A Study of the diets of Feral Goat Populations in The Snowdonia National Park.

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SUMMARY

A study of the botanical composition of feral goat (*Capra hircus*) diets was carried out using faecal analysis. Two groups of goats in the northern part of the Snowdonia National Park were selected, one using mainly lowland deciduous woodland, the other restricted to upland heath at over 400 m altitude.

Diets of male and female goats were analysed separately on a monthly basis and related to information on range, group structure and habitat utilisation.

At the upland site little segregation of the sexes took place and overall diets between the sexes were similar. Thirty plant species were identified in the faeces, and the overall diet consisted of approximately 50 % monocotyledonous plants (mainly grasses and sedges), 40 % ericaceous shrubs, and 10 % ferns, herbs and bryophytes. Dwarf shrubs were important throughout the year. Grasses, especially Nardus stricta, were consumed in late winter and spring but were replaced by sedges in late spring and early summer.

At the lowland site the group was much larger, and a greater degree of dispersal and sexual segregation occurred. Over fifty plant species were identified and overall faecal composition differed between the sexes. Male diet consisted of approximately 15 % monocotyledonous species (mainly grasses), 67 % tree browse (leaves) and dwarf shrubs, 10 % ferns and 8 % herbs and bryophytes. Overall, female diet contained a higher proportion of monocotyledons (21 %), less browse (62 %) and similar proportions of other material. Monthly differences in diet composition between the sexes were often large. A variety of woody shrubs were eaten throughout the year, grasses were replaced by tree browse over the summer months and ferns formed up to 30 % of the diet in late autumn.

At both sites, similarity in diet composition between the sexes was lowest in late winter when females separated prior to kidding.

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List of abbreviations used in text

ANOVA	Analysis Of Variance
CCW	Countryside Council for Wales
CI	Confidence Interval
DWt	Dry Weight
GMT	Greenwich Mean Time
HMSO	Her Majesty's Stationary Office
MANOVA	Multivariate Analysis of Variance
KSI	Kulzynski's Similarity Index
NCC	Nature Conservancy Council
NP	National Park
OD	Over Datum
OS	Ordnance Survey
PLc	Public Limited Company
RSNC	Royal Society for Nature Conservation
SA	Surface Area
SE	Standard Error
SNP	Snowdonia National Park
SSSI	Site of Special Scientific Interest
UCNW	University College of North Wales

Chapter 1. Introduction and Objectives

Feral goats (*Capra hircus* L.) are a noteworthy and somewhat controversial feature of the landscape of the Snowdonia National Park which have attracted little scientific scrutiny. Recently there has been concern over the implications of larger populations of goats in the British uplands due to both the possible natural proliferation of wild herds and the increasing diversification of sheep farms into cashmere production. Goats have a reputation for destructive feeding behaviour and have been associated with severe damage to native vegetation and environmental degradation in many areas of the world (Coblentz 1978, Parkes 1990). This destructive ability has been exploited by using Goats for the control of scrub and other weed species (Batten 1979, Bullock & Kinnear 1988, Radcliffe 1986). In North Wales, loss of semi-natural native woodland and upland heath are a matter of concern (Ratcliffe 1977), large herbivores have been implicated in the lack of woodland regeneration, and the impact of additional numbers of goats on these types of vegetation is not fully understood. Knowledge of the feeding habits of feral goats can give an insight to the potential impacts they might have on sensitive environments and can provide a basis for management decisions.

Early work on the feral goats in Snowdonia by Milner, Goodier & Crook (1968) and Crook (1969) concentrated on the behaviour, number, and distribution of goats in the northern part of the National Park. Brown (1977, 1983) concentrated on goat populations in the Rhinogau, looking chiefly at the social and spatial organisation of the different herds. More recently, a brief study of a group of goats located in Coed Allt Wen, (Smith 1989), and a more extensive study (Hellawell 1991) of the management of goats in the Rhinogau have been carried out, both using faecal analysis to study dietary composition.

Relatively little work has been done in Britain on the dietary composition of large herbivores feeding in woodland, and most long-term studies have concentrated on deer (Hosey 1981, Hearney & Jennings 1983, Putman *et al.* 1993) or cattle and ponies (Putman *et al.* 1987). Bullock (1982) studied the diets of three groups of feral goats, one of which had access to a Pinus/Larix plantation and in Wales, Smith (1989) carried out a short-term study of goats feeding partly in oak-hazel woodland in late summer. Recently, Hellawell (1991) studied diet composition of two goat herds over a two year period, but only one group utilised woodland, and then only for part of the year.

More studies of feral goats feeding on upland vegetation have been carried out (e.g. McDougall 1975, Grant *et al.* 1984, Bullock 1982) but possible differences in the diet between males and females were not examined. Segregation of the sexes has been observed in feral goat groups (e.g. Munton 1975, Riney & Caughley 1959), and Bullock (1982) and Gordon (1989) both recorded differences in habitat selection between male and female goats.

Seasonal segregation of the sexes has been observed in many other ungulate species, and studies of Red Deer (Clutton-Brock *et al.* 1982a), Rocky Mountain Sheep (Shank 1982, Miller & Gaud 1989), and Fallow Deer (Putman *et al.* 1993) have shown significant differences in the botanical composition of male and female diets. Explanations for such potential resource partitioning have been based on the different physiological constraints that apply to males and females due to their size and weight differences (Illius & Gordon 1987). Feral goats are sexually dimorphic in body size (Bullock 1991), and might also be expected to select different diets for similar reasons.

The objectives of the present study are to extend the work on the diets of goats in Snowdonia and to look at particular aspects of diet. These include describing the botanical composition of diets from goats feeding in very different habitats: deciduous woodland and upland heath; describing and investigating any seasonal or intraspecific differences in diets; and relating information gathered during fieldwork on ranging behaviour and group structure to dietary composition.

Two groups of goats utilising different habitats were chosen for this study. The first group, based in the Cwm Ffynnon area (see Figure 2.3) was located on open hill land dominated by acidic upland-heath communities at approximately 500 m OD. The second group was based in a deciduous woodland and disused quarry on the shores of Llyn Padarn (see Figure 2.2) at approximately 200 m OD. This latter group was previously studied by Smith (1989). A description of these sites and background information is given in Chapter 2.

Techniques to study dietary composition in free-ranging wild herbivores such as goats are limited and selection of faecal analysis as the most suitable method is discussed in Chapter 3. Although this technique can only give an approximate indication of actual dietary composition it may be suitable for investigating comparative differences in diet between similar animals over time.

Problems were encountered with the use of faecal analysis to identify particular plant species, so before embarking on analysis of the samples collected, certain aspects of the technique were investigated as part of a training programme to improve accuracy. A large collection of plant reference material was required, and drawings, photographs and permanent slides of almost 100 species were prepared. Two dichotomous keys were developed to detect possible problem areas and to assist in the identification of plant fragments from the two sites.

Collection of faecal samples from identified individuals required long periods of fieldwork and this enabled information on goat ranges, group structure and habitat utilisation to be collected. These data are presented alongside information on faecal composition in Chapter 5. Finally, possible explanations for the dietary composition observed and the seasonal patterns of both diet and habitat selection are discussed.

Chapter 2. Background.

2.1 Location and description of sites.

2.1.1 Location.

Fieldwork began with initial reconnaissance of several potential sites in the northern part of the Snowdonia National Park (N.P.). Sites had to be reasonably accessible with sufficient numbers of goats that could be located easily each month. Two goat groups were eventually chosen, one feeding mainly in woodland, the other feeding on open hill land with typical upland vegetation. The two study areas are referred to as "Padarn" and "Cwm Ffynnon" respectively (see Figures 2.1 to 2.3). The study period was from March 1991 to February 1992.

The Padarn site (SH 580610) covers an area of approximately 4 km^2 located north-east of Llyn Padarn from the village of Fachwen to just beyond the south-east shore of Llyn Peris (Figure 2.2). The area lies partially within and adjacent to the northern boundary of the Snowdonia N.P. Much of this site lies within the Llyn Padarn Country Park and the disused quarries of the Dinorwic Pumped Storage Scheme (National Grid Plc.). One sighting of the Padarn goats was made at Pont-y-Gromlech (SH 630566) some distance up the Llanberis Pass, but as this was somewhat unusual and the vast majority of observations took place between Fachwen and Llyn Peris, it is this area that is described in detail.

The Cwm Ffynnon site (approximately 3 km^2) is centred on SH 650570 and covers the area south of the summits of Glyder Fach and Glyder Fawr to the northern shore of Llyn Ffynnon near Pen-y-Pass (Figure 2.3). The area lies wholly in the Snowdonia N.P. and the western side of the cwm lies within the Glyderau SSSI (Site of Special Scientific Interest).

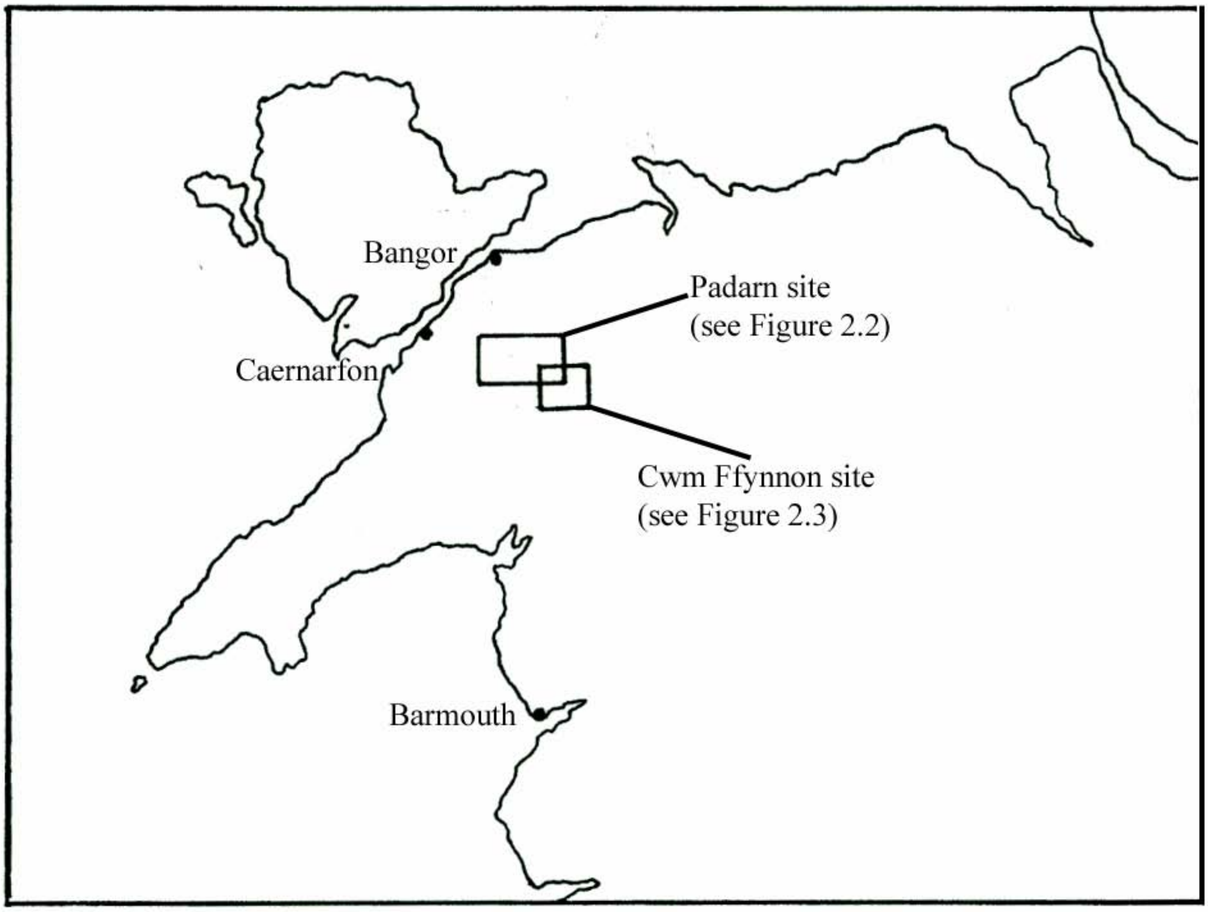


Figure 6.1 Location of study sites in N.Wales

2.1.2 Topography.

The Padarn area stretches linearly generally less than 1 km from the shores of Llyn Padarn and Llyn Peris and ranges in altitude from 105 m OD to approximately 400 m OD in the Dinorwic Quarries, below the summit of Elidir Fawr (924 m). Much of the area consists of either steep wooded hillside facing southwest, or a complex landscape of slate quarry excavations, spoil heaps, inclines, disused buildings and open hillside. Drainage is generally good, especially so in the quarries, though in the northwest towards Fachwen there are some small waterlogged sections. Several roads (including the A4086), regularly-used tracks, paths and the Llanberis Lake Railway are found in this area, as well as many boundary walls and fences. Few of these appear to form serious barriers to the movements of the goats.

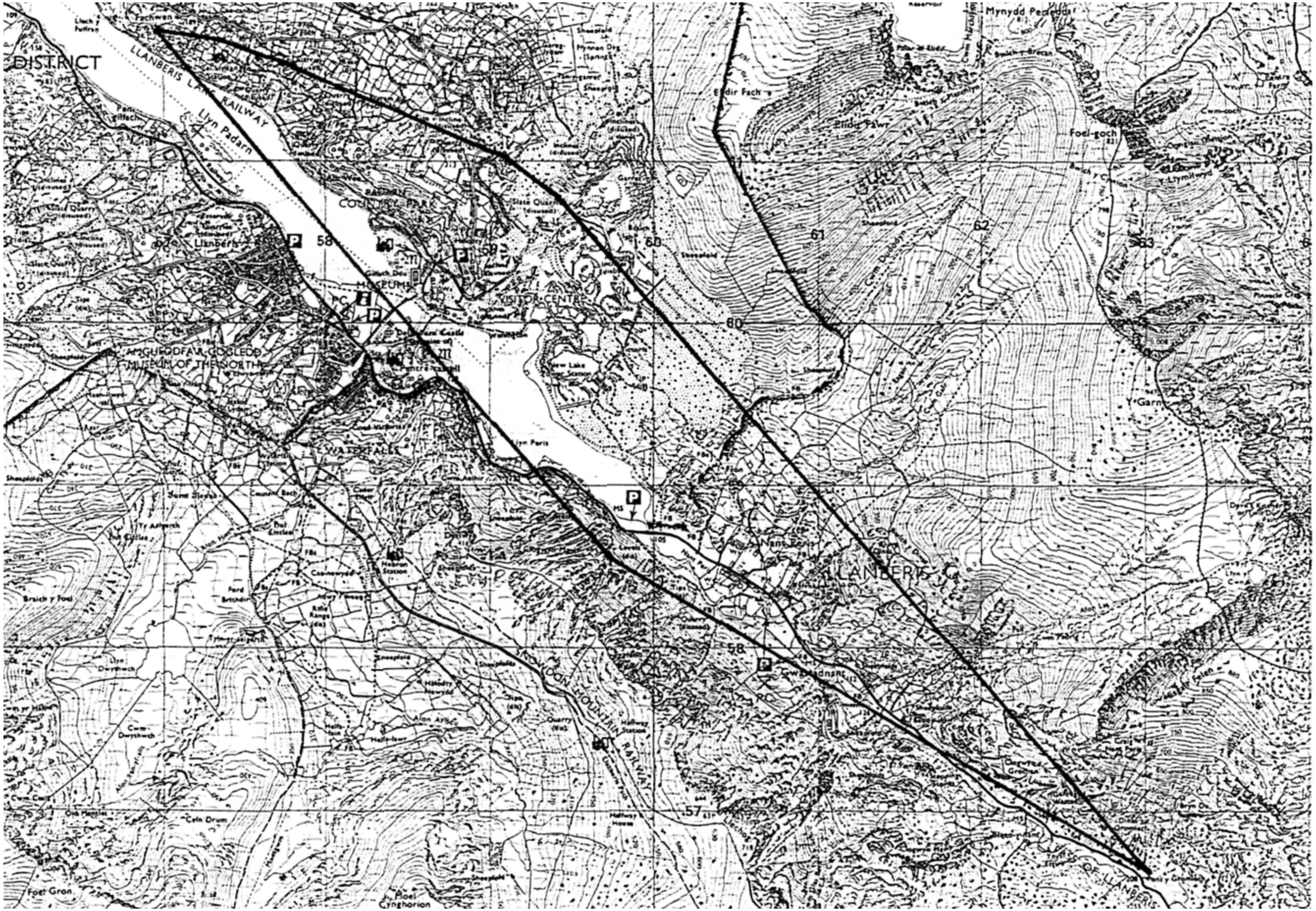


Figure 6.2 Extract from O.S. 1:25 000map (sheet SH) showing the Padarn study area. The outermost observations of all goats in the main group are linked to form the 12-month range

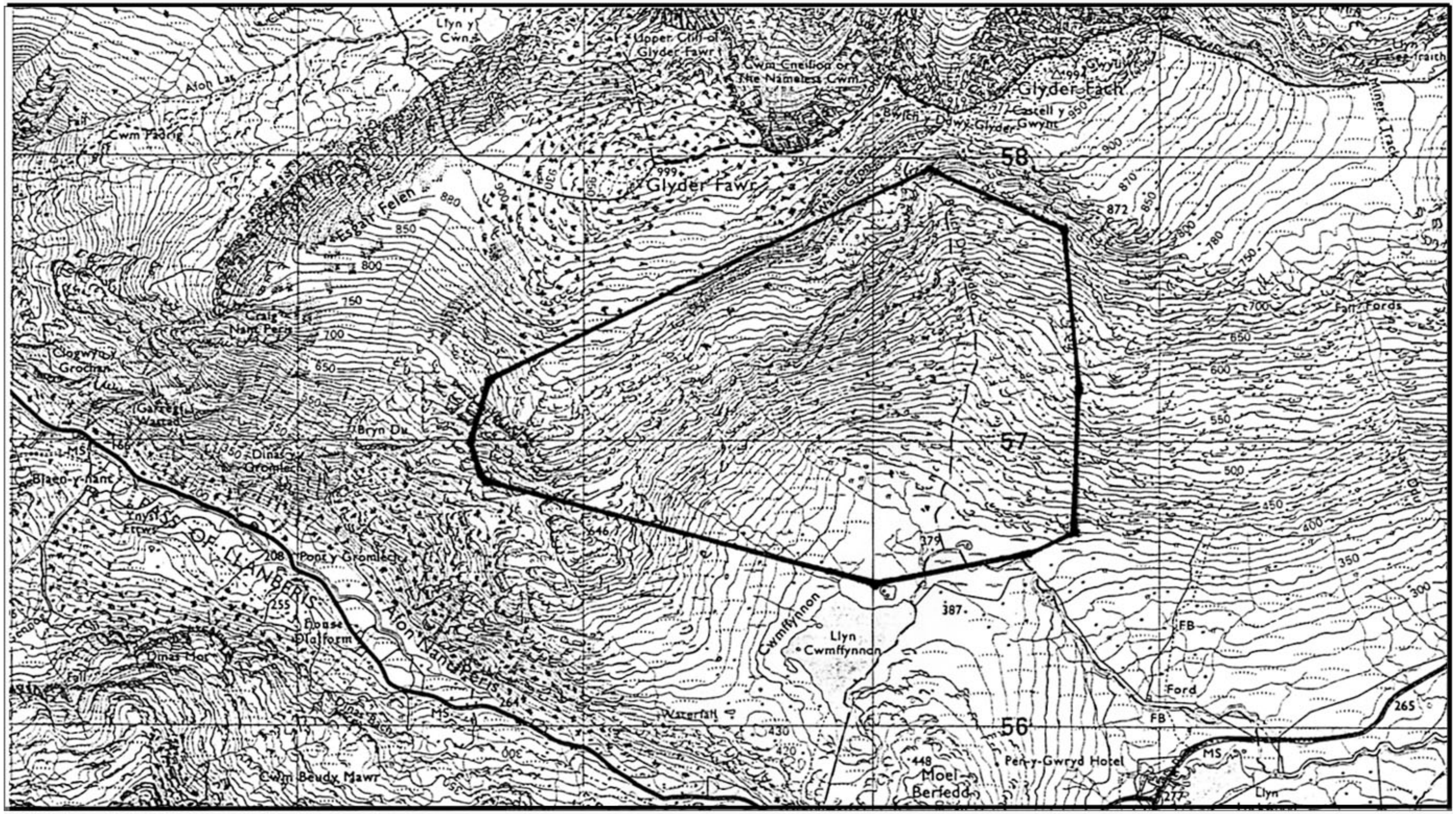


Figure 6.3 Extract from O.S. 1:25 000 map (sheet SH) showing the Cwm Ffynnon study area. The outermost observations of all goats in the main group are linked to form the 12-month range.

Cwm Ffynnon ranges in altitude from 390 m OD to 860 m OD below the summits of Glyder Fach (994 m) and Glyder Fawr (999 m). It forms an open slope facing due south or south-east, the western section is more open and less rugged than the central section which is made up of large stable boulder screes running off broken cliffs. The area is poorly drained and boggy throughout, especially so along the northern shore of Llyn Ffynnon. Several small streams run into the Afon Nantgwyrd which flows eastwards out of Llyn Ffynnon, and an indistinct footpath follows the main stream down the centre of the cwm.

2.1.3 Climate.

Lying close to the north-west coast of Wales, both sites are influenced by the moist maritime air masses associated with frontal systems advancing from the Atlantic. Consequently, temperatures are generally moderate throughout the year, and rainfall and humidity are high. Altitude has a marked effect and the two sites, though less than 5 km apart have somewhat different climates.

Cwm Ffynnon
No climatic data were available for the Cwm Ffynnon site during the period of study, but gauges nearby at Llyn Teyrn (SH 644544) and Llyn Llydaw (SH 638550) give mean annual rainfall at 149.7" (3800 mm) and 132.0" (3353 mm) respectively (Ball, Mew & MacPhee 1969). Carr & Lister (1948) give the annual rainfall at Pen-y-Gwryd (SH 660558) as 135" (3429 mm) and the average number of days with more than 0.01 inches of rain as 243. It is likely that Cwm Ffynnon receives an average annual rainfall of between 3400 mm and 4000 mm that is well distributed through the year with the winter months generally being wetter, though as was the case in the study period, midsummer rainfall totals can also be high. Snow covered the higher ground (>800 m) during the study period for variable lengths of time between December and April.

Little data on mean temperatures for the Cwm Ffynnon area are available, the Climatological Atlas of the British Isles (HMSO 1952) gives both Cwm Ffynnon and Padarn areas mean daily minima and maxima between 37^{o}F and 64^{o}F (2.8^{o}C to 17.8^{o}C) respectively, and mean monthly temperatures of between 41^{o}F and 61^{o}F (5.0^{o}C to 16.1^{o}C). It is likely, however, that mean temperatures in Cwm Ffynnon may be at least two to three degrees Fahrenheit lower than at the Padarn site (given a lapse rate of 1 degree per 100 m change in altitude), and the range in temperatures in Cwm Ffynnon is also likely to be larger.

The median accumulated temperature above 0^{o}C for the period January to June (a measure of heat energy available for crop growth in the early part of the year) is less than 1050 day-degrees for the Cwm Ffynnon area (Rudeforth *et al.* 1984), reflecting the short growing period for vegetation.

No data on wind speed and direction are available for Cwm Ffynnon but observations made during the fieldwork suggest that the prevailing winds were generally from the west and south-west.

Padarn
Climatic data for the Padarn site was available from the nearby Meteorological Office recording station at Dinorwic (SH 592626). Mean monthly temperatures and rainfall data for the study period are presented in Figure 2.4.

Although average annual rainfall for the Padarn area is given as between 70" and 100" (1778 mm to 2540 mm) (Bransby-Williams 1954), during the study period only 1528 mm was recorded at the Meteorological station at Dinorwic. Rainfall was well distributed through the year, with more than 0.2 mm recorded on 224 days. Minimum rainfall (63 mm) occurred in May, a maximum (258 mm) in October, the driest period being the summer (May to September).

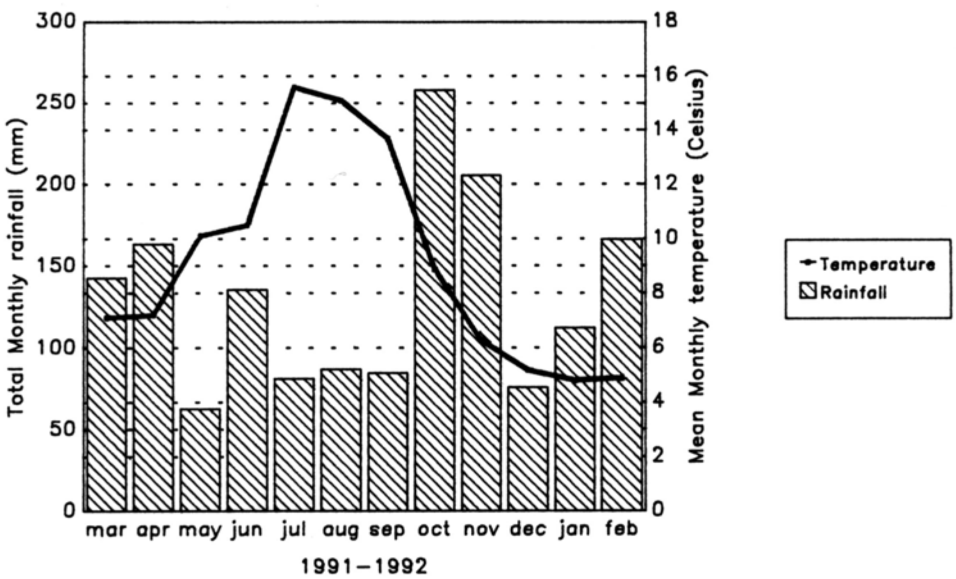
During the study period, snow persisted on the ground for only two days at Dinorwic, though a thin cover of snow remained for longer periods above 600 m on the slopes of Elidir Fawr.

Mean monthly temperatures were between 4.3°C and 15.6°C with mean minima and maxima between 1.8°C and 19.0°C respectively. The median accumulated temperature above 0°C for the period January to June is between 1150 and 1350 day degrees (Rudeforth *et al.* 1984), reflecting the considerably longer growing season than that of Cwm Ffynnon.

From observations during the fieldwork, prevailing winds for the Padarn area were west to southwesterly.

Climatic generalisations do not give the whole picture however, and the effects of topography (for example the presence of large boulders, buildings, or gullies) and vegetation (tree cover, tall dense shrubs) on microclimates at the two sites may be considerable.

Figure 6.4 Climatic data for Dinorwic Meteorological Station March 1991-February 1992



2.1.4 Geology & Soils.

Cwm Ffynnon

The geology in the Cwm Ffynnon area is composed mainly of acidic volcanics, with Ordovician rhyolites of the Snowdon Volcanic Group to the west and rhyolitic tuffs and breccia of the Capel Curig Volcanic formation to the east. In the central part of the cwm, there are small base-rich doleritic intrusions. The north-western section of the cwm is more complex, with bands of Pitts Head tuffs, sandstones, siltstones and dolerite running north-west to south-east. Overlying this solid geology are large areas of eroded material and boulder clay drifts (Howells *et al.* 1985).

Soils in the Cwm Ffynnon area are of three types, all are poor or intermediate in fertility. (Rudeforth *et al.* 1984). Ferric stagnopodzols of the Hafren association are found in the central and eastern part of the area. These are loamy, permeable upland soils, with a wet, peaty surface horizon. Very acidic, poorly drained Raw Oligo-amorphous Peat soils of the Crowdy association are found to the west and south of the cwm. Better drained Humic Brown Podzols of the Moorgate association are found in the remaining area to the west and above approximately 800 m OD.

Padarn

The geology of the Padarn area is complex but all mainly Cambrian in age. It comprises acidic Padarn ash flow tuffs in the north-west, through siltstones and sandstones of the Fachwen formation, to the large area of silty mudstones of the Llanberis Slate formation clearly exposed in the Dinorwic Quarry. The south-western slopes of Elidir Fawr are composed of bands of sandstones (Bronllwyd Grit and Nant Ffrancon Formations) and mudstones (Marchlyn Formation), which being resistant to erosion are often prominent. Scattered throughout the area are occasional intrusions of more basic doleritic rocks. (Howells *et al.* 1985)

Soils of the Padarn area are chiefly moderately fertile podzols of the Manod Association. These are well drained, fine silty loams of variable depth, with rock occasionally exposed (Rudeforth *et al.* 1984). Within Coed Dinorwic the interaction of geology and soils appears to have marked effects on the vegetation: trees growing on the ridges of harder slates are shorter, have lower canopies, and are more contorted than those growing on the deeper soils in the hollows between. Soils within the Dinorwic Quarry have not been surveyed but are generally very thin and are found on the artificially created flatter areas of reclaimed land or trackways. Soils of the Hafren Association are found on areas of sandstone amongst the slates higher in the quarry.

2.1.5 Vegetation.

Cwm Ffynnon

Information on the vegetation of the Cwm Ffynnon area comes mainly from the Upland Vegetation Survey completed in 1988 by the NCC (Nature Conservancy Council 1988). Vegetation was classified using the Ratcliffe/Birks system (NCC 1980). (See Figure 5.1 Vegetation communities of Cwm Ffynnon). A map produced from this survey by the NCC was digitised with slight modifications, and used to analyse vegetation class usage by the goats (See Chapter 5).

The central part of the Cwm is a mosaic of plant communities dominated by dry Calluna Heath (class B1a) with small areas of species-poor grassland (C2a), soligenous flushes (H5, H3c) and Bracken (*Pteridium aquilinum*). Characteristic species in the central heath area are *Calluna vulgaris*, *Erica cinerea*, and *E. tetralix*, with small areas of *Vaccinium myrtillus* and, at higher altitudes, *Empetrum nigrum*. Grasses include *Nardus stricta*, *Festuca* spp., *Deschampsia flexuosa*, *Agrostis capillaris* and *Molinia caerulea*. Rushes, sedges and mosses are also common as drainage is generally poor, these include *Juncus squarrosus*, *J.effusus*, *Luzula multiflora*, *Carex* spp., *Eriophorum* spp., *Scirpus cespitosus*, *Polytrichum* spp. and *Sphagnum* spp. Other species are found throughout, including the herbs *Potentilla erecta*, *Galium saxatile*, *Polygala vulgaris*, *Viola palustris* and the fern *Blechnum spicant*. Parsley fern (*Cryptogramma crispa*) is found on the drier, scree covered areas. Scattered, occasionally dense patches of Bracken occur low down in the more sheltered and better drained parts of the cwm.

The more open slopes to the west and higher in the cwm are dominated by *Nardus stricta*, *Festuca* spp, *Deschampsia flexuosa* and *Juncus squarrosus* (species-poor grassland, class C2a). Again, areas of poor drainage and base-rich flushes occur which are characterised by species such as *Molinia caerulea*, *Juncus effusus*, *Carex* spp., *Eriophorum* spp., *Polytrichum* spp. and *Sphagnum* spp.

Level parts of the western and northern shores of Llyn Ffynnon are covered by Blanket Bog and Soligenous Flushes (G3a, G3b, H5 and H3c) including *Eriophorum* spp., *Molinia caerulea*, *Erica tetralix*, *Carex* spp., *Sphagnum* spp. and Rhyncospora alba.

To the east of Llyn Ffynnon there lies a large area of species-poor Molinia grassland with poorly drained areas of *Eriophorum-Sphagnum* mire. Goats were not observed in this area which was separated from the main part of the cwm by a fence and the river flowing from Llyn Ffynnon.

Padarn

Vegetation for much of this area was covered in a Phase One habitat survey carried out by the NCC in 1989 using the NCC/RSNC habitat classification (NCC 1989, NCC 1990). Again, maps produced by the NCC for this survey were digitised and used to analyse vegetation class usage by the goats. (See Chapter 5). An incomplete list of flowering plants and mosses is also available in the Padarn Country Park Management Plan (Gwynedd County Council 1980).

The Padarn area is large and contains several major vegetation communities summarised below: (See Figure 5.13 Vegetation communities of Padarn)

1. Disturbed Rock Communities: Much of the Dinorwic Quarry comes under this category, typified by species attempting to colonise the more stable areas of scree and slate spoil. Species include: occasional shrubs and trees such as *Ulex gallii*, *Cotoneaster simonsii* and *Betula pubescens*; many herb species including *Digitalis purpurea*, *Sedum anglicum*, *Teucrium scorodonia*; the fern *Cryptogramma crispa*; the grasses *Festuca ovina*, *F. rubra*, *Agrostis* spp., *Anthoxanthum odoratum* and *Aira praecox*, and the mosses *Homolothecium sericeum*, *Dicranum majus*, *Pohlia nutans* and *Bryum* spp,

Within the Dinorwic Quarry there are also areas of Heath Community on rocky bluffs, small remnants of woodland and improved neutral grassland on reclaimed areas of slate spoil.

2. Woodland Communities: Semi-natural broadleaved woodland forms a significant proportion of the Padarn study area and is found in three main parts: Coed Padarn on the slopes of Allt Wen is the largest area but is divided by the Vivian Quarry into two sections of similar character; to the north-west, outside the boundary of the Padarn Country Park, is a smaller area of more scattered woodland, old coppice growth, and hedges surrounding gardens and disused farmland. Dominant species in this latter area, below the village of Fachwen, are *Quercus petraea*, *Betula pubescens*, *Corylus avellana* and *Fraxinus excelsior*. Ground vegetation is varied but *Rubus fruticosus* agg., *Pteridium aquilinum* and *Ulex* spp. are common.

Dominant tree species in Coed Padarn are *Quercus petraea*, *Corylus avellana*, *Betula pubescens, Sorbus aucuparia, Crataegus monogyna* and *Ilex aquifolium*. Other tree species include *Fraxinus excelsior*, *Salix capra* and less commonly, *Prunus spinosa*, *Acer pseudoplatanus*, *Pinus sylvestris*, *Rhododendron ponticum,* and *Fagus sylvatica*.

Epiphytes such as *Hedera helix* and *Lonicera periclymenum* are frequent, and dwarf shrubs such as *Calluna vulgaris*, *Erica cinerea*, *Vaccinium myrtillus* and *Rubus fruticosus* agg. are the dominant ground vegetation in many areas, often associated with *Deschampsia flexuosa*, and *Polytrichum* spp. *Luzula sylvatica* grows densely at the northern end of Coed Padarn and ferns such as *Dryopteris felix-mas* and *Blechnum spicant* are common throughout. In some parts *Oxalis acetosella*, Endymion non-scriptus, *Potentilla erecta*, and *Melampyrum pratense* are found in dense patches and *Teucrium scorodonia* is also common.

