Albon, 1989), and all of the individuals appear a little "lazy" during this period of 5-6 days directly pre- and post-partum, although it must be stressed that no quantifiable data was recorded on this particular aspect of hind behaviour.

However, the energy demands of yeld (non-breeding) hinds may be as little as half that of a milk (breeding) hind (Anderson, 1976), Calving hinds are recumbent directly pre-partum and undoubtedly drained directly post-partum. Thus the potentially reduced activity of both milk and yeld hinds may be casual factors in the apparent decrease in the proportion of time spent grazing in the post-calving study period.

With an increase in the milk demands, a corresponding increase in the grazing time of milk hinds would be expected. However, the initial demands may be tempered by the physical capacity of the new-born calves but as they grow over the proceeding weeks so the volumes of milk required increases accordingly. This aspect is discussed further in habitat use.

Stags followed the same trend with regard to grazing and resting, but showed significantly more time moving during both periods. The same hypothesis proposed earlier to explain the unexpectedly high proportion of time spent moving around remains feasible here. If the field season were extended, it may be expected to observe an increase in BRPM and time spent grazing in stags, as the rut approached. This would correspond to the higher energy constraints of this period with 80% of body fat and up to 20% total mass being lost in a matter of weeks (Clutton-Brock & Albon, 1989).

Overall, the activity patterns exhibited by the Deer observed in Sutherland are broadly comparable with those found on Rhum (Clutton-Brock *et al.*1982). A slight difference was found in the BRPM values, this may be due to sampling occurring at different times of year, or an artefact of the different vegetation communities

5.2 Habitat Use:

Figure 14 shows the total area of habitat available over the full study period. NVC types M18 and M17 (raised and blanket mires) are the predominant habitat types. This is entirely to be expected considering the area in which the study was performed. The M25 and U4 grasslands also occur over a large area, although substantially less than the M17/M18 mires.

The utilisation by deer in terms of total area used shows a similar pattern, (Figure 15). Deer were observed most frequently in the M17 and M18, which is probably not surprising as these habitat types are so dominant in the study region.

Taking the area used as a proportion of the area available, (Figure 16) provides a more meaningful view of the actual utilisation of the habitat. Immediately it can be seen that although M18 was the largest area used by deer, taking use relative to the proportion of M18 available, the actual degree of utilisation is very small. Only ca. 1% of the available M18 is used by the Red Deer during the study.

Identical results were obtained for the utilisation of the M17, where again as little as 1% of the total available area was actually used.

Somewhat surprisingly the grassland types, M25 and U4 were also poorly used, with only 1.5-2% of the available area being used by the Red Deer. This may be partly due to the large areas of U4 being semi and improved pasture and therefore fenced off and inaccessible to the deer. Although as previously mentioned the actual physical presence of fences often infers little or no restrictions on the movement of the animals.

Most of the areas of pasture are however, near to houses and/or roads which may cause disturbances to the deer, particularly during the daylight hours, when this study was conducted. Experience at night on the roads in the area suggests that the deer move into these areas when human activity levels have diminished. Indeed short forays made by torch light into fields unoccupied by deer during the day, often revealed their presence at night. This leads me to suggest that the U4 is primarily used at night, although further work is required to asses the overall habitat use by the deer, out of daylight hours, and its overall significance. This was unfortunately not possible during

the during the field study due to time constraints, and impractical due to the presence of nesting birds and ewes with lambs in the majority of the fields concerned.
In addition roads commonly have a fringe of U4 along the margins and this was certainly observed to be used by deer at night (pres. obs., Twiss, 1994, unpublished). However, the deer generally avoid the roads during the daylight hours (when this study was conducted), so the extent of this utilisation was not investigated.

M25, although a grassland habitat, is not usually heavily used by deer (Clutton-Brock and Albon, 1989) *Molinia caerula*, the predominant species in this area is well adapted to withstand grazing pressure, with the edges of the individual blades being tough and sharp. In addition the tussock growth form means that new tender shoots are protected by last years growth, until they harden. This may explain the low usage of the U4/M25 areas, with the *Molinia* deterrent effective even when mixed with the more palatable U4.