Common grasses include *Agrostis capillaris*, *Anthoxanthum odoratum*, *Brachypodium sylvaticum*, *Dactylis glomerata*, *Festuca* spp., and *Holcus mollis*. The diversity of bryophytes, lichens and ferns contribute to the conservation status of Coed Padarn and are too numerous to describe in detail.

Within the main areas of woodland other small but distinct vegetation communities are also found, including small areas of mire, bracken, and disturbed rock communities, callunetum on rocky bluffs, and seral grassland along tracks and in clearings,

Coed Padarn is described by Ratcliffe (1977) as an unusual ungrazed example of upland sessile oakwood containing an understorey of hazel and holly with field communities of *Luzula sylvatica* in the upper part, and bilberry and bramble elsewhere. It was notified as an SSSI in 1976 as a little-grazed example of Woodsage-Oak/Birch type woodland which are relatively scarce in Wales (Countryside Council for Wales (CCW) 1985).

3. Heath Communities: These areas are typified by *Calluna vulgaris*, *Erica cinerea*, *E. tetralix*, *Vaccinium myrtillus* and *Ulex* spp. and are found on the upper parts of the Dinorwic Quarry, as small patches in Coed Padarn, and between areas of scrub further west towards Fachwen.

4. Neutral grassland and Scrub: These vegetation classes cover a diverse area of land at the north-western end of the Padarn area composed of disused farmland and the gardens of various properties in Fachwen. The area is complex, with scattered trees and hedges, semi-improved grassland, heathland, willow carr and bracken. Amongst these areas are gardens containing a wide variety of native and exotic shrubs and herbs.

5. Species-poor Improved Grassland: This vegetation class is found mainly on the artificially levelled, reclaimed areas of the quarry. Species diversity is low, with the main grass species being *Agrostis capillaris* and *Aira praecox* and colonising herbs such as *Teucrium scorodonia* and *Digitalis purpurea*.

6. Semi-improved Acid Grassland: This is found mainly on the upper slopes of Elidir Fawr and the area east of the Dinorwic Quarries. Dominant species are the grasses *Nardus stricta*, *Festuca* spp., and *Agrostis* spp. but dwarf shrubs including *Calluna vulgaris*, *Erica cinerea*, *Vaccinium myrtillus* and *Empetrum nigrum* are also often present as well as the herbs *Galium saxatile* and *Potentilla erecta*.

7. Marshy areas: Small areas of marshy grassland and soligenous mires are found within the Dinorwic Quarry, near the south-eastern shore of Llyn Peris and in occasional patches in the woodland below Fachwen. Common species found in these communities include *Molinia caerulea*, *Juncus effusus*, *Carex* spp., *Eriophorum* spp. and *Sphagnum* spp.

A map of vegetation in the Padarn area is given in Chapter 5., Figure 5.13

2.1.6 Land Use and Conservation Status

Cwm Ffynnon

Most of the land in the Cwm Ffynnon area is owned by Mrs Esme Kirby of Dyffryn Mymbyr and sheep from this farm have been grazed there for many generations. Until recently, attempts were made to maintain separate flocks in Cwm Ffynnon and Dyffryn Mymbyr, but now the sheep are run as one flock and grazing in the Cwm is probably lighter (Kirby *pers comm*.). The area lies in the Snowdonia National Park and partly within the Glyderau Site SSSI. It was suggested that the SSSI be extended to cover the eastern part of Cwm Ffynnon and the summit area of Glyder Fach so as to ensure protection for certain features of outstanding botanical importance, namely Calluna heath, Eleocharis multicaulis-Rhyncospora alba flushes and summit heath vegetation. (Nature Conservancy Council, Upland Vegetation Survey 1988).

Despite its location close to the major walking centres of Pen-y-Pass and Pen-y-Gwryd, Cwm Ffynnon is remarkably undisturbed, with most walkers passing along the summit ridge rather than going through the cwm itself.

Padarn

The Padarn area can be divided into three main areas of differing land use:

The eastern section includes the Dinorwic Quarry, now disused and under the ownership of National Grid Plc for the Dinorwic Pumped Storage Scheme. Within the quarry are several public footpaths and there is an informal access agreement to most areas for rock-climbers. Some sheep are grazed in the quarry, but most are restricted to the upper slopes of Elidir Fach, outside the fenced boundary.

The central part of the area is covered by the Coed Padarn section of the Padarn Country Park. This was designated by the Countryside Commission as a Country Park in 1970, and as a Local Nature Reserve in 1976. Much of the woodland of Coed Padarn is given SSSI Grade One status. The whole area is managed by the Gwynedd County Planning Department who have created several woodland paths and nature trails. In the summer months these attract many walkers, school parties and tourists visiting the woods and other facilities in the park. Although most of the perimeter of Coed Padarn is fenced with 1 m stock fencing, there are several weak points and stray sheep were frequently seen grazing in the woodland, especially during the winter months.

To the north-west of Coed Padarn, between the shore of Llyn Padarn and the village of Fachwen is an area of very varied land use including active smallholdings, derelict farmland, cottage gardens and scattered scrub-woodland. In the past this area was much more intensively farmed and the woodland managed for coppice. At present grazing is light, human disturbance is low and much of the area is reverting to woodland.

2.2 Details of Goat groups.

2.2.1 Description Goat groups, pelage patterns, history

Crook (1969) and Hellawell (1991) give accounts of the probable derivation of the feral goats of Snowdonia. It is generally assumed that the present herds are the remnants of domesticated stock that were not removed when goat keeping became less popular in the late 18th and early 19th centuries. Goat numbers at that time were almost certainly higher than at present with accounts of some 149 goats being counted on the slopes of Snowdon from a boat on Llyn Padarn in 1774 (Johnson 1816). There is evidence of a systematic reduction of numbers from that time and goatkeeping was discouraged due to their destruction of young plantations (Cathrall 1828). However, not all the goats were removed and despite fluctuations in numbers in the 19th and 20th century (Crook 1969) many herds still survive both on the Glyderau, Snowdon, Rhinogau and many other areas of North Wales. There has been some speculation that feral goat numbers are on the increase, possibly linked to the milder winters in recent years, but variable monitoring methods make comparisons difficult. A survey carried out in December 1991 by the CCW counted 47 goats on the hills of the Glyderau plus approximately 35 in the Padarn area. This is thought to be a considerable underestimate (Roberts *pers comm*.), and a total of between 150 and 200 goats for the entire Glyderau area is more likely.

A description of the Glyderau goats is given by Crook (1969) and the Cwm Ffynnon group seem to be fairly typical of other groups seen in the area. Males in this group were shaggy coated, with scimitar shaped horns and a pelage pattern that was basically white with varying degrees of darker hair on the face, forequarters and saddle regions (see Figure 2.5). The females had shorter coats, smaller, thinner horns and were predominantly white, with darker markings along the back, lower legs, rump and over the eyes.

Individuals in the much larger Padarn group were more varied in their appearance and the females especially were dissimilar from those in Cwm Ffynnon. Pelage patterns in the males ranged from almost totally black/chocolate brown through to almost pure white. Piebald individuals had either dark streaks; dark forequarters and rump with a white mid-section and face; or were white with varying degrees of dark hair on the neck, rump

or saddle regions (see Figure 2.6). All the females had large patches or spots of dark hair on a white background, three with distinct chocolate brown patches could easily be recognised. Six individuals were hummels, that is, naturally hornless animals all of which were apparently sexually active males.

Figure 6.5 Goats in the Cwm Ffynnon area: Male (top) and female (bottom).

Figure 6.6 Goats in the Padarn area: Males (top) and young female (bottom).

2.2.2 Present numbers, sex & age groups

Cwm Ffynnon
Little information is available on the recent history of the goats in Cwm Ffynnon but no disturbance to this group seems to have occurred in recent times. Crook (1969) counted nine females there in 1967 and estimated there to be 10 males and 15 females in Cwm Ffynnon and Afon Ddu (SH 673564) areas in 1968. During the present study five females and four males were regularly observed in the cwm although other groups from the Afon Ddu area also made use of the area during the summer period.

A summary of the individuals identified and estimated ages is given in Table 2.1 Ages are estimated from counts of horn rings as described by Bullock & Pickering (1984) and were recorded half way through the field work in August 1992.

Table 6.1 Sex, age classes and identification codes given to individual goats in Cwm Ffynnon (August 1992).

Age (Years)	Number	Identification Codes and sex
0-1	0	(2 kids born February 1991 but later died)
1-2	1	Y1 (Yearling Female)
2-3	1	M3 (Youngest Male)
3-4	3	M2, M4, F3 (2 males, 1 female)
4-5	4	M1, F1, F4, F2 (1 male, 3 females)
Total	9	4 males, 5 females

Padarn
The recent history of the Padarn group of goats is more complicated. Crook (1969) made no mention of any goats in the Padarn area at that time, though he did observe groups in Nant Peris and the Llanberis Pass. Earliest reports of goats seen regularly in the quarries by local people are around the early 1970's. Ratcliffe (1977) valued the unusual ungrazed status of Coed Padarn and it seems likely that there were few or no goats to be found in the area at that time. At some time in the 1980's it seems that a settled population of goats were spending time in Coed Padarn and damage to trees within the Park, nearby gardens and a Spruce plantation was being reported. (M. Ansells *pers comm*.). Smith (1989) counted at least 31 individuals between July and September 1988 and commented on a browse line and patches of extensive tree barking in Coed Padarn. In January 1990 at the request of the Country Park Management Committee, CCW removed 22 goats (2 males, 17 females and 3 hummels) from an estimated population of 34, leaving behind approximately 8 males and 4 females (Hellawell *pers comm*.). However, at the outset of this study in March 1991, 27 goats were counted and this rose to 35 by January 1992 and approximately 40 by March 1992 due to the addition of kids and itinerants. Whether the number of goats remaining after the first capture was underestimated or whether other goats had moved into the area is not known. A summary of the ages and code names of individuals in the main Padarn group is given in Table 2.2. Again, ages were estimated from horn-ring counts recorded in August 1992.

Table 6.2 Sex, age class and identification codes given to individual goats in the Padarn group (August 1992).

Age (Years)	Number	Identification Codes and sex
0-1	7	K2, KY2, KF4a, KF4b, KF5, K3, K6 (6 males, 1 female)
1-2	1	K1 (Male kid probably born in summer 1990)
2-3	5	M12, H3, Y1, Y2, Y3 (1 male, 1 hummel, 3 females)
3-4	6	M13, Mb, Mc, Hnew, F4, F5 (3 males, 1 hummel, 2 females)
4-5	6	M1, M2, M3, M4, M5, H1 (5 males, 1 hummel)
5-6	6	M6, M10, M11, H14, H17, F11 (3 males, 2 hummels, 1 female)
6-7	4	M7, M9, M15, H13 (3 males, 1 hummel)
Total	35	22 males, 7 females, 6 hummels (apparent males)

A separate group of approximately 12 goats, usually observed on the opposite shore of Llyn Peris at Wern Farm (SH 592591), were also occasionally seen in the Dinorwic Quarry during the study period, bringing the potential number of goats grazing in Coed Padarn to over 50. Severe bark stripping was noted in several parts of the wood during the study and was clearly visible along many of the tourist paths. Following further reports of damage and high numbers of goats, CCW decided to remove all goats from the site and succeeded in removing 29 goats (including all the females) in October 1992. As a postscript to this, observations in late 1993 showed that several of the uncaptured individuals from the main group we still in the area. The "Wern" group were also seen feeding in Coed Padarn, but it may be too soon to say whether this possible extension of their range will continue.

Chapter 3. Methods

The methods employed in this study are described under two headings: dietary analysis and field methods. Various techniques are available for the study of the diets of large herbivores, but many are not appropriate to the study of feral goats. Faecal analysis was considered to be the most suitable technique available, and the basic assumptions, problems, and different laboratory procedures that have been used by other workers are summarised, followed by the methods used in this study. Accurate use of faecal analysis requires the ability to identify all common forage material from their cuticle fragments and consequently a large reference collection of potential food material from the study sites is needed. Methods for preparing these samples are given in section 3.4, and the species collected are listed in Table 3.1. Problems were encountered in identifying certain species from their cuticle fragments, so investigations into aspects of the accuracy of the technique were investigated. These are described in Chapter 4.

The collection of fresh samples for laboratory analysis necessitated the identification of individual goats and close observation of the goat groups for long periods each month. Consequently, the opportunity was taken to collect data on other aspects of goat ecology that may indirectly influence dietary composition. These included group size and structure, locations of the goat groups, and estimates of the range areas. The methods used during this fieldwork are given in sections 3.5 to 3.9.

3.1 Dietary Analysis.

3.1.1 Techniques available for the study of ungulate diet composition

Information on the types and quantities of foodstuffs consumed is a prerequisite to understanding the relationship between herbivorous animals and vegetation. Methods for gathering such information on the diet of ungulates may be classified into five types as follows:

A. Utilisation techniques, where the type and amount of vegetation removed from a habitat is estimated by comparing plots before and after grazing (e.g. Grant *et al.* 1976 (sheep), Belovsky 1981 (moose)). In this technique vegetation has to be measured in some detail and exclosures are usually needed so that grazing occurs only by the animals under study. This can yield quantitative data on diet composition but measurement of plant losses is difficult and factors such as plant growth during the study period and complex grazing effects have to be taken into account.

B. Direct observation of feeding animals to identify the species and type of plant material eaten. Quantitative information can be gained from an estimate of bite size and bite counts or by timing the period spent grazing on a particular plant species (e.g Smith & Bullock 1993) (goats), Genin & Badan-Dangon 1991 (goats), Harrington 1986 (goats)). This technique requires close observation of grazing animals to accurately identify the relative proportions of food eaten. Consequently it is difficult to use when the animals under study are difficult to approach or where views are restricted.

C. Analysis of mouth, rumen or digestive tract contents from recently killed animals. Depending on the degree of fragmentation, ingested material may be sorted by eye or examined microscopically (e.g Norris 1943 (sheep), Parkes 1984, Coblentz 1977, Mitchell *et al.* 1987 (goats), Crete *et al.* 1990 (caribou), Anthony & Smith 1974 (deer)). This technique allows identification of undigested or partially digested food that can provide accurate information on diets. However, samples collected from the mouth or rumen in this way may only represent single meals. As with other gut content analyses, there are problems of identification and possible differential digestion of the plant fragments. Added to this, there are ethical constraints to the killing of animals and so this technique is suitable only for common animals.

D. Analysis of oesophageal or rumen contents by use of a fistula inserted into the animal. Again, examination of finely chewed material usually requires microscopic examination (e.g Wilson *et al.* 1975, Taylor & Kothmann 1990 (goats), Free *et al.* 1971 (cattle), Pfister & Malechek 1986 (goats & sheep)). Holechek *et al.* (1982a) state that fistula techniques can give accurate information on dietary composition but are low in precision, requiring a large number of animals to be sampled. Fragment identification and possible differential digestion problems remain and the technique is very disruptive to the animals due to both surgical implantation of the fistulas and the recapture to remove samples. As animals have to be retrieved regularly it is more suited to tame or domesticated herbivores.

E. Faecal analysis. As with analysis of rumen or stomach contents this technique requires microscopic examination of partially digested plant material. Similar problems of fragment identification and differential digestion may apply and these may be more severe as faecal material has spent a longer period in the animals digestive tract (Putman 1984). There is considerable debate over the degree of accuracy the technique can provide (e.g Havstad & Donart 1978, Sidahmed *et al.* 1981, Takatsuki 1978, Vavra *et al.* 1978, Smith & Shandruk 1979, Holechek *et al.* 1982a, Alipayo *et al.* 1992). However, faecal analysis has several advantages over other techniques: Although accuracy may be lower, precision can be higher as more samples are usually available for analysis; it is non-lethal; far less disruptive to the animals under study; requires little equipment and may reflect a longer feeding interval than samples of ingesta taken from higher in the gastro-intestinal tract. Frequently it is the only appropriate technique available.

Suitable techniques for the study of feral goats in Snowdonia are limited. Utilisation techniques are inappropriate as sheep are also present at all sites and the construction of exclosures is difficult and expensive. Fistula techniques are also unsuitable due to the difficulty of recapture of wild animals in rough terrain, and lethal methods are out of the question both for ethical reasons and the small numbers of animals available. Direct observation is more feasible, but feral goats in this area are easily disturbed if approached closely, and when feeding in tall vegetation, quantification of the species eaten is difficult. Therefore, faecal analysis was deemed the most suitable method for the present study. McDougall (1975), Bullock (1982), Smith (1989) and Hellawell (1991) came to similar conclusions and used faecal analysis to study the diets of feral goats in other parts of Britain.

3.2 The faecal analysis technique.

The technique of analysing plant fragments from herbivore faeces to estimate botanical composition of diet has become popular in recent years despite controversy about certain basic assumptions and the difficulty of producing quantitative results. Most authors agree that the technique can be used qualitatively, that is, all major dietary components can be identified (e.g Stewart 1967, Free *et al.* 1970, Zyznar & Urness 1969) and results can be used comparatively to show differences over time or between similar herbivores on the same range.

3.2.1 Assumptions.

Quantitative analysis, relating proportions of plant cuticle in faeces to the relative dry weights of species ingested is controversial, as various groups of researchers around the world offer different conclusions related to use of the technique in their particular region. Basically, disagreements are linked to the non-acceptance of certain basic assumptions namely:

1.Plant cuticle survives passage through the digestive tract and all species can be identified from these remains with equal ease.
2. Digestion and fragmentation affects all plant species equally.
3. Histological preparation affects all plant species in the same way.
4. A predictable relationship exists between the proportions of plant material ingested and the proportions of cuticle fragments represented in the faeces.

Doubts have been raised about certain plant species which may not be identified in faecal matter because they are totally destroyed by digestion and/or laboratory preparation (Croker 1959, Slater & Jones 1971, Johnson & Pearson 1981, McInnis *et al.* 1983). However, other studies (Todd & Hansen 1973, Stevens 1977, Chatterton & Powell 1974, Johnson & Wofford 1983) have suggested that even these fragile plant species are not completely destroyed by digestion and sufficient cuticle can be identified provided certain precautions are taken with the laboratory technique.

Many authors find the identification of some species easier than others and this can lead to errors of under- or over- estimation (Dearden, Hansen & Pegau 1975, Gill *et al.* 1983, Havstad & Donart 1978, Samuel & Howard 1983). Others note that the proportion of cuticle surviving in faeces varies between plant species due to differential digestion and fragmentation (e.g Storr 1961, Dunnet *et al.* 1973, Stewart 1967). Counts of fragments would overestimate those species which break into many smaller pieces and vice versa but the effect of digestion on identifiability is less predictable. The identification of certain species may be improved through the loss of obscuring pigments or reduced if fragments are so small that they lack diagnostic features. Preparatory techniques including chemical digestion, milling and sieving have been blamed for causing loss, damage or excessive fragmentation of the more fragile species (Stevens 1977).

For some or all of the reasons given above, many authors find that certain components of a diet are over- or under-estimated by faecal analysis. Differential digestion and fragmentation have been related to lignin content and cuticle thickness (Vavra *et al.* 1978, Croker 1959, Dunnet *et al.* 1973) both of which can vary over time as plants senesce. Similarly, identifiability may vary with plant age as recognition features on the cuticle become more or less common. The digestibility of a species may also be affected by the presence of other species in the diet and recent dietary history (Putman 1984). For these reasons, the relationship between the quantity of fragments in faeces and what that represents in the diet may not be constant.

Several authors have attempted to rectify these problems in various ways:

Improved preparation of faecal material can increase identifiability of cuticles by reducing damage and excessive fragmentation (Stevens 1977). Technician error is a major source of inaccuracy and a training period can reduce errors of mis- or non-identification (Todd & Hansen 1973, Holechek *et al.* 1982b, Holechek & Gross 1982a).

The problem of differential fragmentation has been approached in several ways. Milling and sieving of faeces can reduce the material to similar sized fragments allowing simple enumeration methods to be used. Alternatively, measurement of cuticle area may be used which can be converted to relative dry weights ingested using surface area to dry weight ratios of plant material in the diet. However, such ratios are often difficult to measure and have been shown to vary between plant species and in the same species at different locations and time of year (Storr 1961, Dunnet *et al.* 1973).

Several authors have developed correction factors that account for variation in digestibility, fragility and identifiability. Correction factors have been derived from faecal analyses of animals fed on known diets (Takatsuki 1978, Voth & Black 1973, Dearden, Pegau & Hansen 1975, Adams *et al.* 1962), and from comparison of paired faecal and oesophageal/rumen fistula samples (Mann 1983, quoted in Putman 1984). Predictive equations have also been calculated from microscopic analysis of hand compounded mixtures digested in vitro (Sparks & Malechek 1968, Dearden, Pegau & Hansen 1975, Westoby *et al.* 1976, Leslie *et al.* 1983) or derived from dry matter- or cell wall- digestibility estimations (Putman 1984). Use of correction factors can improve the accuracy of microhistological analysis (Voth & Black 1973, Vavra & Holechek 1980, Dearden, Pegau & Hansen (1975) but has rarely been carried through to estimate true dietary composition for free-ranging animals (e.g Hansen & Dearden 1975, Leslie *et al.* 1984, Ritchie 1990).

Using hand-compounded mixtures, Sparks & Malechek (1968) converted the number of microscope slide fields a species occurred in out of 100 locations to its relative density using a table developed by Fracker & Brischle (1944). They found a near 1:1 relationship between estimated relative densities and actual dry weight percentages and suggested that the additional accuracy gained from use of correction factors may not be necessary. Many American authors have gone on to use Sparks & Malechek's technique, normally presenting their results at face value whilst noting those species they suspect to be over- or under-estimated (e.g. Hubbard & Hansen 1976, Burrell 1982, Sowell *et al.* 1985, Fox & Smith 1988). Putman (1991) came to the conclusion that provided forages had a similar digestibility, correction factors made little difference to the actual dietary profile obtained. More recently, Alipayo *et al.* (1992) found that differential digestion of plant species had little effect and showed that faecal analysis estimations can have a high degree of similarity to actual diets without the use of correction factors. Outside North America few researchers have used the standard Sparks & Malechek technique, most preferring to use counts of fragments to give the percentage occurrence of a species in the faeces. In Britain most results have been presented for qualitative or comparative purposes and have not been claimed to represent diet composition by dry weight.

In conclusion, use of the faecal analysis technique appears to be acceptable as a means of collecting dietary information providing that precautions are taken so that all basic assumptions are fulfilled. Due to the lack of time and the diverse nature of the diets it was not possible to develop predictive equations for the numerous plant species encountered in this study. In line with similar work in Britain, results are used in a qualitative manner only.

3.2.2 Methodology.

Analysis of faecal material from herbivores normally requires: the preparation of slides to display the constituent fragments of plant cuticle; identification of these fragments by comparison to reference material; enumeration of a sample of fragments; and calculation of faecal composition. Although slight variations of methodology have been developed, the basic procedure used by most authors can be divided into 10 steps:

1. Collection and preservation of faecal samples
2. Milling.
3. Sieving.
4. Digestion / maceration.
5. Clearing of plant cuticle/epidermis.
6. Staining of cuticle/epidermis.
7. Mounting subsamples on slides.
8. Identification of faecal plant fragments by comparison to prepared plant reference material.
9. Sampling and enumeration of cuticle fragments.
10. Calculation of botanical composition of faeces.

Variations in the methods used are briefly summarised:

1. Collection and preservation of faecal samples. Faecal samples may be collected several months after deposition for analysis but most authors agree that analysis of fresh faeces is preferred as cuticle fragments are easier to identify (Stevens 1977) and weathering may affect the botanical composition (Smith & Shandruk 1979). Where the identification of faeces from different species is difficult, animals must be followed and defaecation observed to ensure correct identification. Preservation of samples is usually by drying, freezing, or storage in formalin-acetic acid-alcohol (FAA).

The number of samples collected and analysed varies depending on the specific research requirements. Scotcher (1979) recommends a minimum of 10 faecal samples per month and 10 to 20 samples per study period per site is commonly used. However, Kerridge & Bullock (1991) found that a sample size greater than five provided a representative sample for dietary analysis. Bullock (1982) compared the botanical composition of four pairs of pellets from the same cluster and found no significant differences, validating such sub-sampling of faeces. Samples may be analysed individually and results given in terms of the percentage of the population of animals in which a diet item is found, or the mean faecal composition from several samples calculated. Alternatively, faecal samples may be amalgamated and analysed en masse to give a single result.

2. Milling of samples. Faecal samples are usually dried in an oven before milling using an electric "Wiley" or "Culatti" type mill with a 0.5 mm to 1.0 mm screen attached (e.g. Free, *et al.* 1970, Holechek 1982). Some authors using area measurements of cuticle have not milled their samples (e.g. Green 1987, Nugent 1983).

3. Sieving. The removal of excessively small fragments of cuticle and other detritus can make identification of the remaining fragments easier. Sieving is usually done by washing the sample over a mesh of between 75 æm and 355 æm (e.g. Green 1987, Sparks & Malechek 1968, Stevens 1977). Fragments of cuticle less than 100 æm across are usually not identifiable and removal of such material should not greatly affect the estimated botanical composition. Other methods of removing the smaller fragments include the decanting of supernatant after centrifugation (Stewart 1967, Storr 1961) and suspending faecal material in panty-hose in a running-water bath (Rogerson *et al.* 1976).

4. Digestion / maceration of plant material. Some authors have attempted to improve the identification of plant cuticle by digesting away attached mesophyll and other cellular material. Chemical maceration is usually carried out using nitric acid (e.g. Stewart 1967) or sodium hydroxide solution (McDougall 1975), other methods include boiling in water (Holechek 1982) and bacterial degradation in a warm water bath for several days (Rogerson *et al.* 1976).

5. Clearing of plant cuticle/epidermis. Clearing of cuticle fragments is used to make identification of cuticle fragments easier by removing obscuring pigments. The commonest clearing agent used is chloral hydrate either with nitric acid (e.g. Storr 1961) or as the combined clearing agent and mountant, Hertwig's solution (Sparks & Malechek 1968). Other commonly used clearing agents are dilute sodium hypochlorite (domestic bleach)(Bullock 1982), or alcohol (Williams 1969).

6. Staining of cuticle/epidermis. Whilst many authors have concluded that staining is not necessary (Hearney & Jennings 1983, Takatsuki 1978), others have found that it can assist identification by highlighting certain diagnostic features. Stains used include Toluidine Blue (Smith 1989), Alcoholic Saffranin (Williams 1969), Gentian Violet (Storr 1961), Basic Fuchsin (Dunnet *et al.* 1973) and Haematoxylin (McDougall 1975).

7. Mounting subsamples on slides. Care must be taken at this stage to remove an unbiased subsample (Stevens 1977) and most authors lightly agitate the prepared sample to ensure mixing of fragments and use a wide-mouthed pipette or scoop to transfer material onto a slide. Depending on the types of clearing and staining agents used, temporary or permanent slides are prepared using a variety of mountants. These include water (Stevens 1977), Hoyers Medium (Bullock 1982), Glycerine (Stewart 1967) and Canada balsam (McDougall 1975).

8. Identification of faecal plant fragments by comparison to prepared plant reference material. Most authors prepare reference standards of plant cuticle and epidermal material using similar maceration and clearing treatments to those described for faecal samples. As many examples as possible of plant material likely to be found in the faeces should be collected from the study site. The epidermal features of any one species are known to vary with location, phenological state and time of year (Davies 1959, Putman *pers comm*.) so a wide variety of plant material should be prepared. Some authors have found that, especially in grasses, one epidermal surface is more easily destroyed by digestion than the other and have concentrated on identifying only the more persistent (usually abaxial) surface (e.g. Dunnet *et al.* 1973). Consequently these authors dissected each surface separately when preparing reference material. Once reference material has been mounted on slides any distinguishing features are recorded in notes, drawings or microphotographs made at x100 to x600 magnification. All these records are kept at hand during analysis and used to identify fragments in the faecal samples. In some instances dichotomous keys have been developed to assist identification (e.g. Croker 1959, Bhadresa 1981, Matrai *et al.* 1986, Riegert & Singh 1982). A wide range of distinguishing features found on the cuticle or epidermis are regularly used including the arrangement, size and shape of cells and the presence, distribution and type of trichomes, stomata, cork and silica cells. Fragments can often be identified down to species or genus level but where this is not possible or unnecessary they may be classified into other broader categories such as 'grass', 'shrub', 'forb' etc.

9. Sampling and enumeration of cuticle fragments. Having prepared slides of faecal material, some standardised method of observing and enumerating plant fragments must be used so that comparisons can be made. A small amount of milled faecal material can contain several thousand plant fragments so attempts are made to enumerate only a representative fraction. Various methods of enumeration have been employed including: 1) Counting the number of fragments of each type in fields of view, slide quadrats or along transects (e.g. Bullock 1982); 2) Estimating the areas of fragments of each type using a microscope graticule (Green 1987), the length of intercept along a transect (Nugent 1983) or using point sampling (Takatsuki 1978); and 3) Recording the presence or absence of different fragment types in a pre-determined number of fields (e.g. Sparks & Malechek 1968, Alipayo *et al.* 1992). If comparisons are to be made between samples then analysis should as far as possible be carried out 'blind' to reduce possible bias.

10. Calculation of faecal botanical composition. Depending on the enumeration method used, there are several ways of presenting the results. When counts or estimates of fragment areas are made, the relative density of each fragment type is usually expressed as a percentage (i.e. the number or area of fragments of a particular type divided by the total number or area of fragments of all types, multiplied by 100). If the presence/absence in a number of fields is measured then results may be presented as: a) the frequency of occurrence in 100 fields (Todd & Hansen 1973); b) the frequency of a species divided by the sum of frequencies for all species ('Frequency Addition' method, Holechek & Gross 1982b), or c) converted to an estimated relative density ('Frequency Conversion' method) by using a mathematical table given in Fracker & Brischle (1944) (Sparks & Malechek 1968) or direct calculation (Dearden Pegau & Hansen 1975). Prior to the determination of faecal composition, correction factors may be applied to some or all species to account for possible biases (e.g. Leslie *et al.* 1984)

3.3 Faecal analysis methods used in this study.

Following a review of faecal analysis literature and the conclusions of experiments described in Chapter 4, the following methodology for analysis of the goat faeces was adopted:

1. Freshly deposited pellet clusters were collected from identified goats and frozen in separate sealed and labelled plastic bags. Samples were collected each month from a minimum number of six goats at each site.

2. Four pellets from each cluster were thawed, gently rinsed to remove surface dirt, lightly crumbled and dried on a hot plate for 2-3 hours. The material was then passed through a 630 æm mesh sieve. Any larger fragments remaining were lightly ground using a mechanical coffee grinder and re-sieved. The process was repeated, re-milling only the remainder each time until all the material passed through the sieve. This avoided continued milling damage to smaller fragments.

3. Material that passed through the 630 µm mesh was caught over a 100 µm mesh sieve and the finer material was disposed of.

4. Each sample was then quartered and placed in four 50 ml beakers. to which 30 ml of 1:5 domestic bleach solution was added and left to stand for 36 hours, agitating occasionally.

5. Samples were then gently added to 1 litre of cold water and left to stand for 20 minutes to remove excess bleach. The sample was recovered by passing it over a 100 µm sieve and the fragments were placed into a shallow petri dish.

6. Approximately 5 ml of dilute (0.1 %) aqueous solution of Toluidine blue was used to stain the fragments for two minutes. Excess stain was removed by gently rinsing the material with cold water over a 100 µm sieve. Prepared material was then transferred to labelled tubes containing 5 ml of water.

7. Slides were made by lightly agitating the tubes to ensure mixing before removing a subsample with a wide-mouthed pipette. One or two drops were placed on a slide and covered with a 22 mm x 40 mm cover slip marked with a 3 mm grid.

8. Each month between six and sixteen samples (all from different individuals) were prepared from each site. Numbers of goats were lower at the Cwm Ffynnon site so all pellet clusters were analysed individually, four pellets taken from each. At the Padarn site, although all pellet clusters came from identified individual goats these were bulked together (four pellets from each goat) for analysis. After drying and milling these bulked samples were divided into four parts, each portion given a random code number by the author and then re-coded by an assistant. For Cwm Ffynnon samples were similarly coded so that neither the assistant or the author who carried out the analyses knew the sex, month or identity of any of the samples.

As samples from individual goats were kept separate at one site but bulked together at the other, two slightly different methods of enumerating fragments were used. For individual goat samples from Cwm Ffynnon two to four slides were prepared and fragments enumerated along randomly located 3 mm wide transects. In this way approximately 150 (148-182) fragments were identified for each individual. Samples from between three and seven goats of each sex were analysed giving a total of 457 to 1065 fragments identified each month. For the Padarn, 100 positive identifications of fragments were made from within 3 mm wide, randomly selected transects on four slides. Thus, a total of 400 fragments were identified for each monthly sample for each sex. Fragments were normally identified at x100 magnification although x400 was occasionally used in problematic cases. All data from analysis of the samples were typed directly into a spreadsheet using a portable computer.

9. After slide enumeration was completed the data for each site was collated. Faecal botanical composition was presented as the relative numerical contribution or "Relative Density" (Curtis & McIntosh 1950) of each plant group, calculated using the simple formula:

$$\left(\frac{\text{Number of fragments of plant group "A"}}{\text{Sum of all fragments identified}}\right) \text{X} \, 100$$

The proportion of unidentified fragments was also calculated as a percentage of the total number of fragments observed (non-identified / (identified + non-identified) x 100).

Data from individual goats were summed to give monthly results for each sex at Cwm Ffynnon. At both sites monthly data were summed to give overall yearly faecal compositions for each sex.

Faecal composition data were analysed using Kulzynski's similarity Index, one-way analysis of variance (ANOVA) and multivariate ANOVA (MANOVA) following normalisation using additive logarithmic transformation (Aitchison 1986). These are discussed further in Chapter 5 and details are given in Appendix 4. All statistical analysis was carried out using SYSTAT computer software (SYSTAT 1986)

3.4 Preparation of Plant cuticle reference material

Plant reference material was prepared in several different ways depending on the nature of the species and the types of cuticle to be prepared. A variety of leaf and stem material for each species was collected from the study sites, a list of the plant species in the reference collection is given in Table 3.1. Grass, rush and sedge samples were cut into short (1 cm) lengths, then cut along the leaf edge and down the central rib to assist separation of the cuticles. Other material was simply chopped into small (2-5 mm) fragments. All dissected fragments were then placed in a solution of 1 part 10 % chromic acid + 1 part 50 % nitric acid and heated in a water bath for up to four hours. The length of time needed to separate the cuticles varied and samples had to be checked regularly before rinsing them in a beaker of cold water. Suitable fragments of cuticle were then removed with a fine brush and stained with Toluidine blue, rinsed again and mounted as temporary or permanent slides. Permanent slides were dried and mounted using "Histomount". Temporary water-mounted slides were photographed at various magnifications from x100 to x600 using a "Leitz Orthoplan" microphotography system loaded with standard 200 ASA colour print film. Drawings and notes were made of distinguishing features on the cuticles and all microphotographs were filed in index boxes for easy access. Additional information on the epidermal anatomy of the species collected was collated from the botanical literature (listed in Appendix 1). Following the experiments described in Chapter 4, and synthesis of the information from notes, drawings and microphotographs, sufficient experience was gained to produce dichotomous keys for the identification of epidermal fragments from the two study sites. Identification of fragments from the faecal samples was made using both these keys and cross-checking with the other reference material. All fragments were identified down to species whenever possible but where this could not be done accurately broader categories were used (see Chapter 4). All epidermal material was placed into these broad categories and any unidentifiable fragments of fibrous tissue were also recorded.

Table 7.1 List of Plant Species in Reference Collection.

Nomenclature follows Clapham, et al. (1987) for dicotyledonous plants; Hubbard (1984) for grasses; Fitter & Fitter (1989) for Sedges, Rushes and Ferns; Smith (1978) for mosses; Smith (1990) for bryophytes; and Purvis et al. (1992) for lichens.

Common name	Specific name	Padarn (P) / Cwm Ffynnon
Trees (17)		
Alder	*Alnus glutinosa*	P
Ash	*Fraxinus excelsior*	P
Beech	*Fagus sylvatica*	P
Birch	*Betula pubescens*	P
Blackthorn	*Prunus spinosa*	P
Box	*Buxus sempervirens*	P
Elder	*Sambucus nigra*	P
Goat Willow	*Salix capra*	P
Hawthorn	*Crataegus monogyna*	P
Hazel	*Corylus avellana*	P
Holly	*Ilex aquifolium*	P
Norway Spruce	*Picea abies*	P
Oak (sessile)	*Quercus petraea*	P
Rhododendron	*Rhododendron. ponticum*	P
Rowan	*Sorbus aucuparia*	P
Sycamore	*Acer pseudoplatanus*	P
Yew	*Taxus baccata*	P
Shrubs (11)		
Bilberry	*Vaccinium myrtillus*	P/CF
Bramble	*Rubus fruticosus agg.*	P
Bell Heather	*Erica cinerea*	P/CF
Cotoneaster	*Cotoneaster simonsii*	P
Cross-leaved Heath	*Erica tetralix*	P/CF
Crowberry	*Empetrum nigrum*	CF
Gorse	*Ulex europaeus*	P
Heather	*Calluna vulgaris*	P/CF
Honeysuckle	*Lonicera periclymenum*	P
Ivy	*Hedera helix*	P
Wild rose	*Rosa canina*	P
Herbs (21)		
Barren Strawberry	*Potentilla sterilis*	P
Cowwheat	*Melampyrum pratense*	P
Dandelion	*Taraxacum vulgaris*	P
Dogs Mercury	*Mercurialis perrenis*	P
Foxglove	*Digitalis purpurea*	P
Hairy Bittercress	*Cardamine hirsuta*	P
Heath Bedstraw	*Galium saxatile*	P/CF
Herb Robert	*Geranium robertianum*	P
Lesser Celandine	*Ranunculus ficaria*	P

Common name	Specific name	Padarn (P) / Cwm Ffynnon
Marjoram	*Origanum vulgare*	P
Marsh Violet	*Viola palustris*	CF
Milkwort	*Polygala vulgaris*	CF
Navelwort	*Umbilicus rupestris*	P
Nettle	*Urtica dioica*	P
Sorrel	*Rumex acetosa*	P
Speedwell	*Veronica officinalis*	P
Stonecrop	*Sedum anglicum*	P
Tormentil	*Potentilla erecta*	P/CF
Woodsage	*Teucrium scorodonia*	P
Yarrow	*Achillea millefolium*	P
Wood Sorrel	*Oxalis acetosella*	P
Ferns (7)		
Bracken	*Pteridium aquilinum*	P/CF
Common Polypody	*Polypodium vulgare*	P
Hard Fern	*Blechnum spicant*	P/CF
Male Fern	*Dryopteris felix-mas*	P/CF
Parsley Fern	*Cryptogramma crispa*	P/CF
Spleenwort	*Asplenium trichomanes*	P
Wall Rue	*Asplenium ruta-muraria*	P
Clubmosses (1), Lichens (4), Mosses (2) and Hepatics (1)		
Fir Clubmoss	*Lycopodium selago*	CF
Lichen A	*Cladonia sp.*	CF
Lichen B	*Lecanora sp.*	P
Lichen C	*Hypogymnia sp.*	CF
Lichen D	*Lobaria sp.*	P/CF
Polytrichum	*Polytrichum spp.*	P/CF
Sphagnum Moss	*Sphagnum spp.*	P/CF
Liverwort	*Scapania spp.*	P/CF
Lilies (Spermatophyta: Liliaceae) (1)		
Bluebell	*Endymion nonscriptus*	P/CF
Rushes (5)		
Hairy Wood-rush	*Luzula pilosa*	P
Heath Rush	*Juncus squarrosus*	P/CF
Sharp flowered Rush	*Juncus acutiflorus*	CF
Soft Rush	*Juncus effusus*	P/CF
Toad Rush	*Juncus bufonius*	P
Sedges (5)		
Carex Sedges	*Carex spp.*	P/CF
Cottongrass	*Eriophorum angustifolium*	CF
Deergrass	*Scirpus cespitosus*	CF
Harestail Cottongrass	*Eriophorum vaginatum*	CF
Star Sedge	*Carex echinata*	CF
Grasses (14)		
Cocksfoot	*Dactylis glomerata*	P
Common Bent	*Agrostis capillaris*	P/CF

Common name	Specific name	Padarn (P) / Cwm Ffynnon
Creeping Soft Grass	*Holcus mollis*	P
Early Hair Grass	*Aira praecox*	P
Mat Grass	*Nardus stricta*	P/CF
Meadow Grass	*Poa spp.*	P/CF
Purple Moor Grass	*Molinia caerulea*	P/CF
Sheeps Fescue	*Festuca ovina*	P/CF
Sweet Grass	*Glyceria sp.*	P
Sweet Vernal Grass	*Anthoxanthum odoratum*	P
Velvet Bent	*Agrostis canina*	P/CF
Viviparous Fescue	*Festuca vivipara*	CF
Wavy Hair Grass	*Deschampsia flexuosa*	P/CF
Wood False Brome	*Brachypodium sylvaticum*	P

3.5 Fieldwork

3.5.1 Initial observations

Counts at both sites during the initial reconnaissance suggested there to be at least 25 goats at the Padarn site and approximately 15 in Cwm Ffynnon. This proved to be an underestimate for the Padarn site but an overestimate for Cwm Ffynnon due to the unusual presence other goats in the cwm. Consequently, sample sizes at the Cwm Ffynnon site were somewhat lower than preferred.

3.5.2 Identification of individuals

So as to ensure that faecal samples were taken from different individuals, an attempt was made to identify all goats in both groups. Drawings and colour photographs were made of as many animals as possible and code numbers were assigned to each individual.

Kids less than one year old could easily be distinguished from adults by their size and relative horn length. The two sexes could also be easily separated using secondary sex characteristics. Males generally had larger and broader swept horns, a thicker 'mane' of hair on neck and shoulders, often a tuft of hair on the forehead and appeared more heavily built than females of the same age. Individuals were aged where possible by counting annual growth rings on the horns (Bullock & Pickering 1984). Most goats at the Padarn site were between three and six years old and those in Cwm Ffynnon between three and five years (See Tables 2.1 and 2.2). Females were rather difficult to age using this method as their horns were both smaller and smoother than the males and rings were not distinct. Several naturally hornless goats (hummels) were present in the Padarn area which could be distinguished by their coat markings but whose ages could only be estimated.

Notes of distinguishing features such as pelage patterns, horn shape and size were made and a reference collection of drawings, notes, and photographs were carried on all field outings (see Figure 3.1). All goats in the Padarn group could easily be identified using their distinctive coat patterns. Individuals in Cwm Ffynnon group were more difficult, with females being almost wholly white. However, these too could be identified at close quarters using darker markings on their tails and lower legs. Some variation in pelage coloration occurred during the moult and when the goats got very wet but these changes were not sufficient to cause a problem.

Other workers have been successful in identifying individual goats using similar methods (e.g. Bonham & Fairley 1984, Riney & Caughley 1959, Smith 1989) and it is much less expensive and less disruptive than tagging.

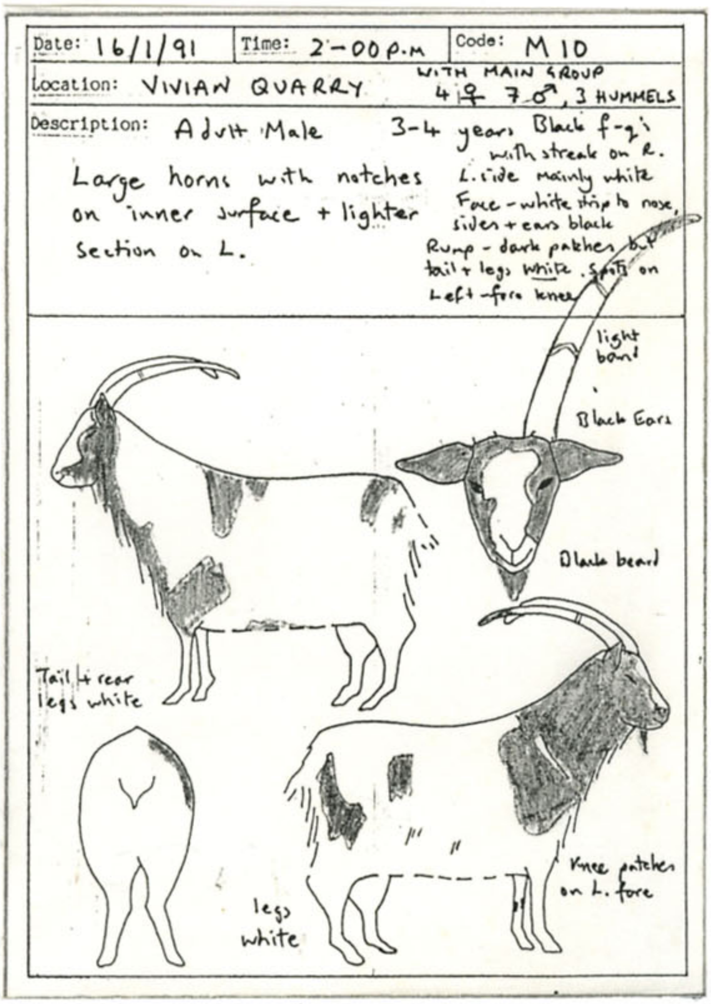


Figure 7.1 Fieldsheet notes for identification of goats (top) and photograph of male “M10”, an adult male from the Padarn group.

3.5.3 Field visits

After the initial period of site location and identification of individuals, a programme of field visits was begun in March 1991. These visits were designed chiefly for the collection of fresh faeces from identified goats and initially this entailed visiting each site for two or three consecutive days each month. With experience this was later reduced to one or two days per month as location and pursuit of the groups became more predictable. Visits took place at approximately four-weekly intervals (see Appendix 2. for dates). At the outset visits were made regardless of weather conditions but it became obvious that the goats sheltered during prolonged heavy rain or thick mist making them extremely difficult to locate. Also, if the goats were sheltering in caves or inside buildings then they could not be approached without disturbance, and collection of faeces from identified individuals became impracticable. In these situations field visits were delayed until the next suitable day.

Due to the difficult terrain, observation at night would have been difficult without disturbing the goats, and all field work was carried out during daylight.

In fine weather, all field observations were recorded directly onto printed field sheets. However, in poor weather, it was found easier to dictate notes onto cassette using a Sony TCM-37V 'Walkman' tape recorder and to transfer the information onto fieldsheets later.

3.6 Faecal Collections

Goat groups were located in different ways at the two sites. In Cwm Ffynnon an approach was made on foot and the cwm scanned first by eye and then using a x20 magnification telescope or 10x50 binoculars. The goats could usually be located quickly from a vantage point on the eastern shore of Llyn Ffynnon, and there was no need to move into the cwm straight away. At the Padarn site, the goats were often more difficult to locate due to the complicated terrain and dense woodland. A circular walk was devised by which most of the area could be viewed, and frequently goats were located after first coming across fresh droppings, evidence of fresh bark stripping and/or noticing their distinctive odour.

Once located, the goats were followed as far as possible without disturbance until sufficient samples had been collected. In Cwm Ffynnon the goats were usually visible at all times without leaving the vantage point at the foot of the cwm. At the Padarn site however, they frequently went out of sight behind trees and buildings or into gullies. Efforts were made to keep them in sight and by approaching slowly, in full view, it was usually possible to remain within 30 m of the group. Their tolerance to such behaviour was very variable and on some occasions it was possible to approach much closer without any apparent disturbance. In Cwm Ffynnon the goats were more easily disturbed and had to be stalked with caution, usually from over 50 m up-wind.

Whenever a goat was seen to deposit faeces, the precise position of the pellet cluster was sketched using nearby rocks and vegetation as landmarks. Goat and sheep faeces are sometimes similar in appearance and in order to ensure correct identification of samples great care was taken to only collect fresh samples observed to be voided by identified goats. When the rest of the group had moved away all the pellets in each cluster were then collected into individual sealable plastic bags, labelled with the sex and identity of the goat, time of production, date and site. On return from the field all samples were immediately frozen at approximately -15^{o}C usually within 4-5 hours of collection. Samples from as many different goats as possible in each group were collected each month.

Whenever possible all faeces at each site were collected on a single day each month. However, this was not always possible either because insufficient faecal samples were seen to be deposited or because individual goats were so dispersed that they could not all be located and followed on one day.

3.7 Mapping of goat movements

Prior to collection of faecal samples, the goats at each site were counted, identified and their location recorded at 30 minute intervals. Accurate location of all individuals proved impractical and if a group of goats was spread over a wide area then the estimated centre of the group was recorded. If an individual or group of goats were separated by more than 40 m then they were recorded as a separate group (Berdecou & Bousses 1985).

3.7.1 Ranges of male and female goats at the two sites.

Locations and altitudes of the Padarn goats were plotted using the (Ordnance Survey 1:25 000 scale Outdoor Leisure Map 17), Ordnance Survey 1:10 000 series, (sheets SH 55NE, 56SE, 65NW, SH 66SW) and Map 1 from the Padarn Country Park Management Plan (Gwynedd County Council 1980). In Cwm Ffynnon location of the goat groups was more difficult as there were few obvious landmarks such as walls, fences or footpaths to act as reference points. This difficulty was overcome by using both the Ordnance Survey 1:10 000 maps (Sheets SH 65NW, SH 65NE) and aerial photographs of the area (Photo 5386054 SNP, J A Story & Partners, Mitcham Surrey) overlaid with the Ordnance Survey National Grid divided at 100 m intervals and adjusted for photographic distortion. Large rocks, scree, streams and patches of vegetation visible both on the ground and on the aerial photographs were then used as reference points to locate goat groups more accurately. Locations for both sites were recorded as eight figure grid references giving a precision of approximately ñ 10 m on the ground. Where possible, altitudes as metres over datum (OD) were recorded to the nearest 10 m using the ordnance survey contour lines, in the Dinorwig quarries no contours are given and altitudes were estimated. Details of all field observations and goat locations are given in Appendix 2.

The positional data collected were used to define seasonal and 12-monthly ranges for the two sites using the minimum area method (Southwood 1978). In this method all points of observation are mapped and the outermost points joined up (avoiding re-entrant angles) to enclose the area. This is a simple and intuitive method for calculating the area enclosed by a set of locations and does not make any assumptions about the shape of the range, however, it is strongly biased by outliers and small sample sizes

Fieldwork was carried out chiefly for the collection of faecal samples, and records of the goats' range were collected rather opportunistically: No observations were made in periods of severe weather or at night, not all members of the group were located each month and observations were generally made on consecutive days and for limited time periods. Given the limitations of the minimum area estimation method and data collection, the ranges defined will be an incomplete record of the movements of the two groups of goats.

3.7.2 Estimation of vegetation/habitat utilisation and selection.

In order to shed light on the monthly faecal composition data, the varieties of habitats present within the ranges and the degree to which each were selected were estimated:

Areas of the 12-month range that the goats covered were estimated using all observations taken during the period of study. For calculation of the utilisation and degree of selection for different vegetation classes only locations where goats were observed feeding were used. Ranges for males and females were defined by the presence of adults (>1 year old) of each sex at each location. Hummels at the Padarn site were all apparently sexually active males and were classified as male. One female in the Padarn area kidded six months later than the others and perhaps because of this, associated with the male group more then the females. As no faecal samples were analysed from this individual and her behaviour seemed atypical she was not included in the estimation of range and vegetation class utilisation.

Estimation of the areas of both male and female ranges and the various vegetation classes were made using the IDRISI (IDRISI 1992) geographical information system. Simplified vegetation maps of the two sites (Padarn: Phase One Survey NCC 1989; Cwm Ffynnon: Upland Vegetation Survey NCC 1988) were digitised and areas of each vegetation/habitat class within the male or female ranges were calculated. Locations of all feeding observations were weighted by the number of goats present and plotted onto these vegetation maps. The relative vegetation utilisation was calculated by dividing the number of observations on each vegetation class by the total number of observation made that month. The degree of selection for each class was calculated using Jacobs electivity index (Jacobs 1974). This index relates the frequency of observations on each vegetation class to the relative areas of each class available to the goats using the formula:

$$E = \frac{Ui - Ai}{(Ui + Ai) - (2*(Ui*Ai)}$$

Where E is the degree of selection;
U_i is the proportion of observations on vegetation type *i*;
and A_i is the proportion of the range occupied by vegetation class *i.*

The index of selectivity, E, ranges from - 1.00 to 0.00 reflecting avoidance, and from 0.00 to + 1.00 for selection, of any particular vegetation class.

3.8 Social Organisation

A record of the number, sex and identity of goats observed in each group was made every 30 minutes and are summarised in Appendix 2. These data were used to investigate the degree of segregation into single sex groups and the varying size and numbers of groups at different times of the year. The number of goats in a group varied between observations on the same day as individuals lagged behind or joined the main group. Thus the maximum group size recorded each month was also noted as an indicator of social behaviour. Sex ratios and group sizes were calculated from the numbers of adult (>1 year old) goats present as young kids were both difficult to sex and often to locate. The timing of obvious behavioural events that may affect dietary choice, such as kidding and progression of the rutting season were also recorded.

3.9 Other field observations

As well as basic data on numbers, behaviour and location of goats, other information was recorded during field observations. These included notes on the current weather conditions (intensity of rainfall, wind strength and direction, cloud level, and snow depth), potential disturbance (passing walkers, dogs, aircraft noise etc), approximate numbers of sheep in the area, and visible changes in vegetation quality (bud-burst, flowering, fruiting etc.).

Any plants seen to be eaten by the goats were recorded and identified to species wherever possible but a detailed study of diet composition by direct observation was not attempted. Precise identification of the plants consumed proved difficult without approaching the goats very closely usually causing some disturbance.

Chapter 4. Aspects of the Faecal Analysis technique

Free *et al.* (1970) Johnson & Pearson (1981) and Holechek *et al.* (1982b) recommend a training period for workers using the faecal analysis technique to gain experience and consistency in identifying microscopic plant cuticle fragments. Holechek & Gross (1982a) identified observer experience as an important factor affecting the accuracy of microscopic analysis. Whilst time was too short to run a comprehensive training programme, it was felt that the examination of some aspects of the technique both to gain experience and to shed some light on appropriate methods would be useful. Four areas of preparatory work were undertaken:

a) analysis of a small number of hand-compounded plant mixtures to investigate different enumeration and calculation methods,
b) investigation into the likely confidence intervals appropriate to different sample sizes and proportions of dietary components,
c) development of dichotomous keys to assist in plant cuticle identification, and d) a test of the ease of identification of cuticle fragments from different species.

4.1 A comparison of composition estimation methods using hand compounded mixtures.

Hand-compounded mixtures of two to five plant species were examined to gain experience in identifying and counting small plant fragments, and to shed light on the most appropriate enumeration and calculation methods to use for faecal analysis.

4.1.1 Methods

Eight mixtures containing between two and five of the following species were made up by an assistant, actual compositions were unknown to myself:

Sheeps Fescue	(*Festuca ovina*)
Soft Rush	(*Juncus effusus*)
Bilberry	(*Vaccinium myrtillus*)
Bell Heather	(*Erica cinerea*)
Hazel	(*Corylus avellana*)
Oak	(*Quercus petraea*)
Wood Sage	(*Teucrium scorodonia*)
Foxglove	(*Digitalis purpurea*)

The plant material was all collected fresh, dried at 80^{o}C for 24 hours, milled and sieved between 500 µm and 100 µm screens. The various mixtures of dried plant fragments were then made up by weight. To simulate digestion, each mixture was cleared and macerated by heating in 50 % nitric acid in a boiling water bath for twenty minutes. The mixture was then rinsed in cold water over a sieve with a few drops of ammonia to neutralise the acid. Fragments were then transferred from the sieve and stained with toluidine blue for two minutes, rinsed to remove excess stain and placed in a beaker with a small amount of water. Fragments were gently stirred, a sample taken using a wide-mouthed pipette and one drop mounted in water on a slide with a coverslip. Slides were examined with a 'Nikon K-St' light microscope at x100 and x400 magnification and fragments identified by species. An average of 65 % of all fragments examined could be identified, the remainder was assumed to comprise species in proportions similar to the original composition.

Five different enumeration methods were used:

1. Quadrat-Number, QN (similar to the particle count method of Sparks & Malechek 1968): Counting numbers of all identified fragments in 100 fields (5 slides x 20 quadrats/slide) demarcated by 3 mm x 3 mm grids drawn on the coverslips. The quadrats were numbered and then located randomly. To ensure that no fragments were counted twice, quadrats were selected once only and any fragments crossing the upper and left-hand borders were ignored. At least 400 fragments were identified from a total of 100 quadrats.

2. Transect-Number, TN (similar to the counts along traverses used by Stevens 1977): Counting numbers of all identified fragments encountered on 25 transects (5 slides x 5 transects/slide) sytematically arranged across the full length of the coverslip. To prevent fragments being recorded twice, the transects were spaced 3 mm apart. Counting was always taken to the end of the transect, approximately 400 fragments were identified for each mixture.

3. Quadrat-Area, QA (similar to the area measurements of Green 1987):
All fragments identified in the quadrats using method '1' were measured using an eye-piece graticule. Fragment areas were estimated from length and width measurements at x100 magnification.

4. Transect-Area, TA (similar to the transect intercept measurements of Nugent 1983):
All fragments identified along transects using method '2' were measured using the intercept distance as an estimation of fragment area. An eyepiece graticule was used and measurements were taken at x100 magnification.

5. Presence/Absence P/A (similar to the frequency percentage method of Sparks & Malechek 1968):
Noting simply the presence or absence of each species in each of the 100 quadrats used in method '1'.

To account for possible differences in the relative surface areas of cuticle per dry weight of each species, an adjustment factor was employed on area (QA) and intercept (TA) results. A surface area to dry weight Ratio (SA:DWt) was calculated for each species by measuring areas of quantities of fresh leaves and then drying the same material to constant weight. Area and Intercept measurements were then multiplied by the SA:DWt ratio to give area adjusted figures (QAA, TAA).

Samples of fresh plant material were collected at the study sites and divided into leaf, petioles and stem material. At least 30 random samples (1-4 g each) of leaves (stems in the case of *Juncus effusus*) of each species were measured. Leaves and stems were flattened beneath sheets of glass and their areas estimated using a Seescan image analysis system. Leaves and stems were assumed to be totally flattened, with negligible thickness. Areas, in square centimetres were then multiplied by two to account for upper and lower surfaces. All samples were then oven dried at $80^{o}C$ to constant dry weight.

The SA:DWt ratio was calculated for each species in cm2g-1 , standard errors of the mean were calculated at the 95 % confidence level. Results are given in Table 4.1

Table 8.1 Surface Area : Dry Weight correction factors

Species	**Surface Area : Dry Wt (cm^2g^{-1})**	**95 % CI (cm^2g^{-1})**	**Number of samples (n)**
Festuca ovina	406.83	± 12.60	30
Juncus effusus	212.00	± 11.31	31
Vaccinium myrtillus	453.42	± 21.51	30
Erica cinerea	310.00	± 23.50	30
Corylus avellana	493.00	± 15.72	30
Quercus petraea	168.64	± 5.21	30
Teucrium scorodonia	292.28	± 26.94	30
Digitalis purpurea	274.57	± 13.39	30

4.1.2 Calculation Methods:

Three calculation procedures used by other workers were tested:

1. Relative Density (RD)
This procedure was used on the QN, TN, QA, TA methods all of which involved counts or area measurements of observed fragments and is equivalent to the particle count calculation method of Sparks & Malechek (1968). It is simply a reflection of the relative number or area (n) of individuals of each species enumerated, expressed as a percentage: i.e.

$$RD = \left(\frac{n\ (\text{species A})}{\sum n\ (\text{all species})} \right) X100$$

2. Frequency Conversion (FC)
This procedure was used only on the P/A method. It uses the relative number of quadrats that a species occurs in (F) to estimate the number of individuals (n) that are likely to be present under strict mathematical probability. F is calculated as:

$$F = \left(\frac{\text{Number of fields of occurence for species A}}{\text{Number of fields viewed}} \right) X100$$

If 100 fields are examined then the number of individuals (n) likely to be present can be looked up directly using a table given by Fracker & Brischle (1944). Otherwise, n can be calculated from the formula:

$$F = 100(1-\exp^{-n})$$

$$n = \exp^{-\left(1-\left(\frac{F}{100}\right)\right)}$$

Relative Densities can then be calculated using the value of n for each species as in the RD procedure $((^{n}/_{\sum n}) \times 100)$.

This method is described by Dearden, Hansen & Pegau (1975) as a better estimate of the amount of a species in a mixture than relative density. Sparks & Malechek (1968) estimated the dry weight composition of hand-compounded mixtures using frequency conversion and relative density (particle count) methods. They found that either procedure could be used with similar degrees of accuracy but recommended the frequency conversion technique as being easier and faster.

3. Frequency Addition (FA)
Again this procedure was only applied to the frequency data from the P/A method. The relative frequency (Rf) of each species is calculated directly from the number of quadrats a species occurs in, divided by the sum of the quadrats of occurrence for all species, expressed as a percentage. i.e.:

$$\mathrm{Rf} = \left(\frac{\text{number of fields of occurence for species A}}{\text{sum of fields of occurence for all species}}\right) \mathrm{X}\, 100$$

This calculation procedure has been used by Holechek & Gross (1982b) and Alipayo *et al.* (1992) to estimate known forage mixtures with a high degree of accuracy. Actual dry weight composition and the results from each technique are presented in Table 4.2. Actual and estimated percentage compositions are given in Table 4.3.

Table 8.2 Actual and Estimated compositions for different enumeration methods.

Mix	Species	Actual Dry Wt. (g)	QN (n)	QA graticule units	QAA graticule units	TN (n)	TA graticule units	TAA graticule units	P/A(fc)* estimated n	P/A(fa)* no. of fields
1.	*V. myrtillus*	.870	276	5,771,725	12,729	309	48,605	107.19	281.34	94
	J.effusus	.650	128	1,746,475	8,238	131	14,175	66.86	113.94	68
	Sum	1.520	404	7,518,200	20,967	440	62,780	174.05	395.28	162
2.	*V. myrtillus*	.700	358	7,852,775	17,318	311	48,343	106.61	460.52	99
	J.effusus	.440	150	1,816,475	8,568	295	7,440	35.09	127.30	72
	Sum	1.140	508	9,669,250	25,887	406	55,783	141.71	587.82	171
3.	*V. myrtillus*	.220	145	2,813,100	6,204	148	23,325	51.44	107.88	66
	J.effusus	.830	296	3,012,875	14,211	257	26,165	123.41	240.79	91
	Sum	1.050	441	5,825,975	20,415	405	49,490	174.86	348.67	157
4.	*F. ovina*	.307	186	5,067,700	12,456	178	22,140	54.42	134.71	74
	D. purpurea	.298	160	3,188,625	11,613	102	12,110	44.10	134.71	74
	E. cinerea	.201	72	2,029,950	6,548	42	7,500	24.19	77.65	54
	Q. petraea	.104	53	696,975	4,132	43	4,330	25.67	43.08	35
	J.effusus	.103	55	1,104,025	5,207	34	4,705	22.19	49.43	39
	Sum	1.014	526	12,087,275	39,958	399	50,785	170.58	439.58	276
5.	*F. ovina*	.104	70	2,136,775	5,252	87	10,295	25.30	71.33	51
	D. purpurea	.107	41	865,750	3,153	52	6,930	25.23	37.11	31
	E. cinerea	.108	20	639,850	2,064	41	7,790	25.12	16.25	15
	Q. petraea	.501	223	3,713,325	22,019	158	18,720	111.00	240.79	91
	J.effusus	.204	66	1,249,275	5,892	75	7,565	35.68	65.39	48
	Sum	1.024	420	8,604,975	38,381	413	51,300	222.36	430.87	236
6.	*F. ovina*	.210	132	3,132,275	7,699	142	16,320	40.11	123.79	71
	J.effusus	.117	48	764,925	3,608	33	2,745	12.94	51.08	40
	C. avellana	.201	80	2,000,775	4,058	48	7,220	14.64	77.65	54
	V. myrtillus	.205	60	1,863,150	4,109	60	9,575	21.11	49.43	39
	T. scorodonia	.301	134	3,365,200	11,513	119	19,375	66.28	138.63	75
	Sum	1.034	454	11,126,325	30,988	402	55,235	155.11	440.58	279
7.	*F. ovina*	.102	82	416,906	1,024	103	19,920	48.96	91.63	60
	J.effusus	.206	94	356,969	1,683	84	13,240	62.45	96.76	62
	C. avellana	.401	125	775,794	1,573	87	32,200	65.31	130.93	73
	V. myrtillus	.104	46	275,956	608	44	14,690	32.39	44.63	36
	T. scorodonia	.208	78	527,256	1,803	100	31,720	108.52	73.40	52
	Sum	1.021	425	2,352,881	6,694	418	111,770	317.65	437.35	283
8.	*F. ovina*	1.411	409	483,325	1,188	325	7,230	17.77	321.89	96
	V. myrtillus	.401	109	99,275	218	60	1,581	3.48	86.75	58
	E. cinerea	.225	23	41,125	132	17	507	1.63	26.14	23
	Sum	2.037	541	623,725	1,539	402	9318	22.89	434.78	177

* fc Frequency Conversion method, fa Frequency Addition method.

Table 8.3 Actual and Estimated Percentage compositions for different enumeration methods.

Mixture	Species	ACTUAL %	QN %	QA %	QAA %	TN %	TA %	TAA %	P/A FC %	P/A FA %
1.	*V. myrtillus*	57.24	68.32	76.77	60.72	70.23	77.42	61.60	71.17	58.02
	J.effusus	42.76	31.68	23.23	39.28	29.77	22.58	38.40	28.83	41.98
2.	*V. myrtillus*	61.40	70.47	81.21	66.91	76.60	86.66	75.24	78.34	57.89
	J.effusus	38.60	29.53	18.79	33.09	23.40	13.33	24.76	21.66	42.11
3.	*V. myrtillus*	20.95	32.88	48.29	30.39	36.54	47.13	29.43	30.94	42.04
	J.effusus	79.05	67.12	51.71	69.61	63.46	52.87	70.57	69.06	57.96
4.	*F. ovina*	30.29	35.36	41.93	31.17	44.61	43.60	31.90	30.65	26.81
	D. purpurea	29.40	30.42	26.38	29.06	25.56	23.85	25.85	30.65	26.81
	E. cinerea	19.87	13.69	16.79	16.39	10.53	14.77	14.18	17.66	19.56
	Q. petraea	10.26	10.08	5.77	10.34	10.78	8.53	15.05	9.80	12.68
	J.effusus	10.19	10.46	9.13	13.03	8.52	9.27	13.01	11.24	14.13
5.	*F. ovina*	10.16	16.67	24.83	13.68	21.07	20.07	11.38	16.55	21.61
	D. purpurea	10.45	9.76	10.06	8.22	12.59	13.51	11.35	8.61	13.14
	E. cinerea	10.55	4.76	7.44	5.38	9.93	15.19	11.30	3.77	6.36
	Q. petraea	48.93	53.10	43.15	57.37	38.26	36.49	49.92	55.88	38.56
	J.effusus	19.92	15.71	14.52	15.35	18.16	14.75	16.05	15.18	20.34
6.	*F. ovina*	20.31	29.07	28.15	24.85	35.32	29.55	25.86	28.10	25.45
	J.effusus	11.32	10.57	6.87	11.64	8.21	4.97	8.35	11.59	14.34
	C. avellana	19.44	17.62	17.98	13.10	11.94	13.07	9.44	17.63	19.35
	V. myrtillus	19.83	13.22	16.75	13.26	14.93	17.34	13.61	11.22	13.98
	T. scorodonia	29.11	29.52	30.25	37.15	29.60	35.08	42.74	31.47	26.88
7.	*F. ovina*	9.98	19.29	17.72	15.31	24.64	17.82	15.41	20.95	21.20
	J.effusus	20.18	22.12	15.17	25.15	20.10	11.85	19.66	22.12	21.91
	C. avellana	39.26	29.41	32.97	23.51	20.81	28.81	20.56	29.94	25.79
	V. myrtillus	10.19	10.82	11.73	9.09	10.53	13.14	10.20	10.20	12.72
	T. scorodonia	20.38	18.35	22.41	26.95	23.92	28.38	34.16	16.78	18.37
8.	*F. ovina*	69.27	75.60	77.49	77.16	80.85	77.59	77.63	74.04	54.24
	V. myrtillus	19.69	20.15	15.92	14.22	14.93	16.97	15.23	19.95	32.77
	E. cinerea	11.05	4.25	6.59	8.62	4.23	5.44	7.14	6.01	12.99

4.1.3 Analysis of results

Actual and estimated percentage composition results were compared using Kulzynski's Similarity Index (KSI) (Oosting 1956). A value for the percentage similarity of two mixtures (with 100 % representing no difference between actual and estimated composition) is given by:-

$$\mathrm{PS}\,(jk) = 100 \,\mathrm{X}\, \frac{2.\sum^{\mathrm{I}} \min\,(\mathrm{P}ij, \mathrm{P}ik)}{\sum^{\mathrm{I}} (\mathrm{P}ij + \mathrm{P}ik)}$$

Where Pij and Pik are percentages of a species i in the two samples j (Actual) and k (Estimated).
Results are given in Table 4.4 and similarity values are ranked for different enumeration and calculation techniques in Table 4.6

Actual and estimated percentage compositions for individual species (combined from all mixtures) were compared using the paired sample t test. The null hypothesis (H_o actual composition = estimated composition) was rejected at $P < 0.1$ and results are presented in Table 4.5

4.1.4 Results and Discussion:

Kulzynski's Similarity Index.
All enumeration and calculation procedures showed reasonably high levels of similarity between the actual dry weight compositions and estimated compositions. Values were within the range of 81.90 to 91.02 and no one method stood out as being considerably better or worse than others (see Table 4.6). Dry weight composition was best estimated using the adjusted areas of fragments located in random quadrats (QAA). One might expect this to be the case as errors due to differences in density and fragmentation should be minimised. Unadjusted area data gave a lower degree of similarity overall suggesting that correction for variations in surface area to dry weight ratio can improve accuracy. Results of enumerating fragments within quadrats and along transects produced differing degrees of similarity. Lower KSI values in the case of transect measurements may be due to the slightly lower number of fragments encountered or possible non-random distribution/alignment of fragments on the slide.