The three habitat types that were observed to be used to the greatest extent are all combination classes, and share a common class. U4/M15 is used to 14% of its availability with U4/H9 and U4/*Juncus* being used 17% and 30% respectively. Such an observation indicates a degree of selection as all three classes are among the least abundant of the NVC groups. However the actual usage may be also be related to the other influences such as sheltering from weather conditions etc. which may affect the deer's food choice.

U4 and M15 are both complex, varied classes and it may be this variety which makes it attractive to the deer. Red Deer will commonly consume an amount of coarser material in addition to more palatable and digestible grasses (Clutton-Brock & Albon, 1989)). Indeed controlled feeding of deer has shown that heather, when consumed with grass is more digestible than when ingested alone, (Milne, MacRae, Spence and Wilson, 1978). With regard to this, it is interesting to note that M15 is also dominated by the heathers, *E. tetralix* and *C. vulgaris*, *Calluna* in particular forms a major part of Red Deer diet, (Staines, 1979, Staines, Crisp and Parish, 1982).

H9 is also dominated by *C. vulgaris* and normally contains a high abundance of *Vaccinium myrtilus*, the bilbery, which has been shown to be readily consumed by Red Deer, (Moss, Welch and Rothery, 1981, Welch, 1984). Another feature of H9 is its dryness. Typically H9 occurs on hummocks or slight rises and is usually substantially drier than the surrounding areas. This may result in Red Deer resting on these areas in preference to the wetter (and often colder) surroundings.

U4/*Juncus* usually occurs on slightly wetter marshy areas, associated with stream gullies, or the margins of M25, although observations suggested that the attraction to the deer grazing here was again the U4, and on no occasion was the *Juncus* spp. observed to be grazed. Whilst not a common U4 combination, it potentially offers greater access to U4 herbs and Grasses, as *Juncus* spp forms discrete clumps or flushes within the U4 sward.

Another class utilised relatively highly is M15/M18, where 10% of the available area is used. This may indicate a preference for a particular species found in either type, but may also be due to the degree of variation in composition found in this habitat type. M18 itself is highly varied, both in structure and specific makeup, and the main feature of the M15 class is its wide specific diversity.

A common feature in these most used NVC/habitat types is the variation that exists. All four are combination categories, possessing a wide floristic composition. It seems that this apparent selection for variation in composition may be an important feature when considering management of Red Deer, (see "Implications for Management" for further discussion).

To summarise, habitats containing an element of NVC class U4 were most extensively used, despite being amongst the least available, whereas U4 itself was predominately unused. More work would be required to ascertain if this factor was a result of disturbance rather than avoidance. In contrast, the predominately available classes of M17, M18 and M25 were little used, with only 1% of the total available area seeming to be occupied.

It may be expected that use of the grassland U4 category would decrease over the autumn months as the grasses die off and the quality of the forage fails, and a corresponding increase in the usage of M15 and H9, predominantly the heathers and *V. myrtilus* may be expected for the same period, with heather being the staple food resource over the hardest winter period.

Once productivity picked up again in habitats less dominated by heather, the degree of utilisation would be expected to change again accordingly.

The rank comparison performed (after Johnson 1980), to assess differences in utilisation and habitat selection, showed no significant difference in either stag vs. hind or hind pre- and post-partum. (Table 11) This result meant that selection ranks could not be subsequently calculated, although the overall picture can be seen clearly from Figures 14, 15 and 16

Therefore the tests suggest that there is no difference in the habitats used, or indeed the degree of usage of each habitat by either stags or hinds, at least at this time of year.

In comparison, studies into the behaviour of stags and hinds on the island of Rhum (Clutton-Brock *et al.*, 1982), found that although the two sexes used different plant communities in slightly different ways, the usage was dependant upon the local conditions and observations were never found to be consistent throughout the study.