Table 8.4 Values for Percent Similarity (KSI) for different mixtures by enumeration methods:

Mix	Species	Dry Weight Composition (%)	QN %	QA %	QAA %	TN %	TA %	TAA %	P/A FC %	P/A FA %
			....................................KSI Values...							
1.	*V. myrtillus*	57.24								
	J.effusus	42.76	88.92	80.47	96.52	87.01	79.82	95.64	86.07	99.22
2.	*V. myrtillus*	61.40								
	J.effusus	38.60	90.93	80.19	94.49	84.80	74.73	86.16	83.06	96.49
3.	*V. myrtillus*	20.95								
	J.effusus	79.05	88.07	72.66	90.56	84.41	73.82	91.52	90.01	78.91
4.	*F. ovina*	30.29								
	D. purpurea	29.40								
	E. cinerea	19.87								
	Q. petraea	10.26								
	J.effusus	10.19	93.65	88.36	96.19	85.16	86.71	90.77	97.34	93.63
5.	*F. ovina*	10.16								
	D. purpurea	10.45								
	E. cinerea	10.55								
	Q. petraea	48.93								
	J.effusus	19.92	89.32	85.33	88.04	86.96	82.40	96.14	86.65	85.45
6.	*F. ovina*	20.31								
	J.effusus	11.32								
	C. avellana	19.44								
	V. myrtillus	19.83								
	T. scorodonia	29.11	90.83	91.02	87.10	84.50	84.80	80.82	89.59	91.84
7.	*F. ovina*	9.98								
	J.effusus	20.18								
	C. avellana	39.26								
	V. myrtillus	10.19								
	T. scorodonia	20.28	88.11	88.69	83.14	81.46	81.21	80.77	87.07	84.51
8.	*F. ovina*	69.27								
	V. myrtillus	19.69								
	E. cinerea	11.05	93.21	91.78	92.11	88.43	91.68	91.64	94.97	84.98
Average for all mixes			90.38	84.81	91.02	85.34	81.90	89.18	89.35	89.38
SE		±	1.81	5.50	3.96	1.79	4.99	5.04	3.98	5.82

Table 8.5 Probability Values for paired sample t test.

Species	n	QN	QA	QAA	TN	TA	TAA	P/A (FC)	P/A (FA)
		Enumeration/Calculation methods							
V. myrtillus	n=6	.203 ns	.124 ns	.747 ns	.215 ns	.095 ns	.436 ns	.233 ns	.319 ns
J.effusus	n=7	.061 ns	.022 *	.309 ns	.035 *	.015 *	.072 ns	.082 ns	.707 ns
F. ovina	n=5	.001 **	.002 **	.018 *	.000 **	.001 **	.030 *	.026 *	.730 ns
E. cinerea	n=3	.002 **	.016 *	.044 *	.164 ns	.606 ns	.264 ns	.072 ns	.681 ns
Q. petraea	n=2	.527 ns	.080 ns	.494 ns	.531 ns	.412 ns	.370 ns	.542 ns	.646 ns
C. avellana	n=2	.384 ns	.355 ns	.256 ns	.254 ns	.151 ns	.187 ns	.378 ns	.496 ns
D. purpurea	n=2	.879 ns	.418 ns	.404 ns	.824 ns	.821 ns	.658 ns	.880 ns	.988 ns
T. scorodonia	n=2	.627 ns	.174 ns	.064 ns	.412 ns	.092 ns	.003 **	.869 ns	.033 *
All Species	n=29	1.0 ns	1.0 ns	.999 ns	1.0 ns	1.0 ns	.999 ns	.999 ns	.999 ns

H_o Actual composition = estimated composition

H_o was rejected at	P < .01	(**)
(Marginal)	P > .01<.05	(*)
H_o not rejected at	P > .05	(ns)

Table 8.6 Methods ranked in descending order of KSI:

Method	**Mean KSI**
Quadrat Area Adjusted (QAA)	91.02
Quadrat Number (QN)	90.38
Presence/Absence Frequency Addition (P/A FA)	89.38
Presence/Absence Frequency Conversion (P/A FC)	89.35
Transect Area Adjusted (TAA)	89.18
Transect Number (TN)	85.34
Quadrat Area (QA)	84.81
Transect Area (TN)	81.90

Paired Sample t test.

Again, when all mixtures are considered together, no method stood out as considerably better or worse than another, for all methods and calculation procedures actual and estimated compositions were similar.

When individual species are considered (for species with n>5), *Festuca ovina* appeared to be poorly estimated with most methods except 'frequency addition'. *Erica cinerea* was also poorly estimated using the 'QN' method. However, due to the very small sample sizes it would be unwise to distinguish any superior enumeration or calculation method for individual species from these results.

4.1.5 Prediction Equations

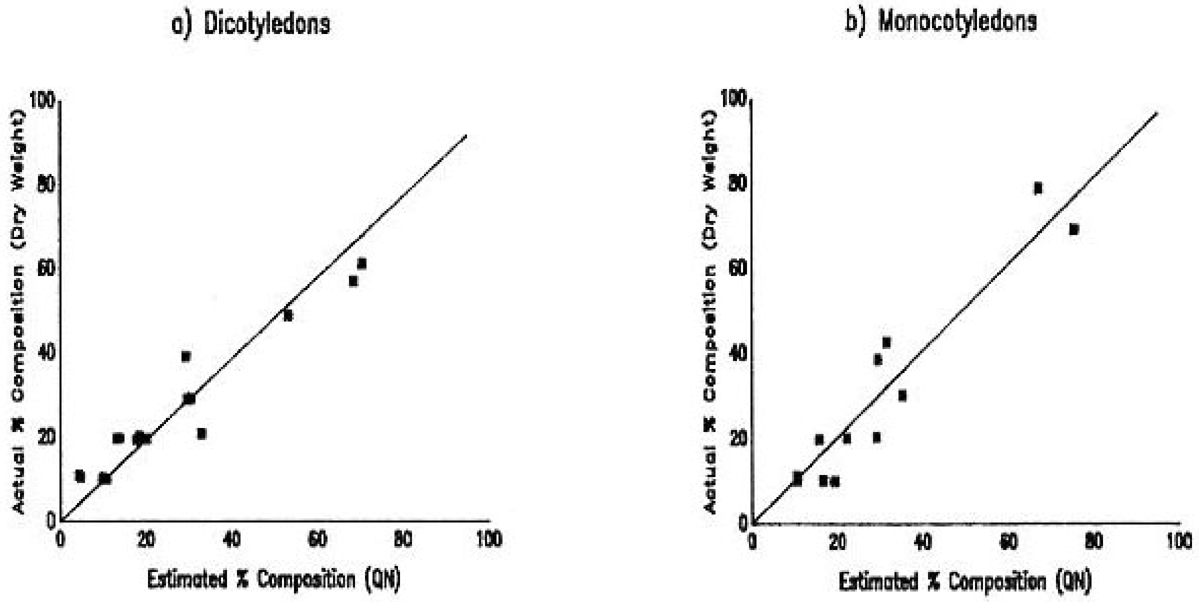
To investigate the relationship between estimated and actual percentage compositions, linear regression equations were developed for groups of species (monocotyledons and dicotyledons) and for all species combined for each enumeration and calculation procedure. Regression coefficients (β) were not significantly different from 1.0 for most categories (see Table 4.7). The two monocotyledons taken together were generally slightly underestimated and the dicotyledons slightly overestimated. A Students t-test showed that there was no significant difference ($P < .01$) between regression equations for monocotyledons and dicotyledons. Consequently it is likely that regression equations are not statistically different from the equation $Y = X$ (i.e. Estimated Composition = Actual Composition). The dry weight composition of the mixtures could be predicted directly from all enumeration and calculation procedures and all could be used with similar degrees of accuracy. Regression coefficients are given in Table 4.7 and prediction equations for the particle count (QN) method shown in Figure 4.1.

Table 8.7 Coefficient values used in prediction equations

$Y = \beta X$ (constant not required)

Method	All Species		Monocotyledons		Dicotyledons	
	β	r2	β	r2	β	r2
Quadrat Number (QN)	.964	.962	1.016	.962	.918	.967
Quadrat Area (QA)	.911	.891	1.043	.875	.826	.933
Quadrat Area Adjusted (QAA)	.968	.969	1.000	.982	.938	.958
Transect Number (TN)	.930	.915	.948	.911	.912	.921
Transect Area (TA)	.892	.870	1.041	.862	.802	.910
Transect Area Adjusted (TAA)	.951	.950	1.014	.974	.895	.933
P/A (Frequency Conversion)	.943	.950	1.037	.951	.872	.964
P/A (Frequency Addition)	1.035	.939	1.093	.947	.983	.936

Figure 8.1 Relationship of estimated composition (using Quadrat Number (QN) method) and dry weight composition for (a) Dicotyledons and b) Monocotyledons.



These results are in agreement with Sparks & Malechek (1968) who also found that simulated diet mixtures could be accurately estimated using particle density (QN) or frequency percentage (P/A FC) methods. Too few mixtures were analysed to develop correction factors for individual species, but recent work on known diets fed to sheep, cattle and goats has shown that correction factors for differential digestion or fragmentation may not be necessary (Putman *pers comm*., Alipayo *et al.* 1992). Holechek & Gross (1982b) examined three calculation procedures and concluded that the frequency addition method gave equal or better accuracy than frequency conversion or relative density methods. They noted however, that in certain cases, frequency conversion gave a better estimate for species that fragmented more, and this same source of error was magnified by the particle density method.
Although only a small number of mixtures and plant species were examined and more would be needed to draw unequivocal conclusions, it would appear that for the mixtures used here no one enumeration and calculation combination gives much better estimates of percentage dry weight composition than any other. This may not be true in the case of other species or the same species in different combinations. Although comparisons of accuracy do not show distinct differences, other practical considerations can be taken into account when evaluating each of the four basic methods:

Area adjustment (QAA, TAA): a large amount of time and effort is needed to derive accurate adjustment ratios. It is known that the Surface Area : Dry Weight ratio varies not only in different portions of any one plant but also exhibits geographic and seasonal variation (Dunnet *et al.* 1973, Storr 1961). Also, considerable difficulty was found in measuring surface areas of certain species (e.g *Erica* spp.) due to leaf shape and structure.

Area Measurement (QA, TA): estimating areas of plant fragments with the use of a microscope graticule can be rather subjective, certain species break up into characteristically shaped pieces, some of which may be easier to measure accurately than others. Also, the fragments of some species have a tendency to fold or curl making measurements difficult.

Non-random alignment of fragments in the case of the transect-intercept method may also be a cause of bias.

Particle count (QN, TN): this method has fewer of the above problems providing that fragments are diluted sufficiently on the slides so that they do not overlap. However, it has been recommended that at least 400 fragments are identified for each sample (Stevens 1977) and species which have a greater tendency to fragment may be overestimated. Counting along systematic transects assumes that fragments are randomly distributed and non-aligned which may be difficult to ensure.

Presence/Absence (P/A): two requirements must be met before this method can be used to predict dry weight composition. Firstly, plant fragments must be randomly distributed over the slide, and secondly, the most common species should not occur in more than 86 % of the microscope fields (Curtis & McIntosh 1950). Again, random distribution of fragments may be difficult to ensure and this method was avoided by Stevens (1977) because of this. Dilution of the material on the slide can ensure that the second requirement is met, but the degree of dilution must be found by trial and error. It is likely that this method is less accurate when there are only or one or two species in the mixture and Smith (1989) discounted this method in favour of fragment counts for this reason.

Taking the above considerations into account the most appropriate methods would seem to be the particle count (QN) or the presence/absence (P/A) methods. Although the presence/absence method may be slightly faster, the particle count method was employed in this study in line with other faecal analysis carried out in the U.K.

4.2 Sample size and attendant confidence limits.

A number of factors need to be considered when designing a sampling schedule for faecal analysis. Scotcher (1979) noted that the span of sampling time may be more important than the number of samples. Whilst sampling period is usually limited, consideration of sampling interval and selection of animal groups are important. The number of individuals from which samples are collected has to be decided, as has the number of defaecations from each animal. For faecal analysis each defaecation is usually subsampled, so the number of pellets per defaecation and the number of plant fragments identified has also to be determined.

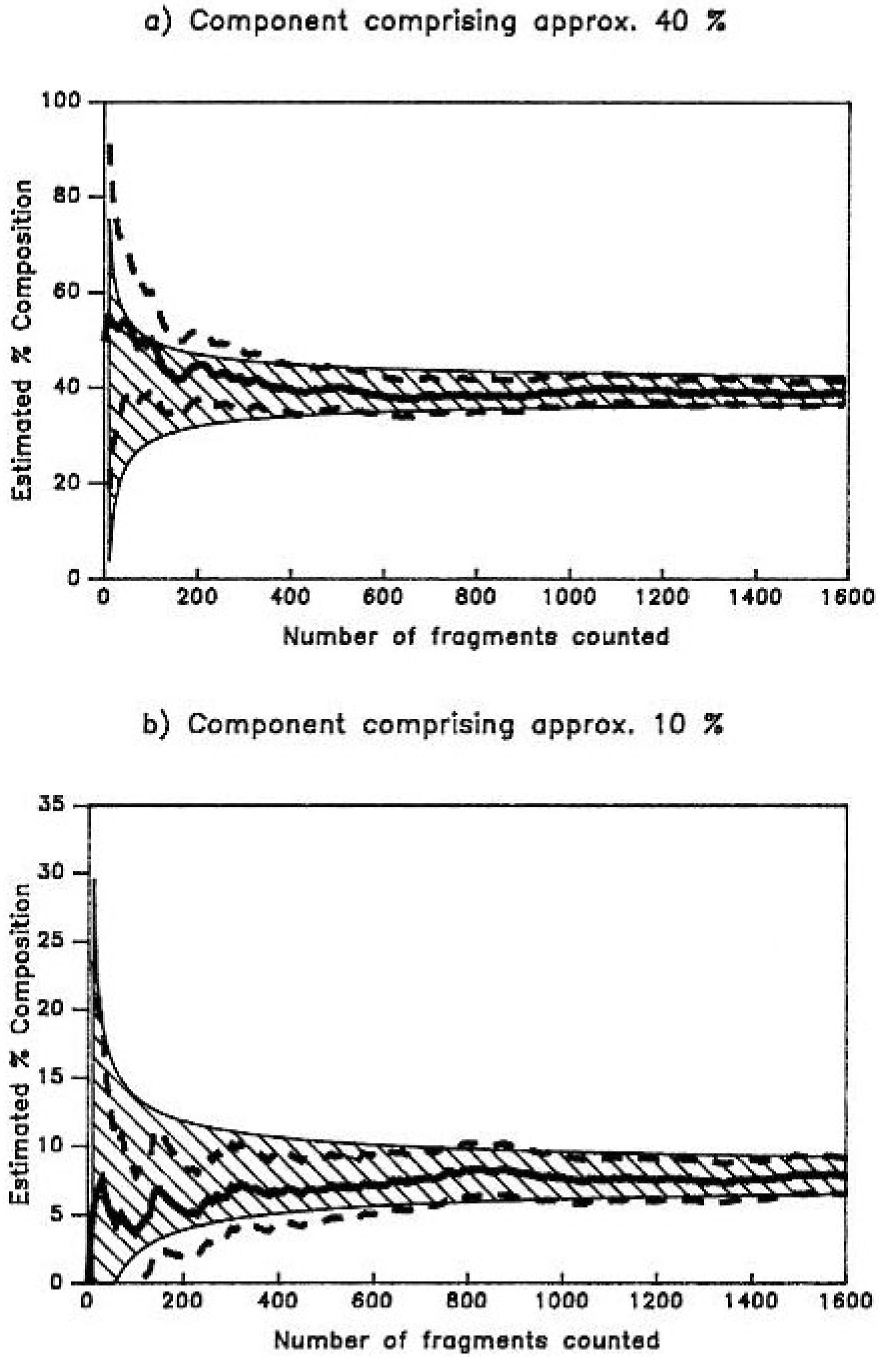
There have been few studies to define the minimum number of faecal samples required to represent animal diet for a particular location or time period. Scotcher (1979) suggested that faecal samples from a minimum of 10 individuals should be examined, preferably analysed separately with pooled results. Anthony & Smith (1974) examined the variances in data from faecal and rumen analysis of deer and found that 15 faecal or 50 rumen samples appeared to be the minimum for studying diet for a particular season. Kerridge & Bullock (1991) found that a sample size greater than 5 provided a representative sample for diet analysis. In this study, a target minimum of five goats per month was set with all samples analysed separately and the results later pooled.

Scotcher (1979) recommended that two to five pellets should be examined for each individual animal. Bullock (1982) compared four pairs of pellets from the same defaecation, found no significant differences in botanical composition between them, and therefore used two pellets from each defaecation. In this study, four pellets were prepared from each individual defaecation.

Stevens (1977) hypothesised that the distribution of plant material within faecal samples approached that of a binomial distribution and concluded that a sample of greater than 400 fragments appeared desirable. Galt *et al.* 1968) investigated the number of microscope samples (using point sampling at grid intersects) needed to make reliable estimates of masticated forage samples. They discovered that components comprising more than 30 % of the mixture could be estimated reliably but reliability decreased for components less than 10 %. Although the precision of component estimates continued to increase with more than 400 identifications, the increase was small in relation to the additional time required. Grimes *et al.* (1965) compared the fiducial limits (95 % confidence level) for various sample means with counts of 100, 250 and 1000 points. The variances calculated from a binomial distribution were compared with those observed in experimental work on herbage samples. They concluded that the confidence limits of any estimate could be predicted using a table of the binomial distribution given in Snedecor & Cochran (1967). Harker *et al.* (1964) also examined the number of points required to estimate various sample means at the 90 % Confidence level. Again, 400 identifications were needed to estimate the percent dry matter to within ± 10 % of the mean when the component was between 30 % to 50 % or within ± 20 % of the mean for components between 16 % and 30 %

Lack of time prohibited a detailed examination of the precision of faecal analysis but when analysis of one faecal sample was continued until 1600 fragments had been identified, the 95 % confidence limits followed a similar pattern to those predicted assuming a binomial distribution (see Figure 4.2).

Figure 8.2 Estimated percentage composition of two components (a, 40 % and b, 10 % approximately) versus number of fragments identified. Dotted lines show the estimated 95 % confidence limits and the shaded area shows the theoretical 95 % confidence limits assuming a binomial distribution, taking the final composition after 1600 identifications as the mean. (Confidence intervals have been corrected for continuity (Snedecor & Cochran 1967).

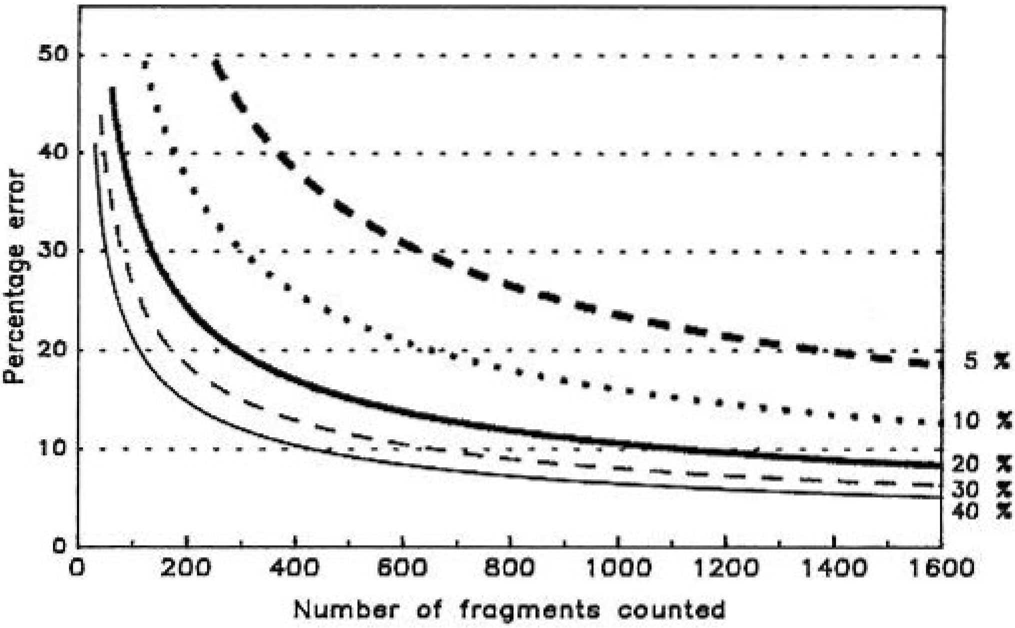


A Chi^2 goodness of fit test (Zar 1984) was carried out on the data (160 x 10-fragment samples) and the null hypothesis that the data was binomially distributed was accepted at 0.25

< P < 0.10 ($X^2_{0.05,6}$ = 15.507 > 10.713).

In this study the hypothesis that sample estimates of each species would be binomially distributed around the mean is accepted. Consequently, the number of fragments needed to estimate various sized components at different confidence levels can be predicted (See Figure 4.3).

Figure 8.3 Estimated percentage error (90 % Confidence level) versus number of fragments counted for various sized components of a mixture assuming data is binomially distributed.



From Figure 4.3 it appears that approximately 400 samples are required to estimate (at the 90 % confidence level) a 40 % component to within ± 10 %. Components comprising less than 40 % theoretically require larger sample populations for the same level of precision. Although several authors have noted this relationship, microscopic analysis of large numbers of fragments from faecal samples is tedious and time consuming, consequently most workers have relied on lower fragment counts, usually in the range of 100 to 300 fragments per sample. Stevens (1977) commented that although the optimal sampling population appeared to be 400, operator fatigue and deterioration in sample quality caused loss of accuracy and he used 200 fragment identifications per sample.

To compare faecal botanical compositions, samples from an average of four goats of each sex were examined each month from Cwm Ffynnon. Approximately 150 fragments were examined from each individual goat so that the number of fragments examined each month were approximately: 150 per individual goat; 600 per sex; and 1200 per group. From the Padarn area individual faecal samples were pooled and 400 fragments from each sex were identified each month. Although the theoretical confidence intervals for monthly dietary components from individual goats may be wide, those for each sex and groups of goats should be acceptable at least for major (>10 %) dietary components.

4.3 Keys to aid identification of plant cuticle fragments.

Faecal analysis requires the ability to identify cuticle and epidermal fragments of all plant species encountered in the samples with equal ease, or else to use correction factors to compensate for biases in identification. Fragment identification is carried out using the presence, shape, size, and distribution of diagnostic epidermal features. These include: stomata (and their subsidiary cells), trichomes (from papillae and prickle-hairs to macro-hairs), silico-suberose bodies (especially in the Gramineae), cell wall features (thickness, degree of corrugation), cell shape (size, proportions and degree of differentiation), and glandular bodies (Radford *et al.* 1974). However, information regarding these diagnostic features is scattered. Although some workers have presented drawings and micrographs of useful features for restricted species, mainly grasses (e.g. Martin 1955, Davies 1959, Clifford & Watson 1977) plant taxonomists have been reluctant to rely purely on cuticular features for identification purposes. Any rules to distinguish between particular species may not be transferable between areas as cell characteristics may vary between plants sampled from different locations with different growth conditions (Putman *pers comm*.). Consequently, most workers have assembled their own unique reference collections and developed their own systems of distinguishing between plant species/groups. Some identification keys have been published (e.g. Croker 1959, Rieghert & Singh 1982) but only two (Bhadresa 1981, Matrai *et al.* 1986) deal wholly with typical European species.

In this study, two dichotomous keys to identify cuticle/epidermal plant fragments were developed (one for each study area). They could have been amalgamated, but as many forage species were present only at the Padarn site, a smaller, separate, key for Cwm Ffynnon was appropriate.

As described in Chapter 3, a large reference collection of plant material thought likely to be found in the diet of the goats was collected and preserved as slides, drawings, colour micrographs and written notes. Most of this was leaf material, but included portions of flowers, fruit, petioles, and stems or equivalent organs. Potential diagnostic features were noted and information collated to form dichotomous keys (See Appendix 1). This was a useful training procedure, providing experience in examining a large number of epidermal fragments from a variety of known species. Despite being a lengthy process, it was felt that the increased accuracy and confidence in identifying fragments from faecal samples made it worthwhile.

Both keys proved valuable in learning to identify fragments from hand-compounded mixtures digested in vitro. However, the full-length keys were of less use when identifying fragments from faeces. Certain species could not be identified further than plant type (e.g. 'tree' or 'sedge') due to loss of diagnostic features on passage through the gut. Also, since species were grouped into taxa in the results, shorter, simpler keys may have been more appropriate.

The keys and examples of plant reference material are presented in Appendix 1. Other photomicrographs, notes and permanent slides of plant cuticle material prepared during this study are held at the School of Agriculture & Forest Sciences, UCNW Bangor.

4.4 Identification of plant cuticle material.

Although Havstad & Donart (1978) examined the ratio of identifiable to non-identifiable fragments for grasses and forbs, the basic assumption that all species can be correctly identified with equal ease has rarely been discussed. There is some variation in the degree to which material from faecal samples has been identified. Whilst some authors have identified the majority of fragments down to species level and presented their results in this way, others have classified material into broader taxonomic groupings, either to simplify the presentation of results or as a reflection of the difficulties in distinguishing certain categories of material. During the development of identification keys and previous experiments, it was noted that certain species were considerably more difficult to identify than others. In some cases it was difficult to separate similar species, although the same material could be identified easily at a higher taxonomic level. For qualitative purposes it may be important to identify all the different species encountered, but if quantitative data is needed on diet composition, then large numbers of fragments have to be examined and identified rapidly. Consequently a balance has to be struck between the level of detail required and the time available. Classifying difficult species into larger groups can save time and reduces the chances of mis-identification. To identify potential problem species and to define suitable plant groupings, a simple test of species recognition was carried out.

Material (mainly leaves) from 53 species/groups of common plants were dried, ground over a 500 æm mesh sieve and macerated using 50 % nitric acid to mimic digestion. Samples were stained with toluidine blue and mounted in water on slides.

A total of 465 randomly numbered slides (5-17 per species/group) were prepared by an assistant. These were then examined at x100 and x400 magnification. Wherever possible only the first fragment located was examined and identified, but in the case of severely macerated material two or three fragments were needed. Using the previously prepared reference material and keys, the slides were classified at three different levels:

1. Monocotyledons or Dicotyledons and others.

2. Taxonomic grouping (Taxa): 'Tree', 'Waxy-leaved plant' 'Heath shrub', 'Non-ericaceous shrub', 'Herb', 'Fern', 'Moss', 'Lichen', 'Rush', 'Sedge', or 'Grass'.

3. Species or sub-group.

The proportions of each taxonomic group/species that were correctly identified are shown in Table 4.8

All slides were correctly categorised at the first level as monocotyledons/dicotyledons-miscellaneous. Identification of the fragments into broad taxonomic groups was also reasonably good, although rushes and sedges were occasionally confused with each other but never with grasses. Herbs could occasionally be mistaken for ferns but this was mainly due to the fragile and indistinct cuticle of *Galium saxatile*. *Lonicera periclymenum* also proved difficult to identify and was mistaken both for a herb and a fern. One slide of *Fagus sylvatica* was classified wrongly as a herb but overall trees, waxy-leaved plants, heath shrubs, ferns, mosses, lichens and grasses were correctly categorised. Identification of fragments down to species level was more variable. Some species were easily recognised even when fragments were very small (i.e. less than 100 μm^2). Others were only identifiable when many different diagnostic features were present on the one fragment. Thus, for qualitative purposes, provided fragments of sufficient size are examined, some at least should be correctly identified to species, although misidentifications may occur. For quantitative analysis, identification of all fragments to species level is too inconsistent. Classification of fragments into larger taxonomic groups can be done with much greater confidence and simplifies the presentation of results when many species are involved. Consequently, it was decided to present faecal composition data by grouping species into the larger 'taxa' as presented in Table 4.8. Whilst identification of some material down to species level remained difficult and time consuming, it is felt that accuracy at all levels of classification was improved by these training exercises and bias through gaining experience during the faecal analysis was minimised.

Table 8.8 Results of an identification test from prepared slides of 53 plant species.

Taxa	**Species**	**Slides identified to species / total**	**% Correctly identified to species**	**% Correctly identified to taxa**
(Dicotyledons)				
Trees	*Betula pubescens*	4/5		
	Corylus avellana	5/5		
	Crataegus monogyna	4/5		
	Fagus sylvatica	3/5		
	Quercus petraea	4/5		
	Salix capra	5/5		
	Sorbus aucuparia	4/5	82.9	97.1
Waxy-leaved plants	*Hedera helix*	7/10		
	Ilex aquifolium	7/10		
	Rhododendron ponticum	6/10		
	Ulex europaeus	10/10	75.0	100.0
Heath-Shrubs	*Calluna vulgaris*	8/11		
	Empetrum nigrum	8/10		
	Erica cinerea	4/10		
	Erica tetralix	6/10	63.4	100.0
Non-ericaceous Shrubs	*Lonicera periclymenum*	5/10		
	Rubus fruticosus agg.	10/10		
	Vaccinium myrtillus (leaf & fruit)	15/15	85.7	91.4
Herbs	*Achillea millefolium*	5/5		
	Digitalis purpurea	5/5		
	Galium saxatile	4/11		
	Melampyrum pratense	4/5		
	Origanum vulgare	4/5		
	Oxalis acetosella	5/5		
	Polygala vulgaris	9/10		
	Potentilla erecta	11/12		
	Teucrium scorodonia	5/5		
	Viola palustris	6/10	76.7	87.7
(Miscellaneous taxa)				
Ferns	*Blechnum spicant*	7/11		
	Cryptogramma crispa	10/17		
	Dryopteris felix-mas	3/10		
	Pteridium aquilinum	13/16	61.1	100.0
Mosses	*Sphagnum spp.*	9/10		
	Polytrichum spp.	12/12	95.5	100.0

Taxa	Species	Slides identified to species / total	% Correctly identified to species	% Correctly identified to taxa
Lichens (Monocotyledons)	*Cladonia spp.*	5/5	100.0	100.0
Rushes	*Juncus acutiflorus*	4/5		
	Juncus effusus	4/5		
	Juncus squarrosus	3/5	73.3	80.0
Sedges	*Carex echinata*	4/5		
	Carex nigra	3/5		
	Eriophorum angustifolium	1/5		
	Scirpus cespitosus	1/5	45.0	85.0
Grasses	*Agrostis capillaris*	12/15		
	Aira praecox	7/8		
	Anthoxanthum odoratum	6/10		
	Brachypodium sylvaticum	4/9		
	Dactylis glomerata	8/10		
	Deschampsia flexuosa	15/15		
	Festuca ovina	11/14		
	Holcus mollis	3/6		
	Molinia caerulea	12/14		
	Nardus stricta	13/15		
	Poa annua	8/9	79.2	100.0

Chapter 5. Results

In this chapter summary data on the male and female ranges, habitat utilisation and selection are presented separately for the two sites, Cwm Ffynnon and Padarn, followed by results of faecal composition analysis. Information on all observations of goats at the two sites are given in Appendix 2, details of the goats sampled, dates of faecal collection, and composition of faecal samples are given in Appendix 3.

Faeces from goats of each sex were collected from freshly voided samples. This necessitated stalking the goats for several hours over 3-6 consecutive days each month. Whilst time-consuming, this enabled observations of other factors relating to diet composition to be recorded. Thus, data on group locations (to 10 m on the ground at half-hourly intervals), habitat utilisation (presence of goats on different vegetation types), group structure (numbers, identities and sex ratios), and other factors such as social behaviour, weather conditions and human disturbance were recorded. Information from vegetation surveys and the field observations gathered at the two sites were analysed using the IDRISI geographical information system (IDRISI 1992) which facilitated estimation of areas of each vegetation type within the goat ranges and their utilisation (see section 3.7). Whilst these field observations were partly opportunistic they are able to shed light on aspects of the faecal composition results.

Although it has been noted that most ungulates select their diets at the individual species level (Harrington 1978), to assist presentation and analysis of faecal composition results cuticle fragments were classified under broad plant groupings and all statistical analyses used these as categories. Monthly percentage compositions are presented for males and females followed by information on the variations in the contribution of each plant group over the year and differences in faecal composition between the sexes. All statistical analyses were carried out using "SYSTAT" computer software (SYSTAT 1986).

5.1 Cwm Ffynnon Field observations

5.1.1 Ranges

Ranges were estimated by the minimum area method (Southwood 1978) which encloses all observation locations within a convex polygon. As observations were opportunistic, rather few, and limited over time, they do not reflect true home ranges but are useful for comparative purposes. The yearly range of the main group of goats observed in Cwm Ffynnon is shown in relation to the vegetation in the area in Figure 5.1 and seasonal ranges of males and females are shown in Figure 5.2 The yearly and seasonal ranges were similar for males and females, the yearly range area of males being 1.94 km^2 and for females 2.02 km^2. Generally speaking, the goats remained in the central area of the cwm throughout the year except in September when they were located on the upper slopes during the rut, and in December when they were observed to move out of the cwm to an area approximately 1.5 km away.

In other studies yearly ranges of between 0.32 km^2 to 6.87 km^2 have been reported (Boyd 1981, Bullock 1982, Hellawell 1991). Range size may be affected by vegetation quality but other factors such as goat numbers and availability of shelter also play a part (Boyd 1981, Bullock 1982). Hellawell (1991) and Boyd (1981) noted seasonal differences in range area and related these mainly to weather conditions and requirements for shelter. Female goats are generally considered to be more sedentary than males which disperse widely at certain times of the year and one would expect the female range to be smaller than the males. In Cwm Ffynnon males and females moved together in a mixed-sex group for most of the year resulting in similar sized ranges. The reasons for this are not clear but may be partly due to the loss of kids early in the year.

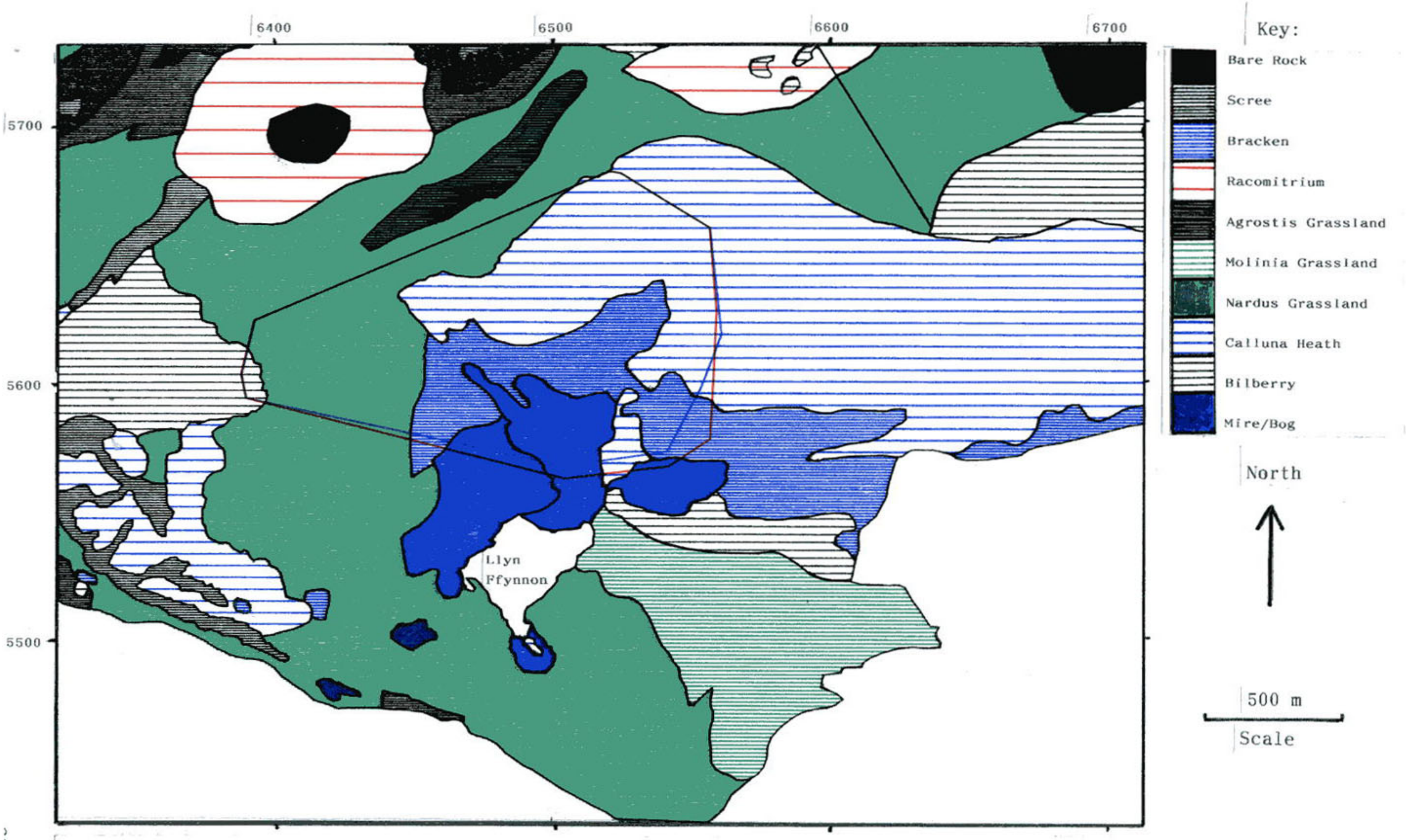


Figure 9.1 Vegetation classification of the Cwm ffynnon area with 12-month ranges of males (——————) and females (——————).

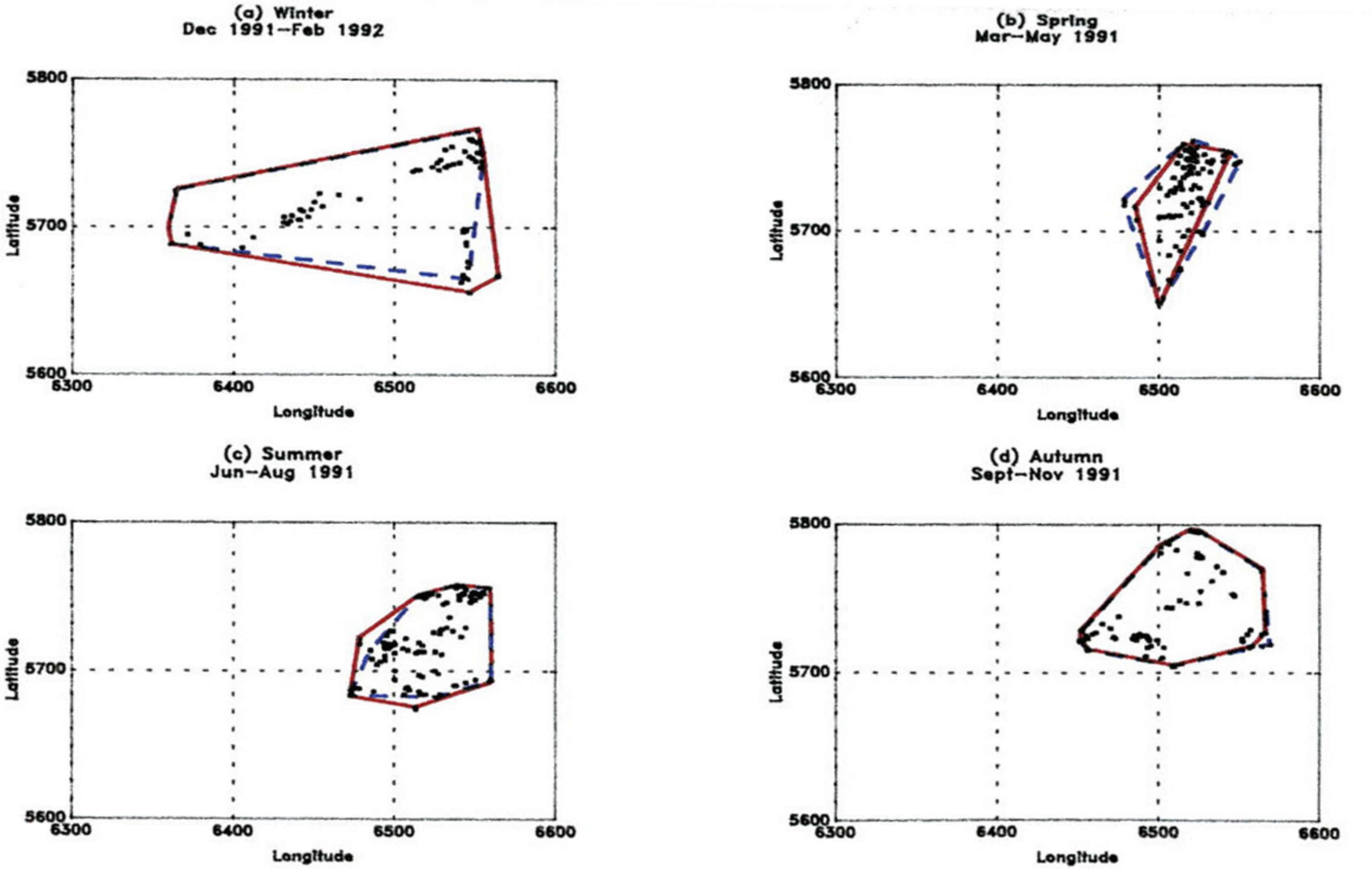


Figure 9.2 Locations of all observations of goats in Cwm Ffynnon, with boundaries of male and female 3-monthly ranges (Males: dashed blue, Females: solid red lines).

5.1.2 Group Structure

On the initial field visits one group of goats was observed in Cwm Ffynnon and individuals were identified using their pelage markings. Fieldwork concentrated on this main group and faecal samples were collected only from these goats. Later in the year other goats were seen in the cwm but were not observed associating with the main group except during the rut. Other workers have also noted that there is only a small degree of overlap between adjacent groups. Other studies have shown that spatial segregation of the sexes occurs in goats, with females becoming solitary during kidding and early lactation, mixing only loosely with males during the summer months before congregating in larger mixed-sex herds prior and during the rut (e.g. Gordon 1987, McDougall 1975). This was not observed in the main Cwm Ffynnon group, mixed-sex groups were observed in every month, and solitary females were observed on only two occasions (although not all individuals were located each month). The maximum group size observed in each month and their structures are given in Table 5.1

Seasonal variations in group size and sex ratios have been observed (e.g. Crook 1969, Bullock 1982, Hellawell 1991) with groups being smallest in spring, but increasing in late summer prior to the rut. This appeared to be true in Cwm Ffynnon, variations being due to the arrival of weakly associated individuals around the rut in September-December, rather than dispersal of the main group during kidding.

Table 9.1 Maximum group size and sex structure of main Cwm Ffynnon group.

Month	Group Size	Males	Females	Kids	
March	7	3	4	2	
	1	0	1	1	*
April	8	3	5	0	
May	8	3	5	0	
June	8	3	5	0	
July	9	4	5	0	
August	9	5	4	0	
September	11	7	4	0	
October	11	8	3	0	
November	9	5	4	0	
December	14	8	6	0	
January	11	7	4	0	
February	7	4	3	0	
	1	0	1	0	*

* Observation of solitary females normally associated with the main group but separated prior or during kidding.

Kids were seen only in the first month, when one female was observed shortly after parturition. At the same time, two other kids, perhaps 1 week old were seen suckling from different females and moving together in a mixed-sex group. Although all three mothers were regularly seen during the rest of the year the kids were not seen again and are assumed to have died in March or early April. Weather conditions were not unusually harsh during these months and it is unclear what the reasons are for these losses. It is possible that the loss of kids so early in the year affected the social behaviour of the group. Female goats have been observed giving birth in late July and August, and are presumed to have become pregnant shortly after the loss of their kid in February/March (Hellawell 1991). If this were a possibility then it would be advantageous for the two sexes to remain together after the death of a kid in case the female came back into oestrous. However, no signs of sexual behaviour were observed other than during the normal rut in September and no late kids were seen in Cwm Ffynnon.

5.1.3 Vegetation class utilisation and selectivity

Vegetation class utilisation was estimated by recording the locations of the goat group at 30 minute intervals on 1-3 consecutive days each month. These data were then plotted onto a simplified vegetation map of the area using a geographical information system (see section 3.7.2) and the percentage of sightings in each vegetation type calculated. Observations were weighted by the numbers of goats in each group and only locations where goats were recorded feeding were used. Figure 5.3 shows the vegetation classes used by males and females each month.

Jacobs electivity index (Jacobs 1974) was used to analyse the degree of selection for different vegetation types (see section 3.7.2 for calculation methods). Table 5.2 gives the monthly percentages of feeding sightings on five broad vegetation categories found in Cwm Ffynnon, the percentage area of each class in the male and female annual ranges and selection indices coded for strong, weak or neutral selection/avoidance of each vegetation class.

Vegetation classes were defined to enable broad comparison with results of the dietary analysis. However, the movements of the goats prior to faecal collection were not known and within a single vegetation class goats could still exert strong selection for particular species. In addition the fine-grained mosaic of vegetation types in Cwm Ffynnon allowed individuals to move from one vegetation type to another in a short space of time. Despite these drawbacks, a basic idea of the preference for certain types of vegetation can be gained.

Table 9.2 Percentage of observations, Electivity Index* and percentage of each vegetation class in the 12-monthly range of male and female goats in Cwm Ffynnon

a) Males

Month					Vegetation Classes**						No. of obs.
	"Heather"		"Bilberry"		"Nardus"		"Mire"		"Bracken"		
March	57.1	(+)	0.0	(--)	0.0	(--)	18.4	(+)	24.5	(+)	49
April	98.7	(++)	0.0	(--)	0.0	(--)	0.0	(--)	1.3	(--)	78
May	60.0	(++)	0.0	(--)	0.0	(--)	13.3	(=)	27.0	(+)	90
June	22.6	(-)	0.0	(--)	0.0	(--)	29.0	(+)	48.4	(++)	93
July	63.5	(++)	0.0	(--)	0.0	(--)	5.2	(--)	31.3	(+)	115
August	100.0	(++)	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	131
September	28.6	(=)	0.0	(--)	71.4	(++)	0.0	(--)	0.0	(--)	70
October	100.0	(++)	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	75
November	83.7	(++)	0.0	(--)	12.0	(-)	0.0	(--)	4.3	(--)	92
December	11.2	(--)	28.1	(++)	60.7	(++)	0.0	(--)	0.0	(--)	89
January	100.0	(++)	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	113
February	20.0	(-)	0.0	(--)	0.0	(--)	6.7	(-)	73.3	(++)	45
12 months	62.1	(++)	2.3	(--)	12.0	(--)	6.1	(-)	17.5	(=)	1040
% of range	32.3		7.5		27.6		14.0		18.6		

b) Females

Month					Vegetation Classes**						No. of obs.
	"Heather"		"Bilberry"		"Nardus"		"Mire"		"Bracken"		
March	29.1	(=)	0.0	(--)	0.0	(--)	21.6	(+)	49.3	(++)	79
April	88.0	(++)	0.0	(--)	0.0	(--)	0.0	(--)	12.0	(-)	142
May	63.2	(++)	0.0	(--)	0.0	(--)	12.7	(-)	24.1	(+)	158
June	22.9	(-)	0.0	(--)	0.0	(--)	29.3	(+)	47.8	(++)	140
July	62.2	(++)	0.0	(--)	0.0	(--)	5.4	(--)	32.4	(+)	148
August	100.0	(++)	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	151
September	29.1	(=)	0.0	(--)	70.9	(++)	0.0	(--)	0.0	(--)	127
October	100.0	(++)	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	141
November	84.3	(++)	0.0	(--)	12.2	(-)	0.0	(--)	3.5	(--)	115
December	11.1	(--)	27.4	(++)	61.5	(++)	0.0	(--)	0.0	(--)	117
January	100.0	(++)	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	161
February	18.8	(-)	0.0	(--)	0.0	(--)	17.2	(=)	64.0	(++)	64
12 months	59.1	(++)	2.3	(--)	12.0	(--)	7.2	(-)	19.4	(=)	1543
% of range	31.0		6.7			26.7	16.4		19.2		

* Electivity index: (--) = Strong avoidance (-0.5 to -1.0), (-) = Weak avoidance (-0.1 to -0.49), (=) = Neutral (-0.09 to +0.09), (+) = Weak selection (0.1 to 0.49), (++) = Strong selection (0.5 to 1.0).

** Information for the vegetation of Cwm Ffynnon came from the NCC Upland Vegetation Survey (NCC 1988), the Ratcliffe/Birks (NCC 1980) vegetation types used were grouped under the broad headings as follows: "Heather": Dwarf shrub heath, types B1a and B1b. "Bilberry": *Vaccinium* *myrtillus* heath, types B3a and B3b. "Nardus": Species-poor *Nardus stricta* grassland, types C2a"Mire": Blanket bog and soligenous mires, mainly types G3a and G3b (*Molinia-Calluna-Erica tetralix* mire) G4a (*Calluna-Eriophorum* mire) and H5 (*E.angustifolium-Sphagnum* mire) "Bracken" areas of *Pteridium aquilinum*.

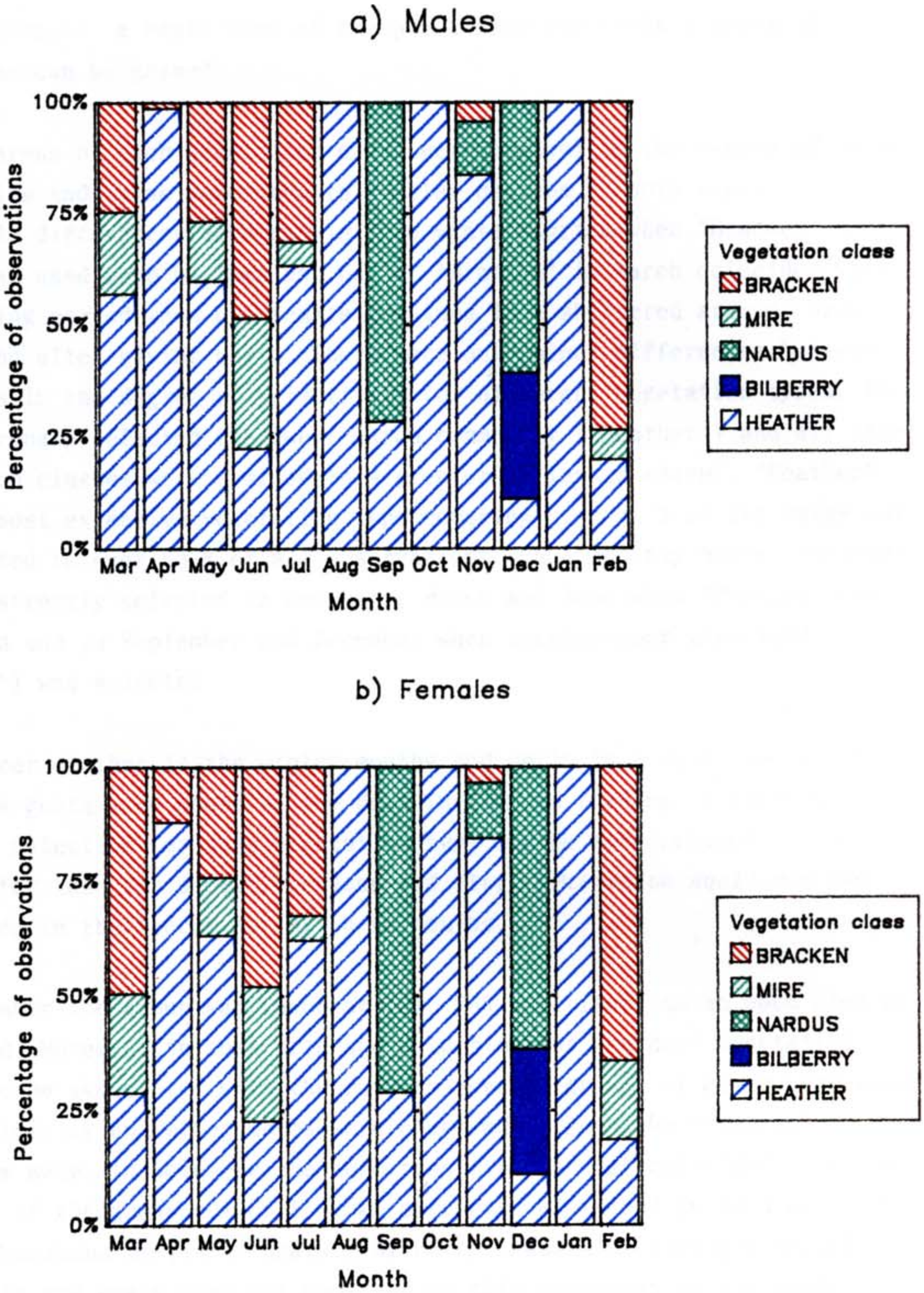


Figure 9.3 Vegetation class utilisation by male and female goats, Cwm Ffynnon 1991-92

Similar areas of each vegetation class were present in the ranges of males and females and these were used to similar degrees by both sexes. Noticeable differences occurred in late winter-spring when "Bracken" or "Mire" was used more by females. Use of "Bracken" in March coincided with the kidding period when one female remained in a sheltered area of bracken during and after giving birth. There were only minor differences between the sexes in the degree of selectivity for different vegetation types. Both sexes strongly selected the dwarf shrub community ("Heather") and all other vegetation classes were avoided to a greater or lesser extent. "Heather" was the most extensive vegetation type covering over 31 % of the range but contributed to over 63 % of all observations. On a monthly basis, "Heather" was not strongly selected in February, March and June when "Bracken" was preferred and in September and December when species-poor grassland ("Nardus") was selected.

During poor weather in the winter months and again in a cold, wet spell in June, the goats were observed low down in the cwm feeding in areas of bracken. Selection for this vegetation type may be more related to the need for shelter than for dietary reasons and little *Pteridium aquilinum* was identified in the faeces during these months.

In September the group was found at over 800 m altitude on an open area of grassland. Movement to this area and selection for "Nardus" vegetation seemed to be associated with the rut, as several groups of goats were also in the vicinity and other males were observed to join the congregation from over 2 km away. In December the selection for "Nardus" coincided with the movement of the group out of the cwm over open grassland to an area of dry heath. *Vaccinium myrtillus* heath ("Bilberry") was also strongly selected in this month and goats were not observed on this community at any other time.

Weak or neutral selection for the "Mire" communities coincided with strong selection of the adjacent "Bracken" areas and again may be related to the need for more sheltered conditions low in the cwm.

In other studies strong selection for dwarf shrub communities have also been noted (e.g. Crook 1969, Gordon 1989) but the reported trend for greater use of this community in winter and a stronger selection for grassland in summer is not obvious in Cwm Ffynnon. Gordon (1987) noted that the severity of weather conditions affected vegetation community use on Rhum and goats were restricted to grazing close to the shelter of sea caves in winter. Similarly Hellawell (1991) found that the strongest selection for woodland occurred in the winter and spring months.

5.1.4 Other factors that may affect habitat selection and diet.

Whilst diet composition and vegetation community selection are interlinked, an animals choice of habitat may not always be dictated by its dietary requirements. Other factors that may have played a part in the range of goats in Cwm Ffynnon and hence the variety of plant species available are given below:

Meteorological conditions: As mentioned in the previous section, poor weather appeared to limit the range of the goats in Cwm Ffynnon to lower altitudes or more sheltered areas. Other studies have shown that goats have a low tolerance of severe weather often cutting short feeding bouts in order to shelter. Similarly, goats have been observed to move to higher altitudes during fine weather in summer, moving to lower levels in winter (Boyd 1981, Brindley *et al.* 1989). This appeared to be true for goats in Cwm Ffynnon which were only seen over 650 m altitude in August and September and were found at the base of the cwm (440 m) in poor weather.

Competition with other herbivores: Potential competition existed with sheep and other groups of goats and estimates were made of the numbers grazing in the area each month. Sheep numbers in the goats' range were low for most of the year (between 10 and 50, i.e. approximately 15 km^{-2}) but rose sharply in spring and early summer (approximately 100, or 50 km^{-2}). However, sheep were only seen in small numbers on the dwarf shrub community in the centre of the cwm as they tended to graze on the open grassland areas on the flanks and upper slopes. Total numbers of goats in the cwm remained fairly constant (7-12 adults) except in summer and early autumn when numbers rose (15-30 adults) prior to and during the rut. Both Gordon (1989) and Hellawell (1991) found that goats tended to select grassland habitats in spring, summer and autumn and it is not clear why goats in Cwm Ffynnon did not follow a similar pattern. Malechek and Leinweber (1972) suggested the possibility of direct competition for grasses between sheep and goats in summer where the two species are grazing common range. Goats are less able to utilise short grass swards due to their narrow muzzle and low bite size (Gordon & Iason 1990) and it is possible that goats in Cwm Ffynnon avoided the more heavily grazed areas of grassland for this reason. During late summer when goat numbers increased, they were observed feeding on high rocky areas which were not used by either sheep or goats at other times of the year. Whilst intra-specific competition was potentially high at this time, the abundance and quality of plant material may reduce the problem to some extent. Bullock (1985) suggested that greatest competition for food could occur in the autumn when goats are attempting to lay down fat reserves for the winter. The numbers of goats sharing Cwm Ffynnon dropped sharply after the rut, reducing potential competition in the autumn and early winter.

Disturbance and Predation: Human disturbance of goats in Cwm Ffynnon was slight during the study period, with very few hill-walkers seen within the range and shepherding activities being minimal, it is therefore not thought that to have directly affected habitat selection by the goats. Crook (1969) noted that goats moved to higher, rocky terrain when disturbed, perhaps as a defense against predators. Although foxes were occasionally seen in the cwm, the most vulnerable time is likely to be around kidding when the goats were seen on the lower slopes. Thus, selection of the steep upper slopes in summer may be more a reflection of dietary preferences.

Topography: Whilst Grubb and Jewell (1966) noted that natural and artificial features of the landscape such as walls, fences, roads and rivers could determine the ranges of Soay sheep. Goats are generally more agile and not as limited by walls or normal stock fencing. The river flowing from Llyn Ffynnon prevented access to grassland to the south but was not thought to have restricted the range as similar easily accessible grassland was not utilised either.

5.2 Faecal Analysis

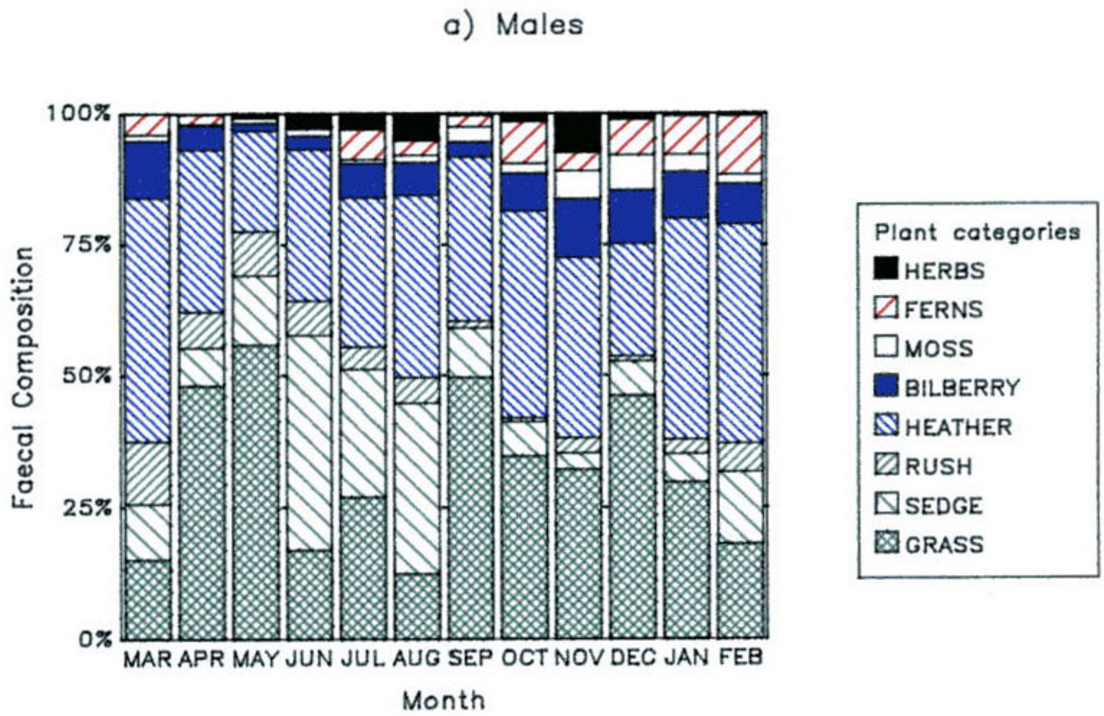
Faecal composition data for goats of each sex in Cwm Ffynnon are presented in Table 5.5 and Figure 5.4

Thirty species or genera of plants were identified from the goat faeces collected from Cwm Ffynnon over the 12 month study period. Plant fragments were classified into eight plant groupings, the individual species identified under each category are listed in Table 5.3 though not all species were observed every month.

The number of goats regularly found in Cwm Ffynnon was quite low, usually only four males and five females. Consequently, monthly sample sizes are small in comparison to the much larger Padarn group. However, the coherence and size of the group enabled results for individual goats to be recorded and these were pooled to give the monthly records. Approximately 150 cuticle fragments were identified for each goat, giving an average of over 600 fragments for each sex and 1200 each month. The amount of unidentifiable material remained quite constant in each month, ranging between 27.7 % and 32.1 % of all fragments examined. It is assumed that the composition of this unidentified portion is similar to the identified component. Original faecal fragment data are given in Appendix 3.

Table 9.3 Plant groupings and species identified in the faeces of goats from Cwm Ffynnon.

Plant Grouping	Species identified
"Grass"	*Nardus stricta, Molinia caerulea, Festuca spp. (*mainly *F. ovina* and *F.rubra), Agrostis spp., Deschampsia spp. (*mainly *D.flexuosa)* and *Poa spp.*
"Sedge"	*Scirpus cespitosus, Eriophorum angustifolium, E.vaginatum,* and *Carex spp.*
"Rush"	*Juncus squarrosus, J.effusus, J. acutiflorus,* and *Luzula spp.*
"Heather"	*Calluna vulgaris, Erica cinerea, E. tetralix* and *Empetrum nigrum*
"Bilberry"	*Vaccinium myrtillus*
"Moss"	Mosses such as *Polytrichum spp., Sphagnum spp.* and lichens such as *Cladonia spp.*
"Fern"	*Pteridium aquilinum, Blechnum spicant,* and *Cryptogramma crispa*
"Herb"	*Tormentilla erecta, Polygala vulgaris, Galium saxatile* and *Viola palustris*



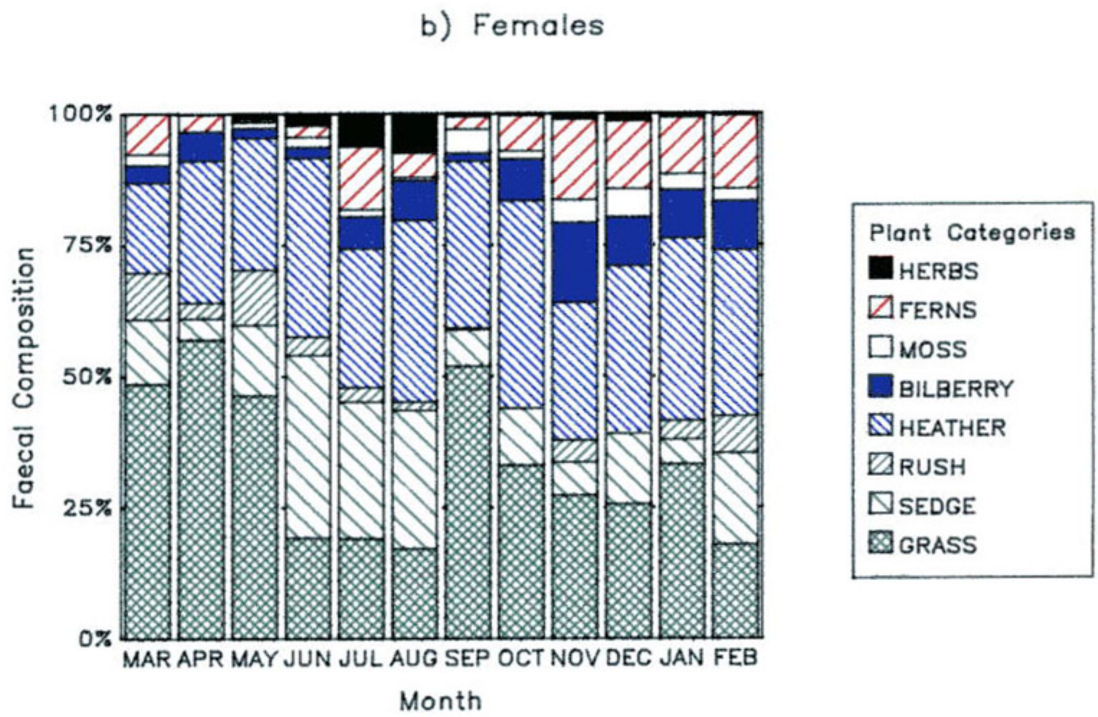


Figure 9.4 Faecal composition of male and female goats, Cwm Ffynnon 1991-92

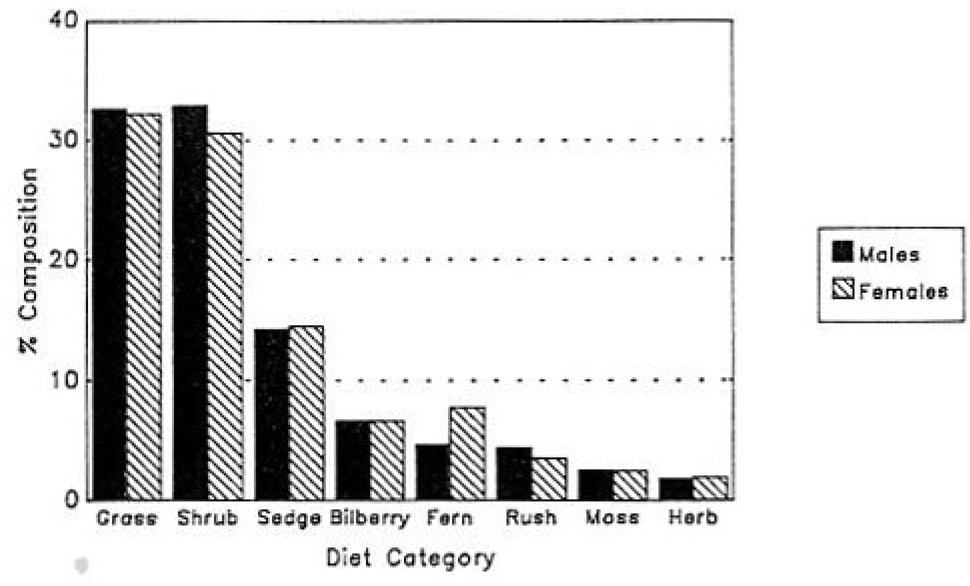
5.2.1 Overall faecal composition for the year.

The yearly average faecal compositions given in Table 5.4 and Figure 5.5 show that both males and females had remarkably similar diets with only minor differences mainly in those categories contributing less than 10 % of the diet. Monocotyledons (grasses, rushes and sedges) comprised slightly over 50 % of the total diet, woody shrubs (heathers and bilberry) almost 40 % and the remainder was made up of ferns (6 %), mosses (2 %) and miscellaneous herbs (2 %).

Table 9.4 Overall percentage faecal composition for male and female goats in Cwm Ffynnon.

Group	Grass	Sedge	Rush	Shrubs	Bilberry	Moss	Ferns	Herbs
Males	32.62	14.28	4.45	32.90	6.68	2.54	4.70	1.83
Females	32.26	14.57	3.54	30.64	6.68	2.48	7.84	1.99
Combined	32.43	14.44	3.95	31.67	6.68	2.51	6.41	1.92

Figure 9.5 Overall faecal composition of males and females in Cwm Ffynnon.