The non-significant result of the same test applied to habitat utilisation by hinds pre- and post-parturition is initially puzzling. One would expect a change in habitat use post-parturition in response to the increased energy demands of lactation. However, this energetic cost peaks some four-six weeks after birth (Moen, 1973, 1978) as initial lactation costs are tempered by the small capacity of the calves. If it had been possible to continue the field study I suspect that increased usage of U4 and U4 combination habitats would have become evident. In addition, the selective influence that may be exerted when the calves begin to graze, some four weeks post-partum may be also worth considering, as it has been suggested that the calves require higher quality, easily digestible forage, such as the relatively herb rich U4 (Clutton-Brock, 1982), which would suggest that again a higher usage of the U4 classes would become evident.

5.3 Implications For Management:

One factor which becomes instantly apparent from this study, is that the deer are very selective users of the available habitat. A large proportion of their diet is taken from a small proportion of the available habitat. This is an important consideration, particularly in areas such as Sutherland, where large scale planting of exotic conifers has taken place. Whilst the immediate effect of this afforestation, i.e. the change in the area planted, is easily described, the longer term implications of such developments are as yet only speculation.

It is not only these such developments that may influence the deer populations in this area, land drainage and improvement alters the composition of plant communities and thus affects the local food resources. This may actually be beneficial to the deer, as herb rich grassland which commonly develops from such land management is a preferred habitat.

A general conclusion to draw is that varied habitats are preferred by the Red Deer in Scotland at this time of year, and areas that offer a mix of bulk forage, such as Calluna, and mixed grassland seem to be the most favoured habitat. It follows that improving or increasing the area of such habitats may well lead to an increase in both the population and quality of the deer in that population, if, at this time of year, food is a limiting factor.

Conversely removal or restriction of deer from such areas would have distinctly negative effects on both population health and density. It is likely that these effects would be disproportionate to the physical area lost or made unavailable, as the habitat is used in such an unequal fashion.

The influence of the deer themselves on their habitat is not inconsequential. A moderate level of grazing maintains both structural and specific diversity. Equally a heavy grazing regime can result in swards of a few resilient species coming to dominate an impoverished assemblage. Deer can quickly remove annual production and by dint of grazing vegetation so low, flowering is prevented, (Clutton-Brock and Albon, 1989). This can obviously have disastrous effects for local diversity.

The action of deer combined with sheep walk, as it so often is, can be beneficial to the structure and diversity of the vegetation. Although sheep and Red Deer essentially compete for the same resources, it seems likely, certainly from a commercial aspect, that a combination of the two is more profitable than stocking one or the other. However, it must be borne in mind that they utilise a common resource, which is also used by grouse. Therefore, a balance must be struck to avoid overstocking the area with sheep, or allowing over population by deer, either or both of which would result in the habitat becoming damaged through overuse.

5.4 Use of GIS in the Study:

The application of GIS to ecological studies is a relatively new field. In this study it provided an excellent solution to the problem of how to accurately quantify the available areas of the habitat types under consideration. Use of the TIN structure, through the viewfield analysis is both a novel and ideal solution. This is only possible through the overlay procedures, unique to GIS, that allow creation of new datasets from existing ones.

That aside, the sheer quantity of data required to perform a study on this scale necessitated some sort of spatial database in order to efficiently sort and manipulate the data collected. This requirement, coupled with the physical scale and variation inherent in the data made GIS the ideal tool for the task. Not only can the data be manipulated, relatively quickly, but the results, graphically displayed, are immediately accessible and available for assimilation. This is unlike more traditional procedures.
As GIS becomes more user friendly, incorporating analytical statistics in the GIS environment, I feel their application and use will spread, particularly in the field of ecology, which so often is geo-referenced and spatially oriented. The coupling of GIS with remote sensing techniques, such as radio-telemetry, satellite imagery and positioning, creates entirely new opportunities to explore, define and understand natural phenomena and processes on an ever increasing scale.

However, GIS is not something suited to the short term study, unless there are already existing coverages. In this study the environment GIS i.e. physical features such as contours, roads and streams were already available (Twiss *et al.* 1994). Digitising coverages does take considerable time, but maps of such features are becoming increasingly available, in digital format, speeding up the process immensely. Time is also required in order to learn how to use the particular GIS to its fullest potential. In this study only the tip of the iceberg has been touched in terms of analysis possible on the dataset.