These results compare well to other studies of goats feeding in upland habitats. Bullock (1982) found that goats feeding in the Southern Uplands had diets composed of between 44 % and 61 % monocotyledons and 29 % to 52 % dwarf shrubs. Similarly, Hellawell (1991) found that goats in the Rhinogau ate approximately 46 % monocotyledons and 49 % woody shrubs. In a much smaller study, Crook (1969) observed goats in Cwm Ffynnon and other areas in Snowdonia N.P. and found the average faecal composition to be 37 % grasses and rushes and over 60 % miscellaneous tree and dicotyledonous material.

Table 9.5 Monthly faecal composition (%) for male and female goats in Cwm Ffynnon.

a) Males

	Percentage contribution								No. of	
	Grass	Sedge	Rush	Heather	Bilberry	Moss	Fern	Herb	Goats	n**
Mar	15.21	10.63	11.88	46.25	10.83	1.25	3.96	0.00	3	480
Apr	48.13	7.26	6.85	30.91	4.56	0.21	1.87	0.21	3	482
May	55.92	13.27	8.37	19.18	1.43	1.02	0.00	0.82	3	490
Jun	17.08	40.80	6.47	28.86	2.49	1.49	0.17	2.65	4	603
Jul	27.14	24.18	4.28	28.45	6.41	0.82	5.76	2.96	4	608
Aug	12.55	32.34	4.89	34.68	6.17	1.49	2.77	5.11	3	470
Sep	49.75	9.42	1.32	31.24	2.81	2.98	2.15	0.33	4	605
Oct	34.87	6.58	0.66	39.31	7.07	1.97	8.06	1.48	4	608
Nov	32.37	3.09	2.89	34.23	11.13	5.36	3.51	7.42	3	485
Dec	46.33	6.43	1.05	21.39	10.10	6.82	6.69	1.18	5	762
Jan	29.92	5.37	2.76	41.95	8.78	3.41	7.32	0.49	4	615
Feb	18.15	13.70	5.45	41.58	7.59	1.82	11.22	0.50	4	606
Year	32.62	14.28	4.45	32.90	6.68	2.54	4.70	1.83	44	6814

b) Females

	Percentage contribution								No. of	
	Grass	Sedge	Rush	Heather	Bilberry	Moss	Fern	Herb	Goats	n**
Mar	48.71	12.23	8.80	17.17	3.22	2.15	7.73	0.00	3	466
Apr	57.11	3.94	3.06	26.91	5.47	0.22	3.06	0.22	3	457
May	46.49	13.42	10.38	25.08	1.76	1.28	0.48	1.12	4	626
Jun	19.37	34.77	3.48	33.94	1.99	1.99	2.15	2.32	4	604
Jul	19.23	26.06	2.71	26.32	6.06	1.42	11.87	6.32	5	775
Aug	17.37	26.32	1.58	34.47	7.50	0.66	4.61	7.50	5	760
Sep	52.08	6.88	0.26	31.69	1.43	4.68	2.47	0.52	5	770
Oct	33.16	10.83	0.26	39.23	7.79	1.59	6.74	0.40	5	757
Nov	27.48	6.18	4.23	26.18	15.12	4.39	15.28	1.14	4	615
Dec	25.77	13.38	0.33	31.48	9.30	5.38	12.89	1.47	4	613
Jan	33.33	4.69	3.57	34.65	9.20	3.00	10.80	0.75	7	1065
Feb	18.05	17.41	7.03	31.47	9.27	2.40	13.90	0.48	4	626
Year	32.26	14.57	3.54	30.64	6.68	2.48	7.84	1.99	53	8134
Combined data										
Year	32.43	14.44	3.95	31.67	6.68	2.51	6.41	1.92	97	14948

** n is the total number of identified fragments

Of the monocotyledonous species eaten, grasses composed 32 % of the total diet, sedges 14 % and rushes just under 4 %. Again this is not too dissimilar from other studies although Bullock (1982) observed rushes to be more common in the diets at three sites in the Southern Uplands. Similar quantities of mosses, bryophytes and herb material have been noted elsewhere (e.g. Bullock 1982, Hellawell 1991) and the presence of ferns is intermediate between the high levels (17 %) at one of the Southern Upland sites and the traces found by Hellawell in the Rhinogau. Fern usage appeared to differ between the sexes, being more frequent in the samples from females.

5.3 Variations in faecal composition by plant category.

Analysis of variance (ANOVA) and multivariate ANOVA (MANOVA) was carried out on the 12-months data after normalisation by additive log transformation (Aitchison 1986) (details are given in Appendix 4). The eight plant groupings were used as multiple dependent variables, data from individual goats were used as replicates nested within sex, and the effects of the categorical variables, sex, month, and sex*month interactions were investigated. ANOVA and MANOVA results for the Cwm Ffynnon data are summarised in Tables 5.6 and 5.7. Faecal composition varied considerably from month to month and such variations were shown to be highly significant for all plant categories (Wilks Lambda P<0.001). Overall, differences in the diets between the sexes were non-significant for all plant categories (Wilks Lambda P=0.429). However, univariate analysis of the plant categories showed that usage of the "Fern" group was significantly different between the sexes (P=0.023). There was a highly significant sex*month interaction for all plant categories taken together (Wilks Lambda P<0.001), seasonal changes in faecal composition took place in different ways for males and females. In ANOVA's using individual plant categories significant sex*month interactions were recorded for sedges, rushes and ferns.

Table 9.6 Levels of significance from ANOVA of the percentage of seven forage classes in the faecal composition of goats in Cwm Ffynnon in relation to identity of individual goats, sex, month and sex*month interaction.

Source of Variation	Degrees of freedom	Level of significance (P) Grass	Sedge	Rush	Bilberry	Moss	Fern	Herb
Individuals	73	.615 ns	.246 ns	.479 ns	.778 ns	.718 ns	.541 ns	.488 ns
Sex	59	.977 ns	.279	.567 ns	.251 ns	.751 ns	.023 **	.449 ns
Month	69	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **
Sex*Month	69	.<.001 **	.014 **	.050 **	.226 ns	.205 ns	.069 ns	.040 **

Table 9.7 Results of MANOVA (Wilks Lambda) of seven forage classes in the faecal composition of goats in Cwm Ffynnon.

Source of Variation	Degrees of freedom	P	Level of Significance
Sex	7, 52	.429	ns
Month	77, 319	<.001	**
Sex*Month	77, 319	<.001	**

Whilst the overall yearly diet relates well to other similar studies, the pattern in the use of certain plant groupings over time is more complex and each of the categories are discussed separately and presented in Figures 5.6 to 5.7.

5.3.1 Monthly variations in faecal composition

"Grass": The proportion of grasses in the diet fluctuated greatly over the year from a minimum of around 20 % in the summer (June-August) to peaks of over 50 % in spring (April-May) and September (see Figure 5.8). These results are in contrast to Hellawell (1991) who observed grass utilisation to be extremely variable with small quantities consumed in the winter months but found that they comprised over 90 % of the diet in late spring and summer. This difference may in part be due to the different species available in Cwm Ffynnon and the two sites (Dinas and Gloyw Lyn) in the Rhinogau. Goats in the Rhinogau were able to select gorse (*Ulex* spp.) during the spring in preference to grasses and fed much more on *Agrostis* species in summer. In Cwm Ffynnon, gorse is absent and *Nardus stricta* and *Festuca* spp. are the most common grasses. It is possible that goats in Cwm Ffynnon continue to feed on these grasses in spring in preference to the limited shrub species available. In late spring and summer sedges appear to be preferred over the limited range of grasses available.

Females appeared to feed more on grasses and less on "Heather" than males in March. In this month the females were kidding and were relatively restricted to sheltered areas of dead bracken low in the cwm (see vegetation class usage, section 5.1.3). However, to what extent diet composition causes habitat selection or vice versa is unclear.

The narrow range of grass species present and ease of identification allowed information on individual grass species to be collected for Cwm Ffynnon. Figure 5.8 shows the percentage of grass in the diet and the species identified are shown in Figure 5.9. *Nardus stricta* and *Festuca* spp. were the most frequently recorded species and this reflected their widespread presence in the goat range. Utilisation of *Nardus stricta* reached a maximum in the winter and spring months, a pattern also recorded by Hellawell (1991) at Gloyw Lyn and by Bullock (1982) at Cairnsmore of Fleet. *Nardus stricta* is generally coarser and of lower digestibility than other grasses such as *Agrostis* spp. (Hunter 1962, Thomas & Fairbairn 1956) and its use during the winter months may reflect the lack of other more preferred species. The other grasses (*Agrostis*, *Deschampsia*, and *Poa* spp.) were all recorded at fairly low levels throughout the year and fluctuations in the proportions of these species may not be significant. *Molinia caerulea*, however, showed a distinct peak in June and July with very little being recorded during the rest of the year. This may be related to the goats feeding partly on mire habitats in these months at the height of the growing season. Hellawell (1991) found that consumption of this species was also highly seasonal and accorded with the selection of wet *Molinia* dominated habitats during the summer. *Festuca* spp. were recorded at the highest levels from September to December which coincided with the utilisation of the species-poor grassland areas.

"Sedge" Utilisation of sedge species was highly seasonal, with a distinct peak in the summer months representing approximately 30 % of the total diet and lower levels (4 % - 17 %) during the rest of the year. In other studies similar quantities of sedges have been noted in the overall diet and utilisation is generally limited to the growing period when nutritional value and digestibility may be highest. Peak utilisation of sedges occurred in June and this coincided with use of the "Mire" habitat rich in *Eriophorum vaginatum* and *E. angustifolium*. Grant *et al.* (1984) showed that when goats were grazed in summer on plots containing both *E. vaginatum* and *Lolium perenne*, the sedge was selected even when *Lolium* was plentiful. Hellawell (1991) noted a peak in sedge usage slightly earlier in the year (March-May) but Cwm Ffynnon is at higher altitude than both sites in the Rhinogau and the growing season here may be somewhat delayed.

"Rush" Less than 4 % of the overall diet was composed of rushes of which *Juncus effusus* and *J. squarrosus* were the most frequent species identified. Usage of the "Rush" category was greatest in winter and spring (5-10 %) and formed less than 5 % of the diet between September and January. Goats have been noted to graze rushes readily especially when the shoots are new in spring and early summer. Grant *et al.* (1984) also observed that goats grazed *J.effusus* in preference to certain grasses and to a much greater extent than sheep, suggesting that goats could be used as a means of controlling undesired rush species on upland pastures. Bullock (1982) observed rushes to comprise over 10 % of goat diets at all of his study sites so it is somewhat surprising that rushes form only a small portion of the diet in Cwm Ffynnon.

"Heather" The proportion of ericaceous dwarf shrubs (mainly *Calluna vulgaris* and *Erica* spp.) in the diet was variable (17-46 %) but did not show the distinct seasonal pattern noted in other studies. Both Hellawell (1991) and Bullock (1985) observed that utilisation of ericaceous shrubs fell to a minimum in the summer months which coincided with maximum use of monocotyledonous species. Although males in Cwm Ffynnon appeared to utilise heathers more in the winter months, this portion of the diet continued to be important (25-35 %) for both sexes throughout the summer. Tall, relatively ungrazed *Calluna* and *Erica* spp. are a striking feature of the vegetation in Cwm Ffynnon and represent a major food resource within the goats' range. As mentioned previously, it is possible that due to the limited variety of grasses in Cwm Ffynnon, ericaceous shrubs continue to be important in the diet over the summer months.

"Bilberry" *Vaccinium myrtillus* formed a relatively minor part of the diet (6.68 % overall) and was most frequently encountered in the late autumn and winter months. In Cwm Ffynnon goats were only once observed feeding within dense patches of V.myrtillus in November, which coincided with its peak presence in the faeces. Other studies have shown Bilberry to be eaten in relatively small quantities and Hellawell (1991) considered that it was never actively selected by either goats or sheep.

"Fern" The only species to be positively identified within this category was *Pteridium aquilinum* although other ferns such as *Cryptogramma crispa* and *Blechnum spicant* are also present in the cwm. Though only forming a minor component of the overall diet (6.41 %) there appeared to be consistent differences in the degree of utilisation between the sexes especially in the late autumn and winter months. At two sites in the Southern Uplands bracken formed a large proportion of the diet between August and October (Bullock 1985), and Kerridge & Bullock (1991) found *Pteridium aquilinum* to be a substantial part of the diet of deer in summer and early autumn.

They commented that although *P. aquilinum* is generally considered toxic and unpalatable to livestock the principle toxins present are at their lowest levels in autumn.

"Moss" This diet category remained a minor component (2.51 % overall) throughout the year, becoming slightly more important in late autumn and winter. McDougall (1975) observed male goats apparently eating *Sphagnum* in winter but ingestion of bryophytes is thought to be mainly accidental, as a consequence of feeding low down in the sward or on the lower stems of heather where *Cladonia* spp. is found. In Cwm Ffynnon little Cladonia was noted in the diet but "Moss" utilisation did appear to be related to periods of grazing on short vegetation in late summer and autumn.

"Herb" This category was also a minor component of the overall diet (1.92 %) reaching a peak (7.5 %) in the summer months. It is possible that faecal analysis may underestimate easily digested plant material likely to be found in the Herb group (see section 3.2.1) and this category could form a more important component of the diet. The most frequently identified "Herb" species were *Potentilla erecta* (Tormentil) and *Galium saxatile* (Heath Bedstraw) and maximum occurrence in the diet coincided with growth and flowering of these species.

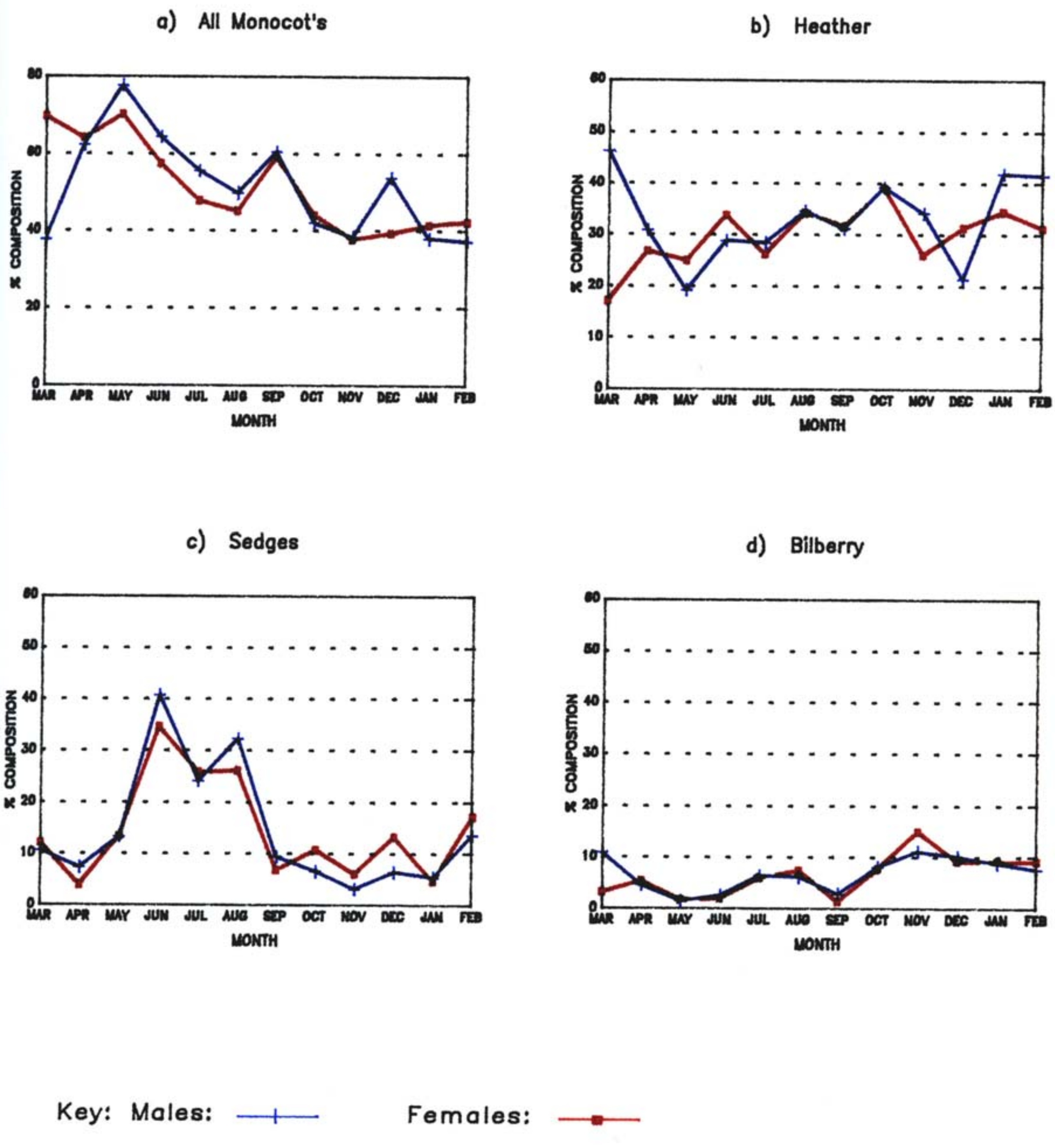


Figure 9.6 a)-d) Monthly faecal composition of male and female goats in Cwm Ffynnon by individual plant categories.

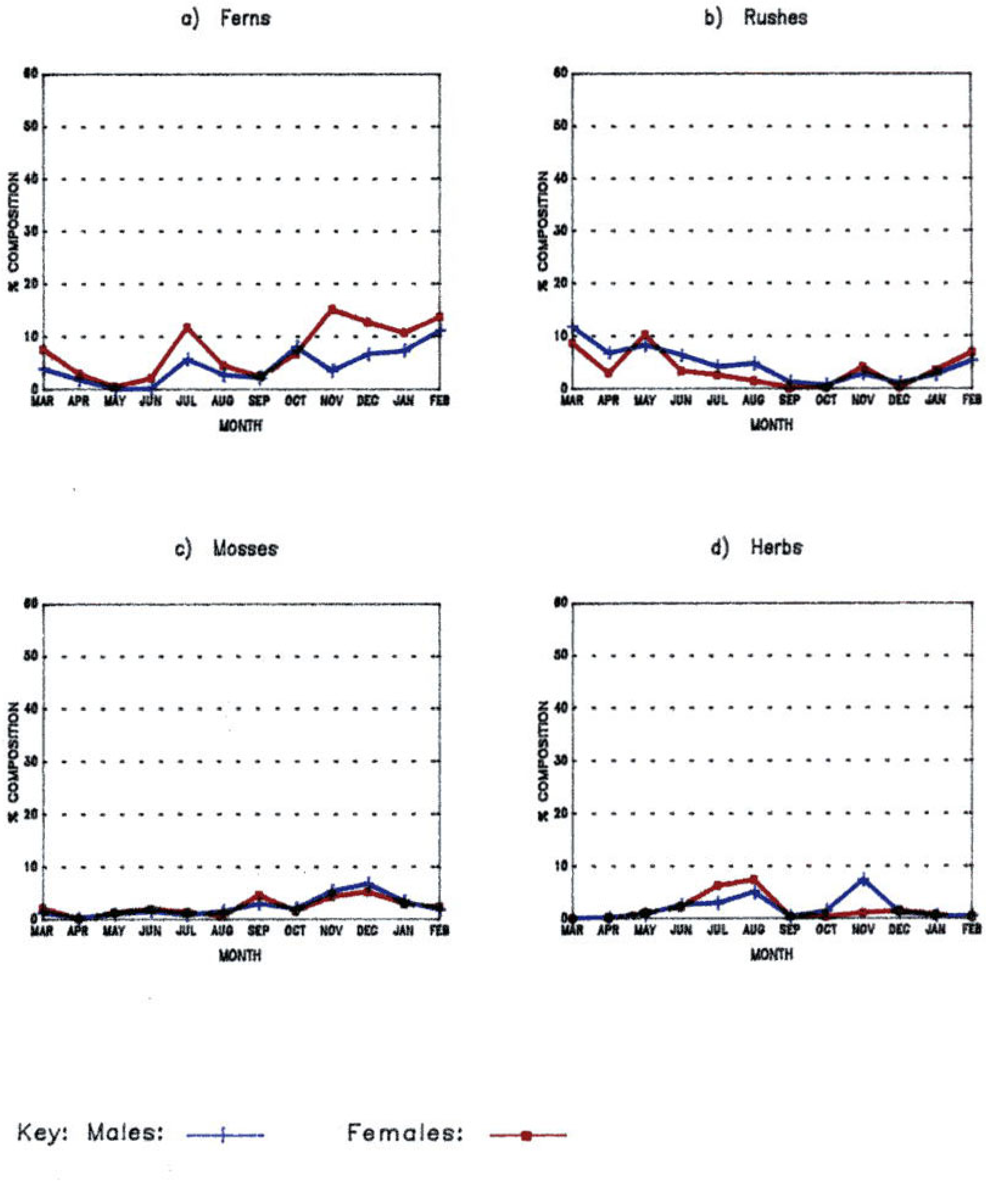
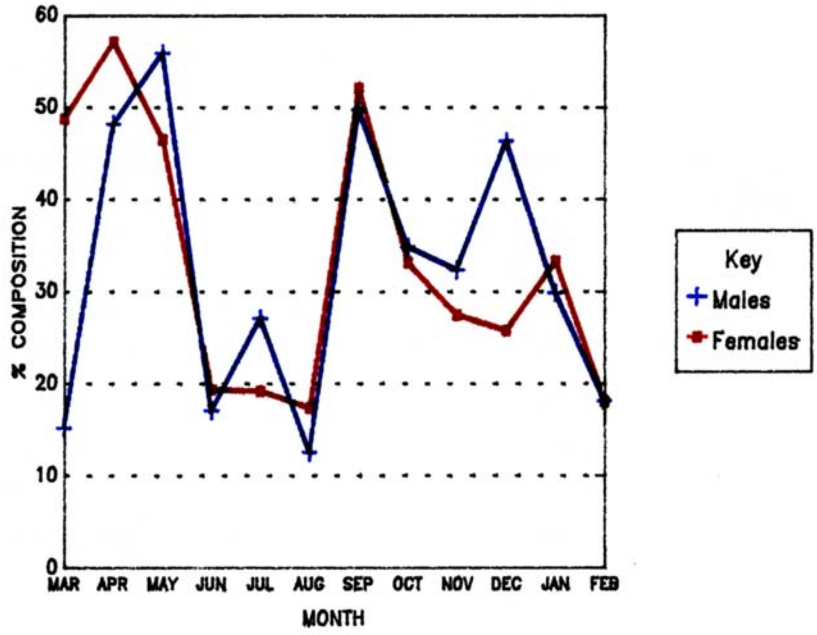


Figure 9.7 a)-d) Monthly faecal composition of male and female goats in Cwm Ffynnon by individual plant categories.

Figure 9.8 Percentage of “Grasses” in monthly faecal composition of male and female goats in Cwm Ffynnon, 1991-92



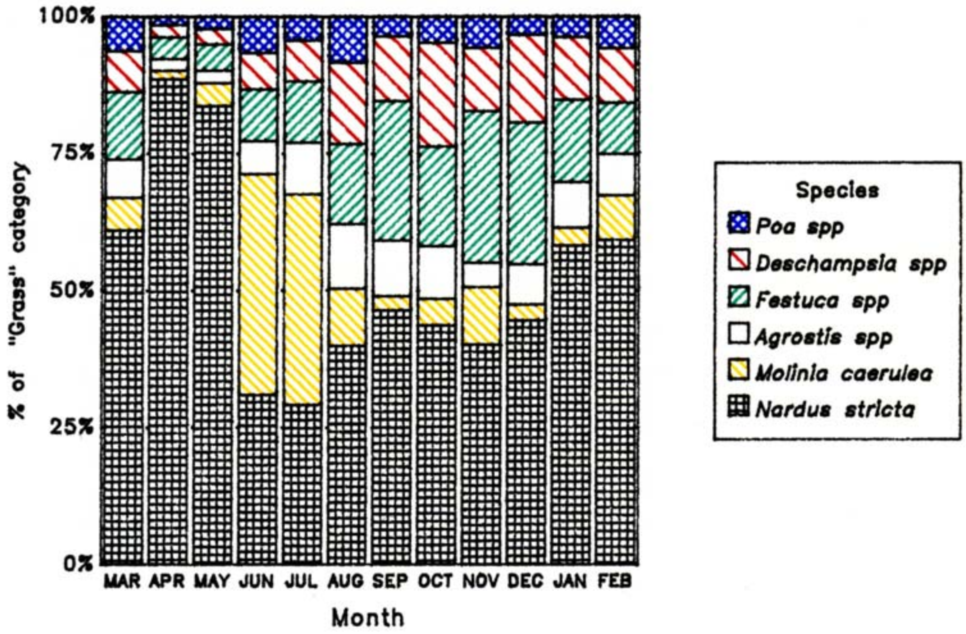


Figure 9.9 Grass species identified as a percentage of “Grass” category in diet of Cwm Ffynnon goats 1991-92

5.3.2 Differences in faecal composition between the sexes.

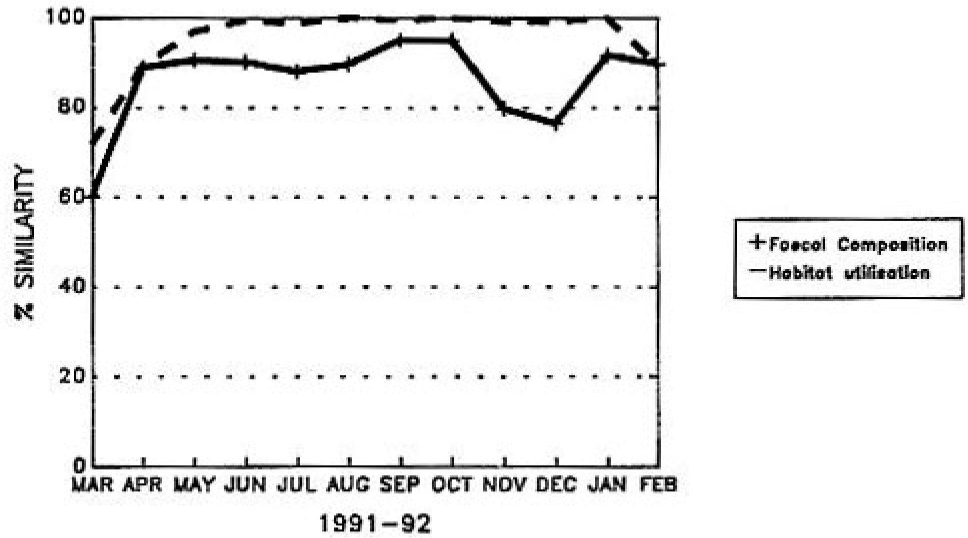
As mentioned previously, no significant difference in overall faecal composition was observed between male and female goats in Cwm Ffynnon and as can be seen in Figures 5.6 to 5.8, the differences that are apparent are not sustained over the whole year. When analysed individually, sex was shown to be a significant factor for only one plant category, "Fern", which was more frequent in the female diet than in the males. Females consistently had a greater proportion of "Fern" in their diet, with an overall frequency of 7.84 %, almost twice that of males (4.70 %). Whether this difference reflects a selection of this plant category by females or a rejection by males is unclear. The presence of bracken (*Pteridium aquilinum*) in the diet did not relate to the utilisation of the "Bracken" vegetation class which was selected strongest in late winter and spring when the bracken was dead. Peak consumption of ferns by females coincided with periods when dense bracken areas were avoided by both sexes. Either females had fed in these areas prior to faecal sampling or they strongly selected fronds of *P. aquilinum* and other ferns growing within the "dwarf shrub" area.

One method of comparing diet compositions between the sexes is by identifying elements of the diet common to both groups using a Kulzynski's similarity index (KSI) (see section 4.1.3). The same method is used to compare the percentage of observations of each sex on the different habitat types found in Cwm Ffynnon and KSI values for faecal composition and habitat utilisation are presented in Table 5.8 and in Figure 5.10.

Table 9.8 Kulzynski's Similarity Index values for male-female faecal composition and habitat utilisation in Cwm Ffynnon

Month	KSI Value	
	Faecal composition	Habitat utilisation
March	60.23	72.00
April	88.90	89.30
May	90.57	96.80
June	90.15	99.40
July	88.04	98.70
August	89.62	100.00
September	95.02	99.50
October	95.03	100.00
November	79.81	99.20
December	76.48	99.20
January	91.62	100.00
February	89.77	89.50
Year	96.41	97.30

Figure 9.10 Seasonal change in percentage similarity (KSI values) of male and female diets and habitat utilisation in Cwm Ffynnon.



Using the Kulzynski's Similarity Index, similarity between the male and female diets for the whole year is high (96.41 %). Values for any one month are lower, usually around 90 % and at two periods, March and November-December diets are much less similar (60.23 and 76.48 - 78.81 % respectively). In March, males had a higher proportion of "Heather" and "Bilberry" in their diet than females, which utilised "Grass" to a greater extent.

Similarities in habitat utilisation between the sexes broadly follows a similar pattern, being most dissimilar in March (72.0 %) but with males and females using similar proportions of each habitat (0 % - 100 %) during the rest of the year. In March, the lower KSI values may be explained by a restriction of the females to lower "Bracken" areas during kidding, resulting in a higher proportion of grasses in the diet.

In November and December, male diet contained more "Grass" than females which utilised more of the "Fern" and "Sedge" categories. In these months both sexes selected similar vegetation communities (KSI values of 99.2 %). However, without knowledge of the nutritional value and digestibility of all diet components throughout the year and information on the quantities of food ingested, it is difficult to say whether such differences in faecal composition reflect a strategy relating to diet quality. Bullock (1985) hypothesised that competition for food in goats may not be highest in winter as food intake and appetite is lower at this time of year. Instead, competition may be more likely in the autumn months when individuals, especially males, are attempting to build up fat reserves for the winter. Results of faecal analysis and habitat utilisation observations in Cwm Ffynnon support this theory to some extent, but similarities in diet and habitat utilisation are at their lowest in March when nutritional demands on the females around the time of kidding must still be very high.

A significant Sex*Month interaction effect in the MANOVA model (see Table 5.7) suggests that the sex of the goat in combination with the season had an influence on diet composition and the sexes had different diets at different times of year. When analysed individually a significant interaction effect was noted for all plant groups except for "Bilberry" and "Moss" which formed only minor components of the diet for much of the year.

5.3.3 Variation in diet composition between individual goats.

As faecal samples were collected from identified individuals and analysed separately it was possible to examine the degree of variability between goats. It was not possible to collect samples from all goats in every month, so a MANOVA was carried out on data from seven months when the same six goats (males M1, M2, M3 and females F1, F2 and Y1) were all present together (see Appendix 4. for details). Faecal composition for these individuals are presented in Figure 5.11 and ANOVA and MANOVA results given in Tables 5.9 and 5.10. Differences in overall diet composition between individuals were non-significant (Wilks Lambda P=0.111), as were differences between individuals of the same sex when analysed separately (Wilks Lambda (males) P=0.184, (females) P=0.151). When diet categories were considered independently, differences between all individuals were significant for "Sedge" (P= .025) and for males "Sedge" and "Rush" categories differed significantly (P=0.041, P=0.046 respectively).

Table 9.9 Levels of significance from ANOVA of the percentages of seven forage categories in the faecal composition of six goats in Cwm Ffynnon in relation to the identity of individuals present.

Source of Variation	Degrees of Freedom	Grass	Sedge	Rush	Bilberry	Moss	Fern	Herb
Male individuals	26	.528 ns	.041 *	.046 *	.218 ns	.341 ns	.915 ns	.187 ns
Female individuals	26	.705 ns	.063 ns	.530 ns	.465 ns	.648 ns	.403 ns	.596 ns
All individuals	28	.732 ns	.025 *	.115 ns	.333 ns	.547 ns	.725 ns	.352 ns

Table 9.10 Results of MANOVA (Wilks Lambda) for seven forage categories in the faecal composition of six individual goats in Cwm Ffynnon.

Source of Variation	Degrees of Freedom	P	Level of Significance
Male individuals	14, 36	.184	ns
Female individuals	14, 36	.151	ns
All individuals	28, 66	.111	ns

Van Dyne & Heady (1965) analysed the degree of variation found between individual sheep and cattle diet composition using rumen fistula samples. They found that the amount of individual variation was greater for sheep than cattle and that this variation decreased as herbage became limited. They concluded that at least nine animals would be required to sample the major dietary components (within 10 % of the mean, and 90 % confidence) using rumen fistulation. Although the number of individuals sampled from Cwm Ffynnon each month were always low, it would appear that individual variation in faecal composition each month was not significant. This may be because faecal remains represent diet over a longer period than rumen samples, or may reflect the fact that the goats were feeding close together on similar habitats, and the limited range of suitable foods restricted individual variation.

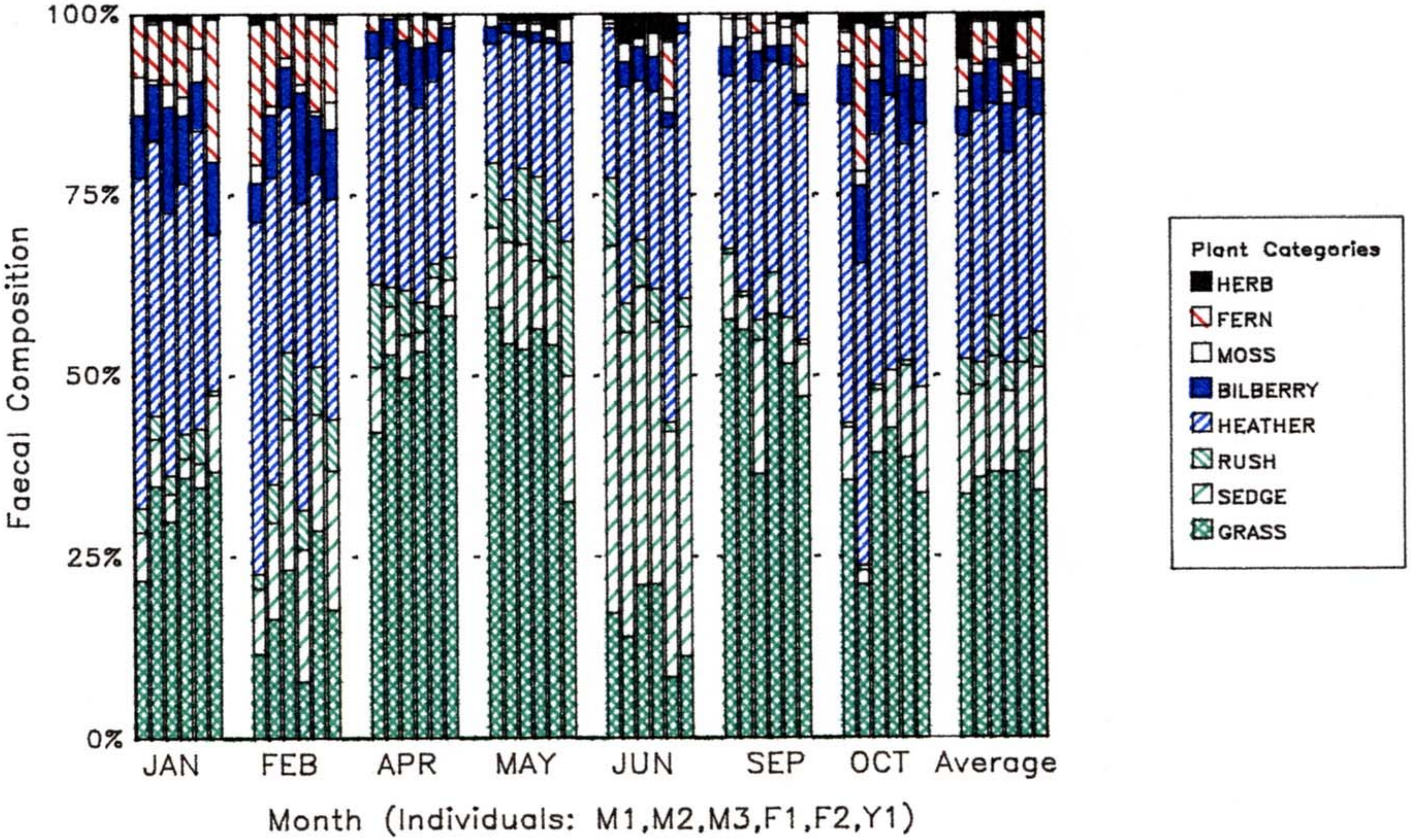


Figure 9.11 Variation in faecal composition in 6 individual goats for 7 months in Cwm Ffynnon

5.4 Field Observations in the Padarn area.

5.4.1 Ranges.

Seasonal ranges of male and female goats in the Padarn were estimated in the same manner as for Cwm Ffynnon and are shown in Figure 5.12. Female range was limited to Coed Allt Wen and the lower areas of the Dinorwic quarry. Males were much less restricted, using areas of heath high in the quarry and woods and derelict farmland at Fachwen to the north-west. In September most of the males appeared to move out of their core area and five individuals were identified six km away, greatly extending their autumn range. The 12-month range (ignoring areas of open water) for females was 1.32 km^2. For males the core range excluding the outlying September observations was 3.07 km^2 or 6.18 km^2 if these are included. Figure 5.13 shows the 12-month range for females and the core area of the males in relation to vegetation in the Padarn area. This pattern of range utilisation, with females being relatively sedentary and males occupying a larger range, is typical of feral goats and has been observed in many other studies (O'Brien 1988, Riney & Caughley 1959).

5.4.2 Group Structure.

Two groups of goats were identified at the Padarn site. The main group from which faecal samples were collected consisted of fifteen males, six sexually active male hummels, six females and seven kids. All the kids seen in March 1991 (six males and one female) survived to the following year, another kid was born in August and in February 1992 four more kids were seen. A smaller group consisting of one male, three hummels, four females and two kids was occasionally seen on the outskirts of Dinorwic quarry but seemed to be based around Wern Farm on the opposite shore of Llyn Peris (SH 591591).

As in Cwm Ffynnon, individuals were identified from their distinctive pelage patterns. The area was geographically very complex and many of the males were not seen when they dispersed into smaller groups although females were easily located. Consequently, observations on ranges, habitat utilisation and group structures are incomplete and can only give an impression of the situation. The numbers of groups observed each month, their maximum size and sex ratios are given in Table 5.11

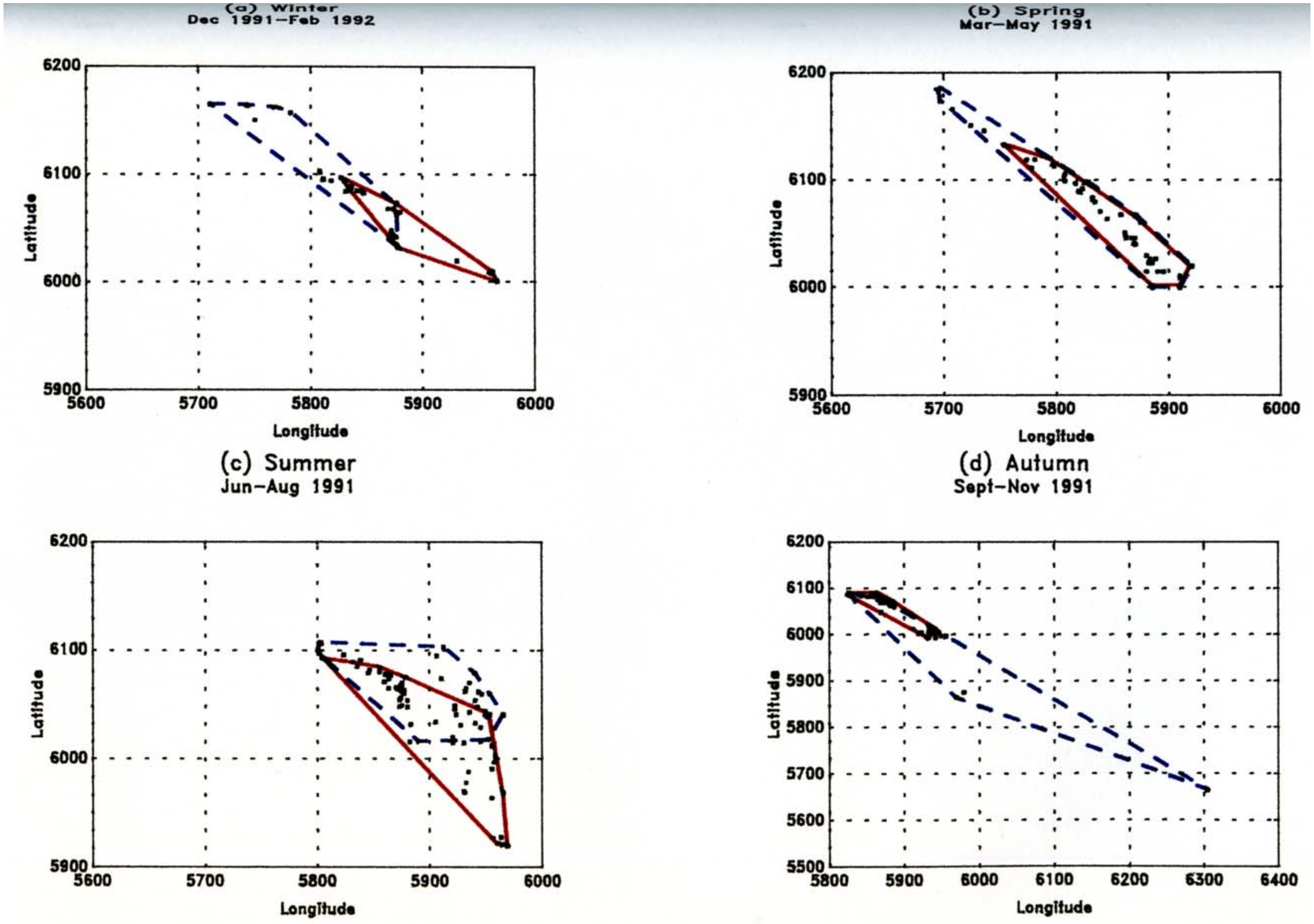


Figure 9.12 Location of all observations of goats in the Padarn area, with boundaries of male and female 3-monthly ranges. (Males: dashed blue, Females: solid red lines).

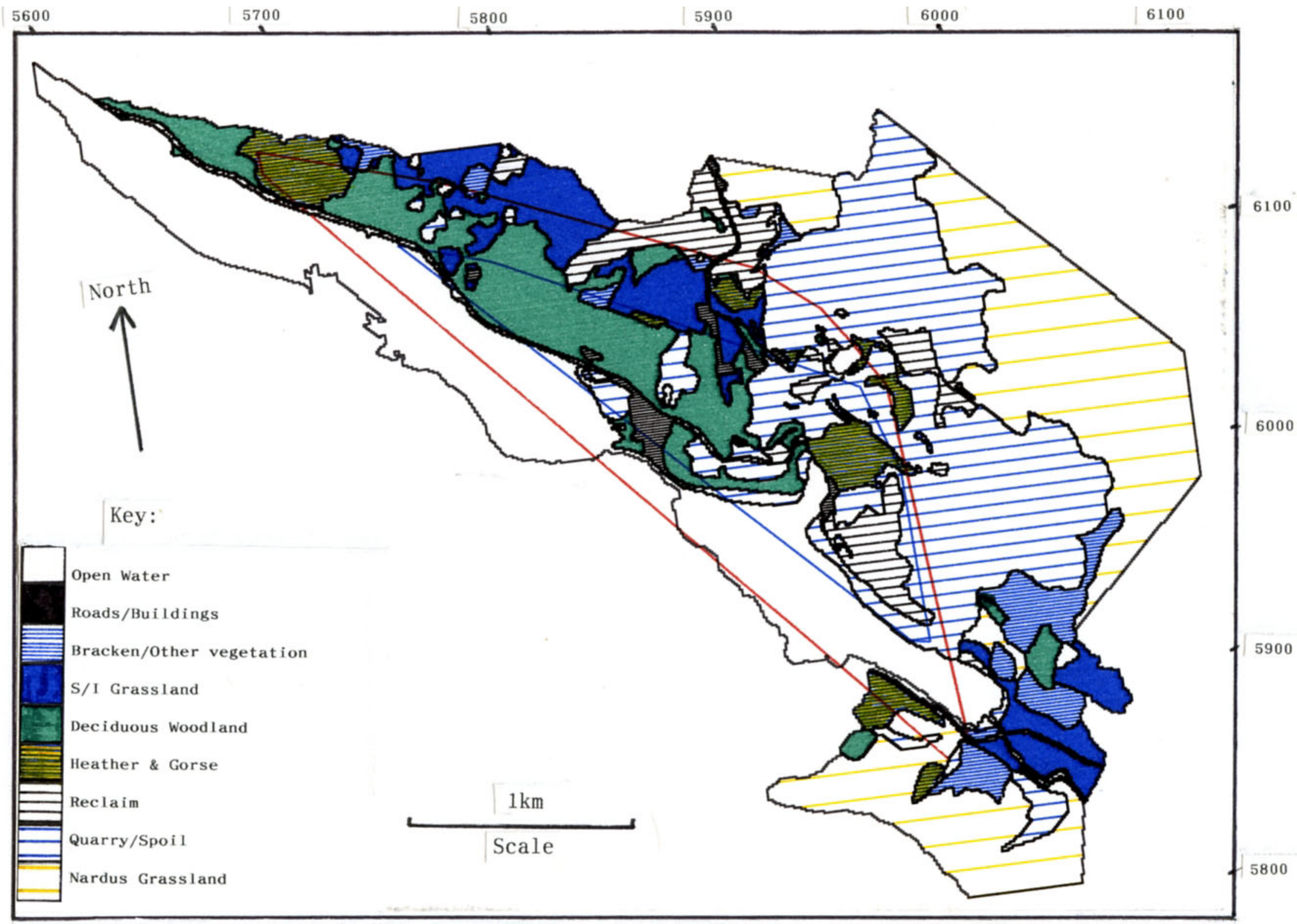


Figure 9.13 Vegetation classification of the Padarn area with 12-month ranges of males (———) and females (———).

Table 9.11 Maximum group size and sex structure (excluding kids) and number of groups observed each month in the Padarn area.

Month	Number of groups	Maximum group size	Males	Females	
March	1	17	12	5	
April	1	20	16	4	
May	2	5	0	5	
		8	7	(1)	
June	3	6	0	6	
		8	7	(1)	
		7	7	0	
July	2	3	0	3	
		20	17	3	
August	3	5	0	5	
		1	0	(1)	
		15	15	0	
September	2	8	5	3	*
		7	1	6	
October	1	14	8	6	
November	1	16	10	6	
December	3	5	2	3	
		1	0	1	
		16	15	(1)	
January	3	4	1	3	
		2	0	2	
		15	14	(1)	
February	4	3	0	3	
		1	0	1	
		2	2	0	
		18	17	(1)	

N.B. The asynchronous female is shown in parentheses
* Females seen in September with these males were not from the Padarn group

Perhaps due to the larger group size, social behaviour was much more complex than observed in Cwm Ffynnon and appeared to broadly follow a pattern seen in other studies: small single-sex groups in the summer months, forming a larger mixed group in the autumn before females become solitary in late winter prior to kidding. The situation was made more complicated by the behaviour of one female which kidded in August, six months late, and apparently had also done so the year before. This female remained with the male group for much of the year, joining the female group only in September following kidding. A large mixed-sex group was not observed in September, when the males apparently left the area leaving the females and one hummel behind. These females probably came into oestrous later in the month and it is not known which males mated with them.

In contrast to Cwm Ffynnon, all kids observed in March 1991 survived, including one pair of twins. Twins were also born to the asynchronous female in August but one was still-born. At least one other set of twins were observed in February 1992. The Padarn area lies at a much lower altitude than Cwm Ffynnon (100 m OD compared to 380 m OD at the lowest points), is much more sheltered and the abundance and quality of forage is higher. Hellawell (1991) linked goat productivity (both fecundity and kid mortality) to the mean altitude of the range and the availability and quality of forage. The contrasting kid survival rates at the Padarn and Cwm Ffynnon are in accord with this hypothesis.

5.4.3 Vegetation class utilisation and selectivity.

Selectivity and utilisation of different vegetation classes were estimated in a similar manner to Cwm Ffynnon. Details of the percentage utilisation and electivity indices for the Padarn are given in Table 5.12 and Figure 5.14 shows the monthly vegetation class usage of males and females as percentage of observations. In estimating the utilisation and area of each vegetation type in the annual range only locations where feeding was observed were used, hence the outlying observations of males in September were ignored. In addition, estimation of the female range excluded observations of the asynchronous female as her association with the male group seemed aberrant.

Information on the vegetation and habitat types present in the Padarn area came from the NCC Phase One Habitat Survey (NCC 1989) and vegetation classes are different to those used for Cwm Ffynnon. Eight classes broadly following the Phase one habitat survey categories were defined and are discussed below:

"Deciduous Woodland" (Broad-leaved semi-natural woodland, code A1):

The most abundant habitat type in the annual range of both males and females was deciduous woodland (34.5 % to 39.8 % respectively) and was strongly selected. It was selected by males in most months but was strongly rejected in June in favour of "Heath" and in September in favour of unimproved "Nardus" grassland. Females selected woodland strongly in spring, late autumn and winter but tended to avoid it in summer and early autumn. Like males, females also strongly avoided woodland in favour of "Calluna Heath" in June and September and were also observed feeding on dry heath vegetation in February.

Hellawell (1991) found that woodland was strongly selected in the winter and spring months and associated this with the need for shelter from severe weather during kidding. In the Padarn, woodland was used to a much greater extent throughout the year although it was selected less strongly in the summer months. Utilisation also appeared to correspond with weather conditions, especially strong winds. However, females strongly avoided woodland in February, preferring to kid on inaccessible ledges of "Calluna Heath" in the quarry, using caves and disused buildings for shelter.

Table 9.12 Percentage of observations, Electivity Index* and percentage of each vegetation class in the 12-monthly range of goats in the Padarn area.

a) Males	Vegetation Classes														
Month	"Nardus"		"Quarry Spoil"		"Reclaim"		"Heath & Gorse"		"Deciduous Woodland		"S/I Grassland"		"Other Vegetation"		number of observations
March	0.0	(--)	28.4	(=)	29.1	(+)	0.0	(--)	42.5	(+)	0.0	(--)	0.0	(--)	148
April	0.0	(--)	4.9	(--)	0.0	(--)	0.0	(--)	95.1	(++)	0.0	(--)	0.0	(--)	308
May	0.0	(--)	5.4	(--)	4.7	(--)	53.5	(++)	36.4	(=)	0.0	(--)	0.0	(--)	129
June	0.0	(--)	51.0	(+)	21.8	(+)	23.3	(+)	0.0	(--)	3.9	(--)	0.0	(--)	490
July	0.0	(--)	18.6	(-)	3.3	(--)	0.0	(--)	78.1	(++)	0.0	(--)	0.0	(--)	520
August	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	100.0	(++)	0.0	(--)	0.0	(--)	176
September	78.1	(++)	8.1	(--)	0.4	(--)	12.6	(+)	0.8	(--)	0.0	(--)	0.0	(--)	246
October	0.0	(--)	18.5	(-)	0.0	(--)	4.9	(-)	71.7	(++)	4.9	(-)	0.0	(--)	81
November	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	100.0	(++)	0.0	(--)	0.0	(--)	75
December	0.0	(--)	0.0	(--)	0.0	(--)	0.0	(--)	100.0	(++)	0.0	(--)	0.0	(--)	87
January	0.0	(--)	4.0	(--)	0.0	(--)	0.0	(--)	68.0	(++)	28.0	(+)	0.0	(--)	100
February	0.0	(--)	5.4	(--)	0.0	(--)	2.7	(--)	91.9	(++)	0.0	(--)	0.0	(--)	37
12 months	6.5	(++)	12.0	(--)	4.9	(--)	8.1	(-)	65.4	(++)	3.1	(--)	0.0	(--)	2397
% in range	1.3		27.1		12.8		9.4		34.5		12.8		2.2		
b) Females															
March	0.0		22.6	(-)	30.2	(+)	0.0	(--)	47.2	(+)	0.0	(--)	0.0	(--)	53
April	0.0		13.1	(--)	0.0	(--)	0.0	(--)	86.9	(++)	0.0	(--)	0.0	(--)	84
May	0.0		0.0	(--)	30.3	(+)	0.0	(--)	69.7	(++)	0.0	(--)	0.0	(--)	33
June	0.0		59.4	(+)	17.2	(=)	23.4	(++)	0.0	(--)	0.0	(--)	0.0	(--)	64
July	0.0		43.8	(+)	0.0	(--)	3.9	(-)	52.3	(+)	0.0	(--)	0.0	(--)	153
August	0.0		31.6	(=)	21.0	(+)	5.3	(-)	42.1	(=)	0.0	(--)	0.0	(--)	95
September	0.0		41.0	(+)	0.0	(--)	56.4	(++)	2.6	(--)	0.0	(--)	0.0	(--)	117
October	0.0		31.2	(=)	0.0	(--)	9.4	(=)	40.6	(=)	18.8	(++)	0.0	(--)	64
November	0.0		0.0	(--)	0.0	(--)	0.0	(--)	100.0	(++)	0.0	(--)	0.0	(--)	56
December	0.0		0.0	(--)	0.0	(--)	0.0	(--)	100.0	(++)	0.0	(--)	0.0	(--)	63
January	0.0		30.1	(=)	0.0	(--)	0.0	(--)	69.9)	(++	0.0	(--)	0.0	(--)	73
February	0.0		0.0	(--)	0.0	(--)	100.0	(++)	0.0	(--)	0.0	(--)	0.0	(--)	21
12 months	0.0		22.7	(-)	8.2	(-)	16.5	(+)	50.9	(+)	1.6	(-)	0.0	(--)	876
% in range	0.0		33.4		14.9		8.5		39.8		2.9		0.5		

* Electivity index: (--) = Strong avoidance (-0.5 to -1.0), (-) = Weak avoidance (-0.1 to -0.49), (=) = Neutral (-0.09 to +0.09), (+) = Weak selection (0.1 to 0.49), (++) = Strong selection (0.5 to 1.0).

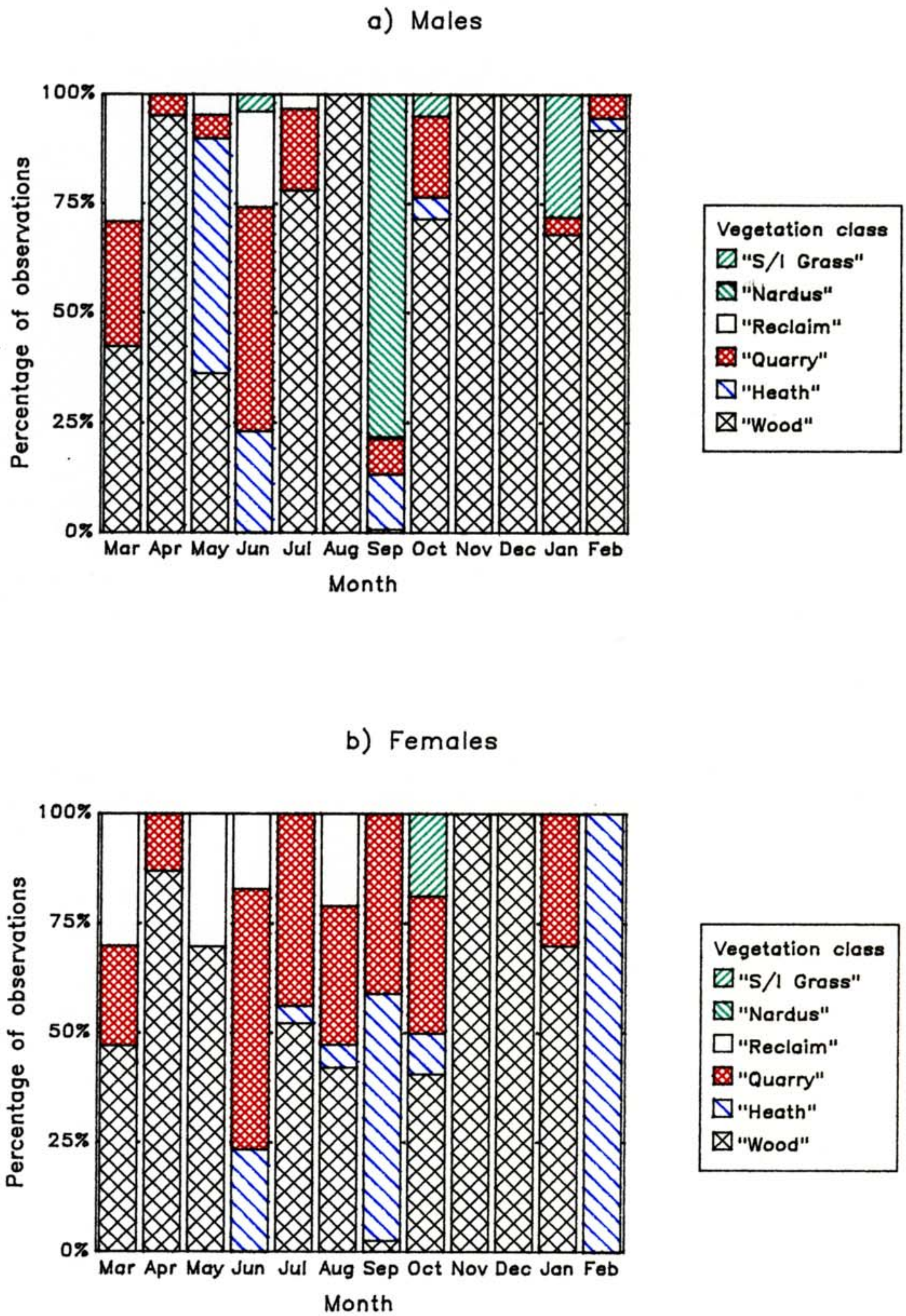


Figure 9.14 Vegetation class utilisation by male and female goats, Padarn 1991-92

"Quarry/Spoil" (Artificial rock exposure and spoil, code I2):
This was the next most extensive category comprising over 33 % of the female range and 27 % of the males. Males usually strongly avoided the quarry areas and showed only weak or neutral selection in March and June. Although females also avoided these areas overall they used them more frequently than males in the summer and early autumn. Vegetation available in these areas comprised mainly scattered dwarf shrubs, including *Calluna vulgaris*, *Rubus fruticosus* agg., woody herbs such as *Digitalis purpurea* and ferns such as *Cryptogramma crispa* plus a sparse covering of grasses such as *Aira praecox*.

"Reclaim" (Poor improved grassland, code B4):
These areas of reseeded but species-poor grassland comprised similar areas in male and female ranges (12.8 to 14.9 % respectively). Selection was only weak or neutral in spring and summer and no usage was recorded at other times of the year. Goats were observed feeding on weed species such as Foxglove (*Digitalis purpurea*) and Gorse (*Ulex gallii*) rather than grazing on grasses in these areas.

"Heath" (Dry and wet dwarf shrub heath, codes D1 and D2 and areas of *Ulex* spp. scrub, code A2):
Areas of heather (mainly *Calluna vulgaris*) and gorse (*Ulex* spp.) comprised approximately 9 % of both male and female ranges and was used slightly more by females. Males were observed feeding on an area of dry heath in the Dinorwic Quarry in early summer and also in September when they moved out of the woodland/Quarry area. In other months males generally avoided "Heath" but were able to continue feeding on ericaceous shrubs growing in "Deciduous Woodland" and "Quarry" habitats. Females also often strongly rejected "Heath" but less so in the summer months, being strongly selected in June, September and February. Selection in February coincided with dispersal of the females prior to kidding when they sought remote, sheltered heath covered ledges in the quarry.

Small areas of continuous Gorse scrub were present in both male and female range (approximately 3 %) but few observations were made of goats on them. Males selected these areas in May and both sexes were seen feeding on them in October. However, feeding on scattered individuals of *Ulex* spp. took place throughout the year in all habitats apart from "Woodland".

"Semi-Improved Grassland" (Acid and neutral semi-improved grassland, codes B1 and B2):
Although over 12 % of the male range comprised of semi-improved grassland it was generally strongly avoided, only weak selection being shown in January when the males were seen feeding on bramble (*Rubus fruticosus* agg.) in derelict farmland in the Fachwen area. This habitat formed only a small part of the female range (2.9 %). Again it was avoided throughout the year except in October when it was strongly selected for no noticeable reason.

"Nardus" (Unimproved acid or neutral grassland, codes B1 and B2):
"Nardus" grassland was only present in the male range (1.3 %) and was generally strongly avoided. However, in September a large group of males were seen grazing on this vegetation over two days and consequently "Nardus" is selected strongly overall. This may not reflect any dietary preference however, as the males moved to this area due to the presence of oestrous females during the rut.

"Other Vegetation" (Other habitat types present in the range, including *Sphagnum* Bog, code E6, Scattered Scrub, code A2 and Bracken, code C1):
These remaining habitats formed only a small percentage of the annual ranges (0.5 % for males, 2.2 % for females). No observations of goats were made in these areas during the study period.

Both Bullock (1982) and Gordon (1989) also recorded differences in habitat selection between male and female goats but due to the different vegetation communities available comparisons with the Padarn are difficult. Gordon noted that females tended to select mesotrophic plant communities more than males, especially in spring and summer. This corresponds with the greater utilisation of "Quarry" and "Reclaim" areas by females in these seasons where although forage is not abundant, quality may be higher.

5.4.4 Other factors affecting habitat selection and diet.

Weather conditions: As mentioned, goats were often seen using woodland during very windy weather and in periods of rain they often made use of the many derelict quarry buildings. As in Cwm Ffynnon, goats were seen at the highest altitudes during fine weather in spring and early summer when exposed ledges in the quarry were utilised. In the winter months lower, mainly wooded areas were used although females preferred to kid in higher parts of the quarry where sheltered sites and buildings were selected. Unlike Cwm Ffynnon, shelter was much more abundant and less likely to limit the areas available for feeding. In addition, the considerably milder weather conditions greatly prolongs the growing season at the Padarn site. The spring growing period begins perhaps four weeks earlier than in Cwm Ffynnon and extends later into the year which may help to explain the timing of utilisation of certain dietary components.

Other herbivores in the area: Monthly estimates of the numbers of other livestock within the entire annual goat range were not made, but records of sheep within the core female range recorded. Although grazing is allowed in the quarry area, fewer than 20 sheep were counted in any month. The boundary of Coed Allt Wen is fenced to prevent the entrance of sheep although small numbers (10-15) were seen in the area over the winter. An adjacent group of around 10 goats were also seen on two occasions in a wooded area close to the end of Llyn Peris. This group were usually seen on the opposite side of the valley and were not believed to share the range of the main Padarn goat group to any great extent. Whilst the population density of sheep and goats in the annual Padarn range is probably higher than in Cwm Ffynnon, the greater diversity, quality and abundance of forage may compensate for the higher potential levels of competition.

Disturbance: The Padarn Country Park and the Dinorwic quarries are popular recreation areas, with large numbers of visitors especially in the summer months between June and September. The many footpaths in the woodland are used by locals walking their dogs and certain parts of the quarry are often busy with outdoor activity schools and climbers. Consequently the levels of disturbance are high, and may partly explain the movements of the goats at certain times of year. Quieter areas of the quarry tended to be used by females in the busy summer months and for kidding in February. Goats were also seen in the country park in these months but often selected areas not visible from the main footpaths. To what degree choice of habitat was affected by the presence of humans is not known, on the occasions when they were obviously disturbed by parties with dogs, the goats simply moved to less accessible parts of the woodland and quickly resumed feeding.

Topography: Although the Padarn area is geographically very complex, the goats did not appear to be restricted by any artificial features. They were frequently seen crossing fences, walls and roads and their agility also allowed them access to vegetation on ledges in the quarry which sheep rarely or never used.

5.5 Faecal analysis of goats in the Padarn area.

Faecal composition data for goats of each sex at the Padarn site are summarised for the year in Table 5.14 and given monthly in Table 5.15.

In total, 51 species of plant were identified in faeces collected in the Padarn area during the 12 month study period. These species were classified into 14 plant groupings to simplify fragment enumeration. Monthly utilisation of the more major diet components are presented individually in Figures 5.17 and 5.18. Although goats were observed feeding on twigs and bark stripped from trees, it was not possible to identify remains of these using cuticle analysis. Most species were identified from cuticle remains of leaf material but a small amount of fruit and seed remains were also encountered. Individual species identified in each category are listed in Table 5.13. For statistical analysis by MANOVA these grouping were further reduced to eight categories by combining "Grass", Rush" and "Sedge" categories as "Monocots"; "Bramble" and "Misc. Shrubs" into "Shrubs"; and "Oak", "Conifers" and "Other Trees" as "Trees", details are given in Appendix 4. Figure 5.15 shows monthly faecal composition for males and females using these categories.

The group of goats in the Padarn area was much larger than the Cwm Ffynnon herd, having over 30 individuals. This allowed larger numbers of faecal samples to be collected from identified individuals, especially males. To reduce the time required for cuticle analysis, samples from individual goats were bulked together and 400 fragments identified for each sex each month (see section 3.3). The amount of unidentifiable material each month ranged from 29.45 % to 49.04 % of all the fragments examined, with an average of 43.41 % for the year. Goats in the Padarn were frequently observed consuming bark, and other woody material which could not be identified. This explains the higher percentage of fragments which could not be identified in the Padarn samples compared to those from Cwm Ffynnon. Again, it must be assumed that the composition of this unidentified portion is similar to the identified component. Original faecal fragment data are given in Appendix 3.

Table 9.13 Plant groupings and species identified from faeces of goats at the Padarn site.

Plant Grouping	Species identified
"Oak"	*Quercus petraea*
"Conifer"	*Picea abies*
"Other Trees"	*Betula pubescens, Crataegus monogyna, Corylus avellana, Fagus sylvatica, Fraxinus excelsior, Salix capra, Sorbus aucuparia* and *Taxus baccata*
"Holly/Ivy"	*Hedera helix, Ilex aquifolium* and *Rhododendron ponticum*
"Heather"	*Calluna vulgaris, Erica cinerea* and *E. tetralix*
"Misc. Shrub"	Mainly *Rubus fruticosus agg., Ulex spp. (U.europaeus and U.gallii)* and *Vaccinium myrtillus* but also included *Lonicera periclymenum, Cotoneaster* spp. and *Rosa canina.*
"Fern"	Mainly *Pteridium aquilinum* and *Cryptogramma crispa* but including *Dryopteris felix-mas, Polypodium vulgare* and *Blechnum spicant*
"Herb"	Mainly *Digitalis purpurea* and *Teucrium scorodonia* but including *Origanum vulgare, Urtica dioica, Potentilla erecta* and *Oxalis acetosella*
"Moss"	Unidentified lichen species and mosses such as *Polytrichum commune* and *Sphagnum* spp.
"Grass"	A wide variety of grass species were identified, all in small quantities. Species/Genera included *Agrostis spp.*, *Aira praecox, Anthoxanthum odoratum, Brachypodium sylvaticum, Dactylis glomerata, Deschampsia* spp. (mainly *D.flexuosa*), *Festuca* spp., *Glyceria* spp., *Holcus mollis, Molinia caerulea, Nardus stricta,* and *Poa* spp. A very small amount of *Endymion non-scriptu*s was encountered and included in this category.
"Sedge"	*Carex* spp.
"Rush"	*Luzula pilosa, Juncus effusus* and *J.squarrosus*

5.5.1 Overall faecal composition for the year.

The yearly average faecal composition for male and female goats are given in Table 5.14 and Figure 5.16. Unlike the group in Cwm Ffynnon there appeared to be dissimilarities in the diet between the sexes for all the diet components except "Herb" and "Moss". The greatest single diet component was the "Heather" group comprising 26.63 % of the overall diet in females, in males the "Tree" group was the most important category and composed 24.71 % of their diet. Monocotyledons composed only 14.6 % and 21.48 % of the diet of males and females respectively. Miscellaneous "Shrubs" other than "Heather" made up the next largest diet component at 14.35 % in males and 11.77 % in females. The remaining categories each composed less than 10 % of the overall diet in both sexes.