Using the TIN and meteorological data it is hoped to assess the use deer make of the shelter offered by the landscape. Daily records off wind speed and direction incorporated into the environment GIS will allow investigation into the movements of deer correlated to prevailing winds, and assess the extent to which wind shadow, caused by physical features is used. It would also be feasible to incorporate data relating to human activity into the GIS.

Correlations between human presence, intensity of human activity and the movement of deer are quite likely, and easily explorable in the GIS environment.

As a management tool GIS has great potential, and a wide application. The only bar to its use being the technical knowledge required to initiate and maintain the system, and the initial fiscal outlay required. That being said, one person utilising the GIS to its full potential, with access to the required databases, can achieve a great deal very quickly.

"In answering the 'where' of an ecological question,
we get closer to knowing the 'why'"
(Thomas, 1993).

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APPENDIX 1

Table 1 shows the data taken from the herd activity scans, combined to provide a total occurrence of each activity type by sex, period and time.

Table 1: Totalled Herd Scan Activities

Period	Sex	Time	Grazing	Resting	Moving	Vigilant	Scratching	Aggressive
1	0	0	12	32	0	0	0	0
1	0	0	80	88	10	29	3	2
1	0	1	49	45	59	34	6	7
1	0	1	417	0	104	30	11	5
1	1	0	381	199	26	6	14	0
1	1	0	113	113	2	0	2	0
1	1	1	0	0	0	0	0	0
1	1	1	646	82	47	1	1	0
2	0	0	0	0	0	0	0	0
2	0	0	4	75	0	0	1	0
2	0	1	36	44	7	0	0	0
2	0	1	101	26	20	3	6	0
2	1	0	22	12	7	0	1	0
2	1	0	221	462	14	0	7	0
2	1	1	7	52	0	0	1	0
2	1	1	98	42	21	2	3	0

Key:

Period refers to study period; Period 1 : Pre-parturition (20th April-10th May)
Period 2 : Post -parturition (6th June-4th July)

Sex:

0 =Stag.
1 = Hind.

Time refers to time of day : Time 0 : Morning (6 am to 2pm)
Time 1 : Afternoon (2 pm to 10 pm)

See section 3.2.2.3 METHOD for activity definitions

APPENDIX 2

Table 11 shows the differences between the totalled availability and utilisation ranks used in the rank comparison procedure described by Johnson (1980).

The data were extracted from GIS coverages as described in section 3.3.2 of METHODS, then sorted and combined using SPSS. The data files containing the ranked availability and utilisation values for individual transects are give in appendix 4.

Table 11 Showing Difference in Availability and Utilisation Ranks, Combined, for Stags and Hinds Over the Full Study Period, and Hinds Pre- and Post Parturition.

HABITAT	FULL PERIOD STAG	FULL PERIOD HIND	PRE-PARTUM HIND	POST-PARTUM HIND
Uncoded	1.0	1.5	1.9	2.1
H9	6.4	6.2	5.5	7.3
H9M15	1.2	2.4	2.8	2.2
H9M17	3.5	3.5	2.4	4.8
H9M25	-4.3	-4.4	-4.4	-4.2
Juncus	-7.0	-7.4	-6.8	-7.2
M15	1.3	0.8	2.7	-1.7
M15M17	-2.3	-1.7	-1.4	-1.6
M15M18	-0.2	0.5	0.07	0.8
M17	3.9	3.5	4.2	2.3
M17M18	2.3	3.2	2.6	3.4
M17M25	4.5	4.2	4.7	3.2
M18	2.9	3.2	4.5	2.3
M19	-8.4	-7.5	-8.3	-7.6
M25	4.2	2.9	3.4	2.2
M25Juncus	-1.0	-1.2	-1.2	-3.0
U4	5.6	5.4	5.1	5.9
U4H9	-2.9	-2.9	-3.9	-2.7
U4Juncus	-7.4	-7.6	7.9	-6.4
U4M15	-5.3	-5.2	-5.0	-5.7
U4M25	4.2	2.4	3.2	1.9
U4M25Juncus	-3.0	-2.8	-2.2	-2.7