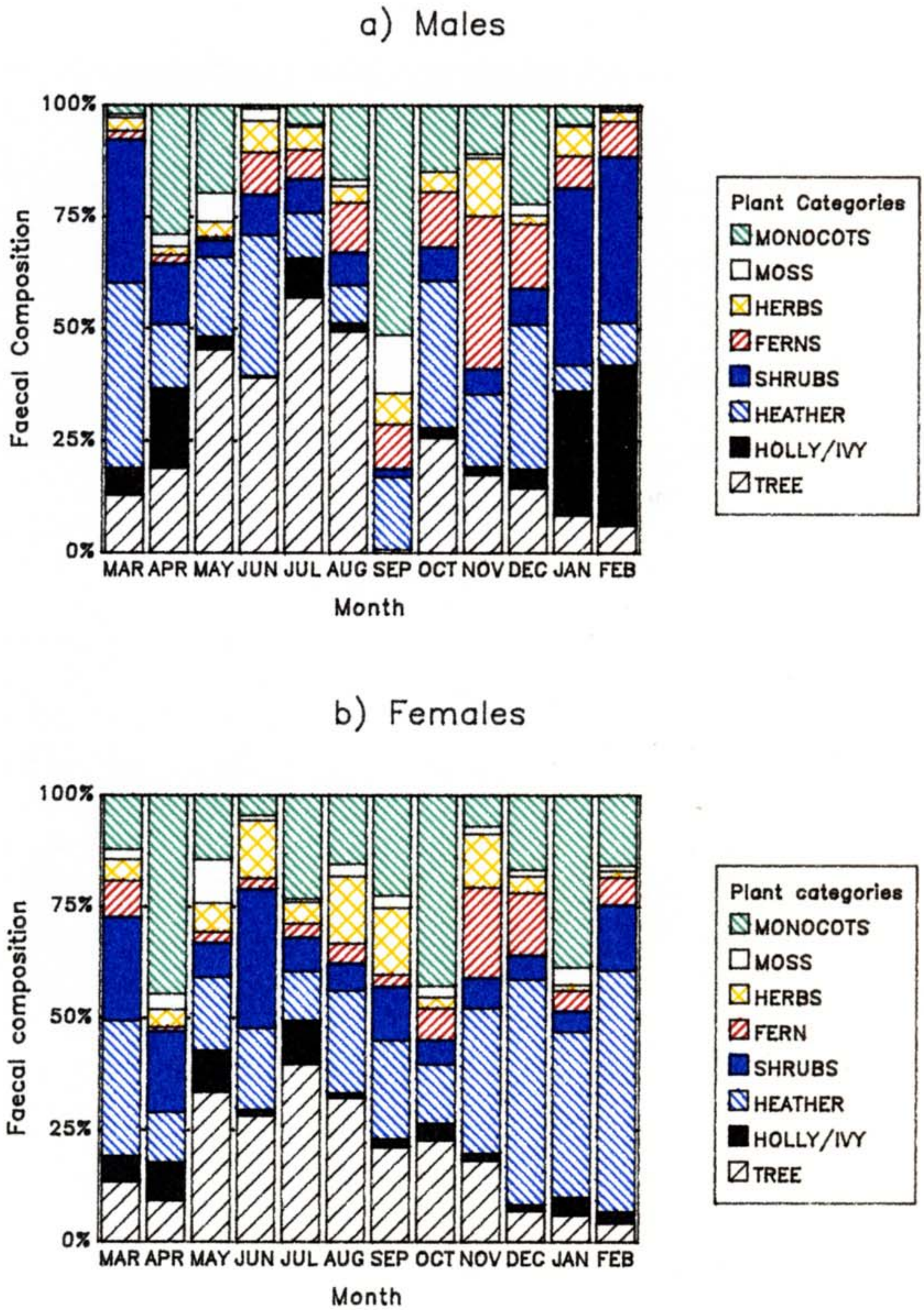
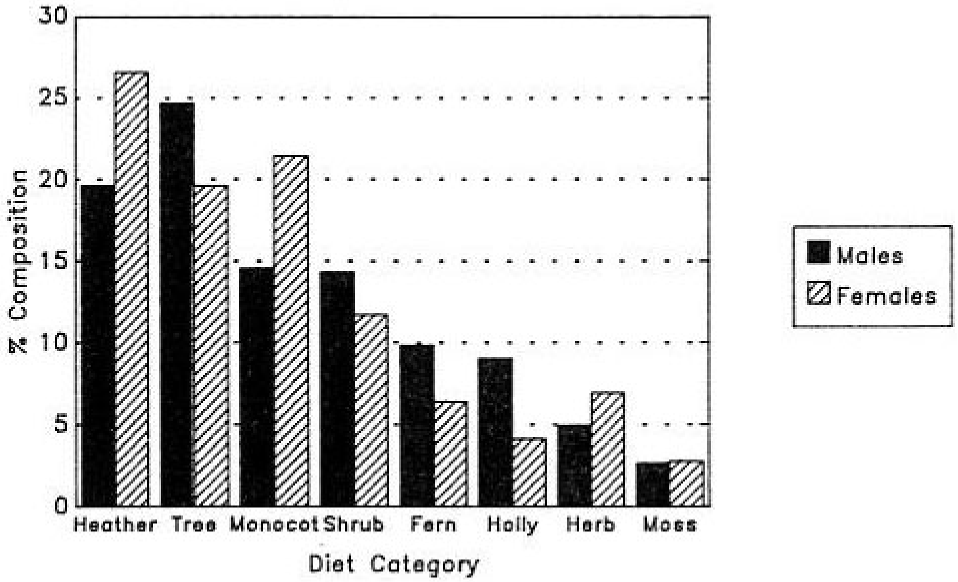


Figure 9.15 Faecal composition of male and female goats, Padarn 1991-92

Table 9.14 Overall percentage faecal composition for male and female goats at the Padarn site.

Group	Heather	Tree	Monocots	Shrubs	Fern	Holly	Herb	Moss
Males	19.69	24.71	14.60	14.35	9.88	9.08	5.00	2.69
Females	26.62	19.67	21.48	11.77	6.44	4.19	7.00	2.83
Combined Average	23.16	22.19	18.04	13.06	8.16	6.63	6.00	2.76

Figure 9.16 Overall diet of male and female goats in the Padarn area.



There have been few other studies of goats feeding largely in British woodland over a long period for purposes of comparison. Smith (1989) studied the same Padarn group in August 1988 using faecal analysis and these results compare well to those of this study for the same month. Though not wholly comparable, in both cases tree and dicotyledonous material formed the major diet component, with grasses, heathers, oak and ferns also being important.

Smith & Bullock (1993) observed goats feeding in the Cheddar Gorge in summer and found that whilst woodland comprised approximately 35 % of the range, over 60 % of records of goats were from this habitat. Of their diet, trees and shrubs (especially *Fraxinus excelsior*, *Taxus baccata*, *Crataegus monogyna* and *Hedera helix*) accounted for nearly 80 %, herbs accounted for 11 %, and graminoids 8.5 %. In the Padarn area, "Woodland" comprised between 34 % and 40 % of the goat range and although it is difficult to compare these results directly with faecal analysis it would appear that goats in both areas are behaving mainly as browsers, with graminoids and herb species being relatively minor components of the diet.

Table 9.15 Monthly faecal composition (%) for male and female goats in the Padarn area 1991-92.

a) Males

Month	Other Oak	Holly/ Conifer	Trees	Ivy	Heather	Bramble	Gorse	Misc. Shrubs	Ferns	Herbs	Moss	Grass	Sedge	Rush	All Monocots	No. of Goats
March	3.75	0.00	9.25	6.00	41.25	6.50	20.00	5.50	2.00	3.00	0.75	1.25	0.00	0.75	2.00	6
April	5.75	0.75	12.50	17.75	14.25	7.00	2.25	4.25	2.00	2.00	2.75	25.00	1.75	2.00	28.75	7
May	5.50	0.00	40.00	2.75	17.75	2.50	0.25	1.00	0.75	3.50	6.50	18.25	0.25	1.00	19.50	7
June	1.75	0.00	37.50	0.25	31.50	1.00	4.25	3.75	9.50	7.00	2.75	0.50	0.25	0.00	0.75	7
July	7.75	0.00	49.25	8.75	10.25	2.25	2.00	3.25	6.50	5.25	0.50	4.25	0.00	0.00	4.25	9
August	8.50	0.00	41.00	1.75	8.50	1.25	3.00	3.00	11.25	3.75	1.50	14.00	0.25	2.25	16.50	11
September	0.00	0.00	0.75	0.00	16.25	0.00	0.00	1.75	10.00	7.00	13.00	48.25	2.00	1.00	51.25	7
October	2.00	0.25	23.50	2.25	32.75	3.00	0.00	4.50	12.50	4.50	0.25	12.25	1.25	1.00	14.50	5
November	3.50	0.00	14.00	1.75	16.25	1.75	3.00	0.75	34.25	13.00	1.00	10.75	0.00	0.00	10.75	5
December	0.25	2.00	12.25	4.25	32.25	1.50	0.75	5.75	14.50	2.00	2.50	20.00	1.25	0.75	22.00	10
January	2.50	0.00	6.00	27.75	5.75	32.50	5.00	2.00	7.25	6.75	0.25	4.00	0.00	0.25	4.25	10
February	1.50	0.00	4.75	35.75	9.50	32.00	4.00	1.00	8.00	2.25	0.50	0.75	0.00	0.00	0.75	5
Year	3.56	0.25	20.90	9.08	19.69	7.60	3.71	3.04	9.88	5.00	2.69	13.27	0.58	0.75	14.60	89

b)Females

Month	Oak	Conifer	Other Trees	Holly/ Ivy	Heather	Bramble	Gorse	Misc. Shrubs	Ferns	Herbs	Moss	Grass	Sedge	Rush	All Monocots	No. of Goats
March	4.50	0.00	9.00	5.75	30.25	5.75	14.00	3.25	8.25	4.75	2.25	11.75	0.00	0.50	12.25	3
April	0.75	0.00	8.50	8.50	11.25	2.50	5.25	10.25	1.00	4.00	3.50	35.75	4.75	4.00	44.50	3
May	5.00	0.25	28.25	9.25	16.50	1.75	1.75	4.00	2.50	6.50	9.75	13.75	0.50	0.25	14.50	7
June	1.50	0.00	26.75	1.25	18.25	1.00	29.50	0.50	2.50	13.00	1.25	3.50	0.25	0.75	4.50	3
July	3.50	0.00	36.25	9.75	11.00	2.50	3.50	1.50	3.25	4.75	0.75	23.25	0.00	0.00	23.25	3
August	6.25	0.00	26.00	1.00	23.00	3.75	1.25	1.00	4.50	15.00	2.75	15.00	0.50	0.00	15.50	5
September	6.75	0.00	14.50	1.75	22.00	10.75	0.00	1.25	2.75	15.00	2.75	22.50	0.00	0.00	22.50	5
October	2.25	0.00	20.50	3.75	13.25	1.75	0.25	3.25	7.25	2.50	2.50	42.50	0.25	0.00	42.75	4
November	3.25	0.00	15.00	1.50	32.50	5.75	0.75	0.25	20.25	12.00	1.75	6.50	0.50	0.00	7.00	3
December	1.00	0.25	5.75	1.25	50.50	1.25	2.25	1.75	14.00	3.75	1.50	16.00	0.00	0.75	16.75	4
January	0.50	0.00	5.50	4.00	37.00	2.00	0.50	2.00	4.75	1.25	4.00	31.50	2.25	4.75	38.50	4
February	0.00	0.50	3.75	2.50	54.00	4.25	6.00	4.25	6.25	1.50	1.25	15.75	0.00	0.00	15.75	4
Year	2.94	0.08	16.65	4.19	26.62	3.58	5.42	2.77	6.44	7.00	2.83	19.81	0.75	0.92	21.48	48

One of the sites (Dinas) which Hellawell (1991) studied incorporated small areas of oak woodland which the goats selected strongly in late winter/early spring. Although the leaves of species such as *Fraxinus excelsior* and *Rhododendron ponticum* were observed to be eaten, no tree leaves were recorded using faecal analysis and graminoids, ericaceous shrubs and gorse remained the dominant features of the diet. This is somewhat surprising as many other studies have shown tree browse to be a principle part of the diet when goats have access to woodland. Goats, however, are extremely flexible and opportunistic herbivores (Malechek & Provenza 1983) making detailed comparisons between diets in different environments hazardous.

5.6 Variations in faecal composition by plant category

Figures 5.17 and 5.18 show the monthly contribution of each plant grouping to the diets of males and females at the Padarn site.

To analyse differences in diet composition between the sexes and over time, MANOVA was used as for the Cwm Ffynnon data. Details are given in Appendix 4 and summarised in Tables 5.16 and 5.17. For each month and sex, four samples of 100 fragments each were enumerated and used as replicates. The effect of replicates, sex, month and sex*month interaction were investigated. Variation between replicates was found to be non-significant (Wilks Lambda P=0.912) but the effects of sex, month and the sex*month interaction were all found to be highly significant (Wilks Lambda P<0.001). This was true for all plant categories when tested by ANOVA, except for "Herb" and "Moss" where variations between the sexes were non-significant (P=0.726, P=0.715 respectively). Sex and month were clearly important factors affecting faecal composition and the strong interaction between the two suggests that males and females show different seasonal patterns in their diet composition.

Table 9.16 Levels of significance from ANOVA of the percentages of seven forage classes in the faecal composition of goats in the Padarn area in relation to sex, month and sex*month interaction.

Source of Variation	Degrees of Freedom	Tree	Holly/ Ivy	Misc. Shrubs	Fern	Herb	Moss	Monocots
Sex	70	<.001 **	<.001 **	<.001 **	<.001 **	.726 ns	.715 ns	.011 *
Month	80	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **
Sex*Month	80	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **	<.001 **

Table 9.17 Results of MANOVA (Wilks Lambda) of seven forage classes in the faecal composition of goats in the Padarn area.

Source of Variation	Degrees of freedom	P	Level of Significance
Sex	7, 63	<.001	**
Month	77, 384	<.001	**
Sex*Month	77, 384	<.001	**

The degree and possible explanations for seasonal- and sex-differences in diet composition for individual plant categories are discussed in the following sections.

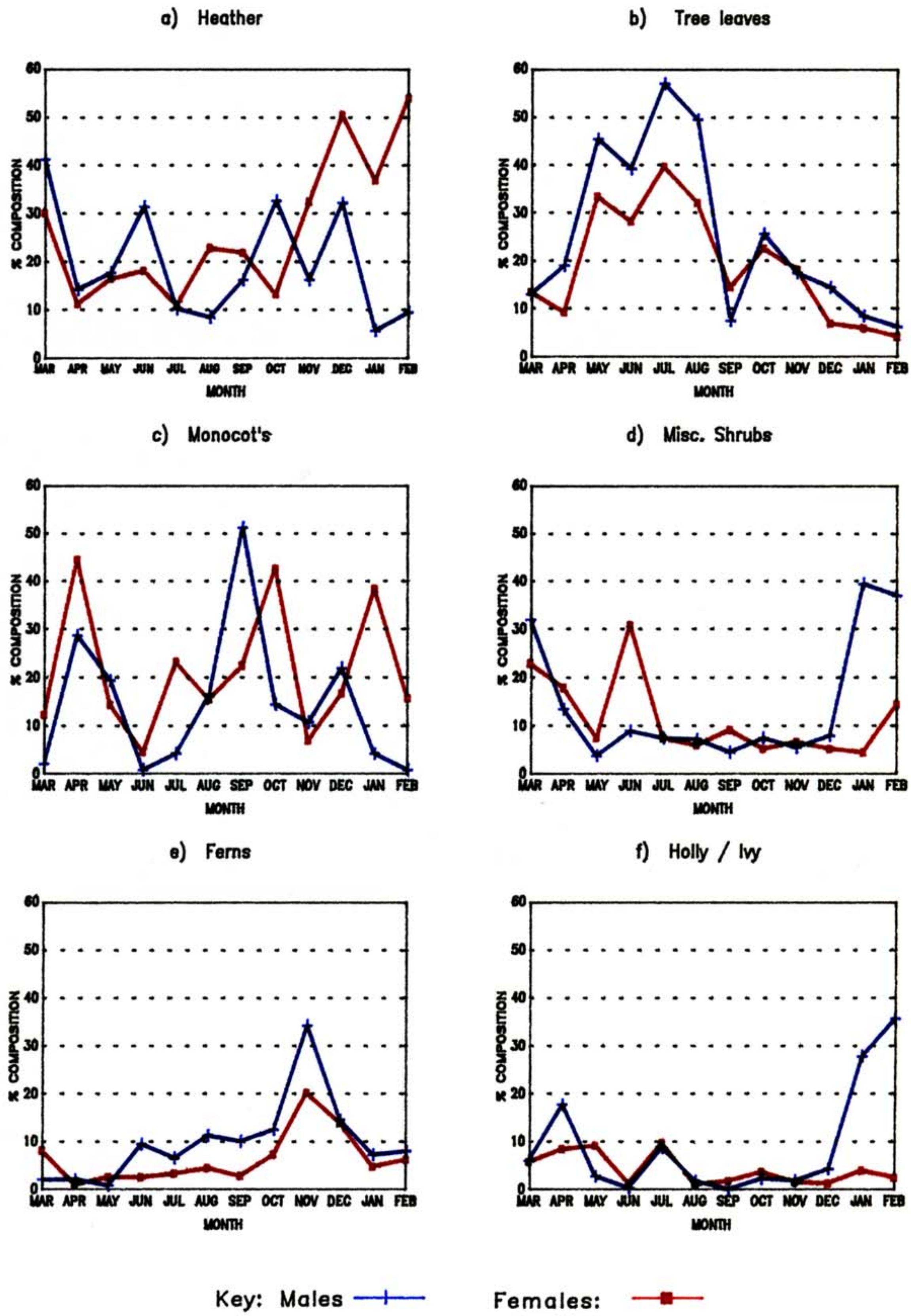


Figure 9.17 a) –f) Monthly faecal composition of male and female goats in the Padarn area by individual plant category.

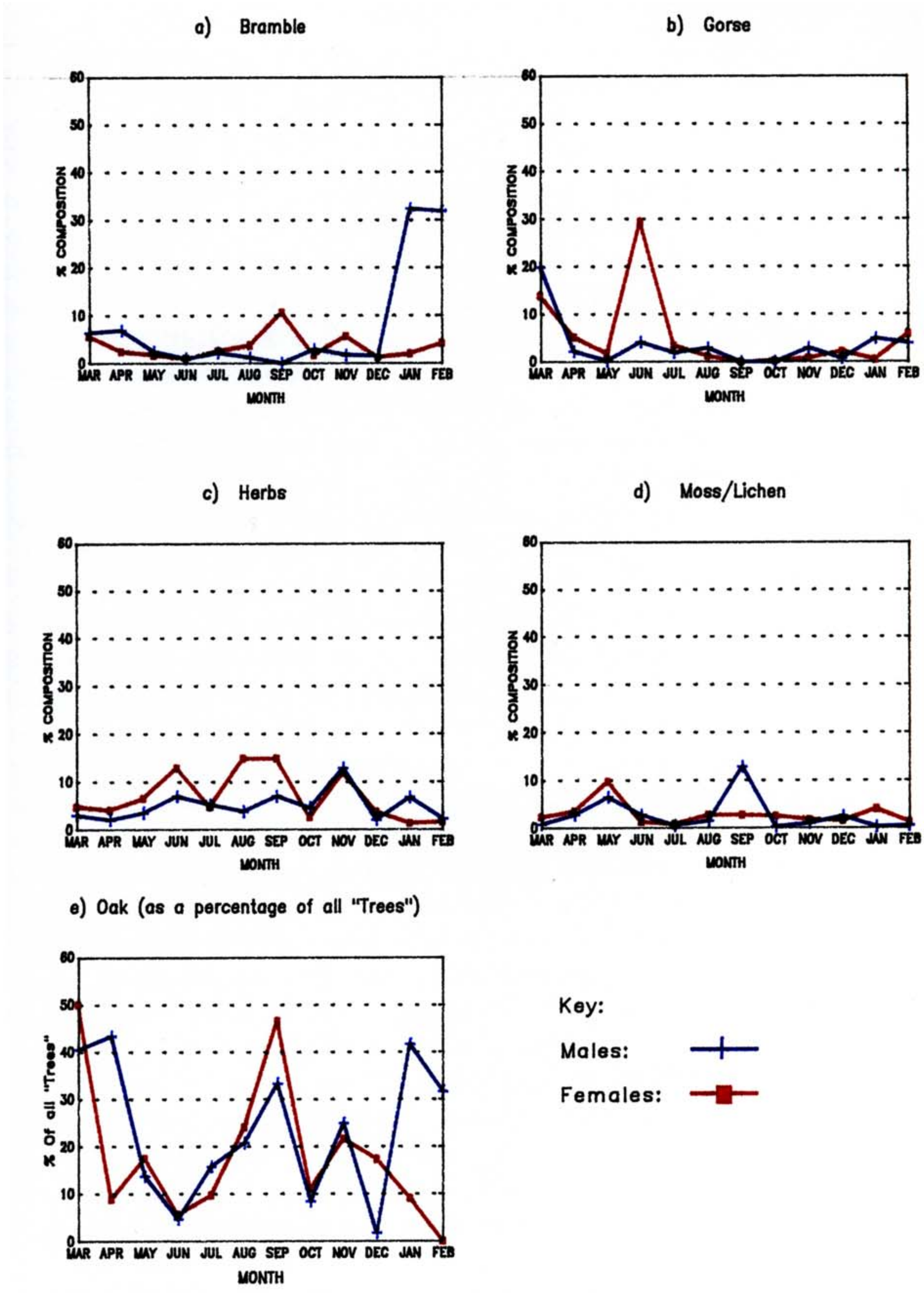


Figure 9.18 a) -e) Monthly faecal composition of male and female goats in the Padarn area by individual plant category.

5.6.1 Monthly variations in faecal composition

"Heather" Utilisation of "Heather" (mainly *Calluna vulgaris* and *Erica cinerea*) was highly variable throughout the year especially in the female diet. In males it varied between less than 6 % of the diet in February 1992 to a maximum of over 41 % in March 1991, with an average of 19.69 % for the year. In females this was higher (26.63 %) mainly due to higher percentages in late autumn and winter which coincided with minimum utilisation by males. In November and December both sexes were located in woodland so this disparity in diet does not seem to be connected to differences in habitat utilisation. In February females were restricted to heather covered ledges in the quarry during kidding whilst males remained in the woodland. Heather was widespread throughout the range of the Padarn goats being present in the quarry as remnants of upland heath and also in the more open areas of woodland.

"Tree" This category includes all tree species including *Quercus petraea* and conifers. Utilisation of tree browse was also highly variable, especially in males where its proportion in the diet ranged from almost zero in September to 57 % in July. In both sexes a seasonal pattern of use was apparent, with a peak in late spring and early summer falling to a minimum in the winter months. Apart from the single month of September, tree leaves were always present in the male diet at levels equal or higher than in females. The rutting season began in September and the Padarn males were located far up the Llanberis Pass, over 6 km outside their normal range. Diet composition appears to reflect availability during this period as relatively few trees are present at that location.

Utilisation of the "Tree" category commenced with the growth of fresh leaves in spring and continuing to a peak (39 % in females, 57 % in males) in July, declining from thereon. Hellawell (1991) recorded only a trace of tree browse in goat diet and observed that only mature leaves seemed to be eaten. However, goats in the Padarn appeared to feed on tree leaves immediately following bud-burst in April. It is perhaps surprising that any leaves of deciduous tree species are found in the diet during the winter months. However, goats were observed feeding in deep leaf litter on several occasions. In the faeces it was not possible to distinguish dead leaves from live, or immature from mature leaves. Studies of goats in deciduous woodland in other parts of the world have shown that leaf litter can be a major element of the diet (e.g. Pfister & Malechek 1986, Wilson *et al.* 1975). From rumen samples, Jackson (1977) noted that acorns and beech mast formed a major food source for fallow deer from September to January. He also recorded small amounts of dead leaves over much of the year but much more frequently in November and December. It is likely that the Padarn goats are also feeding on acorns but to what degree dead leaves are selected or ingested incidentally is not known.

Individual species within the "Tree" category were extremely difficult to identify. Although goats were observed feeding on almost every species present, only *Quercus petraea* was identified in any quantity, contributing up to 50 % of all tree species in the diet. Males apparently ate relatively more *Quercus* than females in April, January and February. (see Figure 5.18e). In September "Tree" fragments comprised less than 1 % of the male diet and no Quercus was identified. Fluctuations in the proportion of oak within the "Tree" category may reflect selection or rejection of other species at certain times of year, or changes in the relative availability of oak leaves over time. In many studies of goat diet outside Britain tree browse and various species of *Quercus* have been shown to be major diet components. (e.g. Cuartas & Garcia-Gonzalez 1992, Papachristou & Nastis 1993). Oak leaves contain high levels of tannins and other secondary compounds which goats appear to tolerate better than many other herbivores and in the United states goats have been used as a means of controlling oak scrub. (Davis *et al.* 1975).

Coniferous "Tree" species could also be distinguished relatively easily but were rarely recorded in the diet and only *Picea abies* was identified. Although there were conifers adjacent to the Padarn range, most of these were mature trees with little browse in reach of the goats. Goats were not seen feeding in either of two younger plantations of *Pinus sylvestris*. Bullock (1985) observed *P. sylvestris* needles to form a large part of the diet at one site when goats invaded a young plantation.

No quantitative observations of feeding were recorded, but species which goats were frequently seen browsing included *Corylus avellana*, *Betula pubescens*, *Crataegus monogyna*, *Salix capra* and *Sorbus aucuparia* all of which are common in the area. Unfortunately few fragments of these were distinguishable in the faeces, but it is likely that the remaining unidentified portion of the "Tree" category was made up mainly of these. As mentioned above, bark and other woody remains could not be identified in the faeces. Stripping of bark was observed by both sexes at all times of year. "Tree" material probably forms a much great contribution to the diet of goats in the Padarn than faecal analysis suggests.

"Monocots" This category was made up almost wholly of grass species, with only small amounts of sedges or rushes (see Table 5.15). Utilisation fluctuated widely over the year in both sexes. In general, the proportion of monocotyledons was high in spring (28.75 % in males, 44.5 % in females), coinciding with the early growth of species like *Deschampsia flexuosa*. In early summer the utilisation of "Monocots" fell to a minimum (0.75 % in males, 4.5 % in females), being replaced in the diet by tree leaves, shrubs and herbs, before gradually increasing to another peak in early autumn (51.25 % in males, 42.75 % in females). In the winter months it remained important in the female diet (15.75 % to 38.5 %) but was reduced to very low levels (0.75 % and 4.25 % in January and February) in males. In September, when the males were located well outside their usual range, "Monocots" (mainly *Nardus stricta* and *Festuca* spp.) composed over 50 % of their diet and this coincided with their movement away from woodland and utilisation of the "Nardus" habitat class discussed in section 5.4.3).

Due to the large number of grass species present in the Padarn area, it was not possible to prepare a complete cuticle reference collection and only 11 genera/species groups were identified in the faeces, (see Table 5.13), although many others were almost certainly consumed. Approximately 45 % of fragments classified as "Grass" were identified further, of which *Deschampsia flexuosa*, *Festuca* spp. and *Agrostis* spp. made up almost 90 %.

Utilisation of non-grass "Monocots" was very low (<2 % overall) compared to goat diet in Cwm Ffynnon. It is possible that when high quality "sweet" grasses are available, these are grazed in preference to species such as *Luzula pilosa* and *Endymion non-scriptus* even though these are available in large quantities.

Smith (1989) observed "Monocots" to form 18 % of the diet of the Padarn goats in August, with Gramineae forming over 97 % of the category and *Festuca* being the predominant grass species. This compares well to the August results in this study, with approximately 16 % "Monocots" in the diet, over 90 % of these being grass species.

"Miscellaneous Shrubs" This category was chiefly represented by gorse (*Ulex* spp.) and bramble (*Rubus fruticosus* agg.); unidentified shrub species and bilberry (*Vaccinium* *myrtillus*) contributed less than 3 % of the overall diet. Whilst normally forming less than 10 % of the diet, bramble increased to over 30 % in males in January and February. Similarly, gorse remained at low levels for most of the year but became more important for both sexes in March and reached almost 30 % of the female diet in June. These differences can in part be ascribed to the different habitats each sex was feeding in during these months. In January and February, males were feeding at the northern part of their range, in an area of derelict farmland and woodland (Fachwen) whilst the females utilised the woodland of Coed Allt Wen and quarry ledges where less bramble was available. In June "Miscellaneous Shrubs" (mainly gorse) formed over 30 % of the female diet and less than 10 % in males. At this time both males and females were recorded feeding on "Calluna Heath" high in the Dinorwic quarry. It is not known whether females were feeding preferentially on gorse or whether males and females had fed in different habitats in the days before sampling.

Hellawell (1991) noted significant amounts of *Ulex* europaeus in goat diet throughout the year with a peak in February/March possibly related to an increase in nutritional value at that time. Smith (1989) recorded similar levels of gorse, bramble and bilberry in the August diet as in the present study.

"Ferns" Utilisation of "Ferns" followed a pattern similar to that recorded by Bullock (1982) and Hellawell (1991): limited over most of the year but reaching a peak in late autumn due to consumption of the dying fronds of *Pteridium aquilinum*. Whilst this species was frequently identified in the faeces, other species, especially *Dryopteris felix-mas* and *Cryptogramma crispa* were seen to be grazed by goats but their cuticle remains could not easily be distinguished. Ferns were more frequent in the diet of males than females throughout the year and in November comprised over 34 % of their diet.

"Holly/Ivy" These two rather disparate plants are considered together as separation of their cuticle fragments in the faeces proved difficult, although both were easily distinguished from other "Tree" or "Shrub" remains. This category was limited to less than 10 % of the diet in females but in males it became a major component of the diet in the winter months, reaching over 35 % in February. Hellawell (1991) also observed Ivy (*Hedera helix*) to be a favoured food of goats and noted a distinct browse line where goats were present. In the Padarn evidence of feeding on Ivy was also common, with an obvious browse line and signs of bark stripping on the thicker stems. Goats were occasionally seen climbing high into trees in their attempt to reach untouched Ivy leaves, and freshly fallen branches covered with Ivy would be quickly attacked. Signs of feeding on Holly (*Ilex aquifolium*) were less obvious, though browsing on leaves was observed and bark stripping of this species was common.

"Herbs" Overall, "Herbs" were a minor part of the diet (5 % in males, 7 % in females) but were more important in the summer months, especially in females, reaching 15 % of the diet. The most frequently identified species were the biennials Foxglove (*Digitalis purpurea*), and Wood Sage (*Teucrium scorodonia*), which both had distinctive trichomes and more lignified cell walls. Cuticle fragments without such distinctive characters were more difficult to identify and it is possible that other species are also important. Neither Smith (1989) or Hellawell (1991) noted any herbs in the diet and Bullock (1982) observed only small amounts present (< 3 %) when feeding in upland habitats. Goats feeding in the Cheddar Gorge however were observed feeding on 38 species of herbs which formed 11 % of their diet in summer (Smith & Bullock 1993). In the Padarn, utilisation coincided with the growth and flowering of several herb species. Goats were observed feeding on the flowerheads of

Foxglove growing in the "Quarry" and "Reclaim" habitats in early summer. Overwintering leaves seemed to be left untouched.

"Moss" As in Cwm Ffynnon, "Moss" formed only a small proportion of the overall diet (< 3 %), although in September it reached 13 % of the diet in males. In this month the males were feeding in an area of "Nardus" grassland heavily grazed by sheep. "Grass" was a major part of the diet at this time and it is likely that mosses were ingested whilst feeding on the closely grazed sward. The most frequently identified "Moss" species were *Polytrichum* spp. although unidentified lichens were also occasionally encountered. As in Cwm Ffynnon, it is likely that species within this category are ingested accidentally when either grazing on grasses and low herbs or when stripping bark from trees.

5.6.2 Differences in faecal composition between the sexes.

As mentioned in section 5.6, there were significant differences in the overall diet between the sexes and also for all individual plant categories except "Moss" and "Herb". The sex*month interaction effect was also highly significant for all plant categories.

Males had higher proportions of "Tree", "Miscellaneous Shrubs", "Ferns" and "Holly/Ivy" categories in their overall diet than females, and less "Heather" and "Monocots"(see Figures 5.17, 5.18 and Table 5.15). Tree leaves and ferns appeared to be eaten more by males in most months with the significant exception of "Tree" in September when goats were feeding in "Nardus" habitat with very few trees present. The "Holly\Ivy" category appeared in the diet in similar amounts in both sexes over much of the year but was much more frequent in the male diet in January and February. This corresponded with the continued use of woodland by males in the winter months when females made greater use of "Quarry" and "Calluna Heath" areas prior to kidding. Dissimilarities in "Misc. Shrub" utilisation are mainly due to differing amounts of gorse and bramble present and can also be partly ascribed to the greater use of woodland by males in the winter months. However, females consumed much more gorse in June although both sexes were found in similar habitat types at this time. Both "Monocots" and "Heather" were highly variable components of the diet in both sexes. Females utilised "Monocots" to a similar or much greater degree than males except in September when males fed more on grasses. For females, "Heather" increased in importance during the autumn and winter months and remained at similar or slightly lower levels than males in spring and early summer.

As with the Cwm Ffynnon data, male and female diets and habitat utilisation were compared using Kulzynski's Similarity Index, results are given in Table 5.18 and Figure 5.19

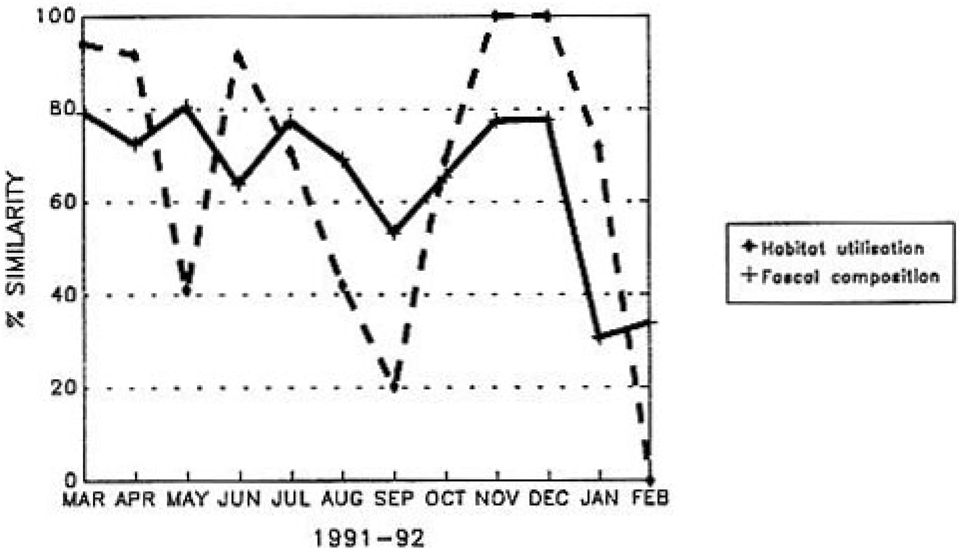
Table 9.18 Kulzynski's Similarity values for Male-Female faecal composition and habitat utilisation at the Padarn site.

Month	KSI Values	
	Faecal Composition	Habitat Utilisation
March	79.25	94.20
April	72.50	91.80
May	80.50	41.10
June	64.00	91.50
July	77.25	70.90
August	69.25	42.10
September	53.25	20.30
October	65.50	68.90
November	77.50	100.00
December	77.75	100.00
January	30.75	72.00
February	34.00	0.00
Year	82.33	83.60

Diet similarity varied considerably over the year, being lowest in January/February (KSI values 30.75 % to 34.00 %) and highest in May (80.50 %). Different habitats were used in September and February which coincided with large differences in diet. In May, diets remained fairly similar (80.50 % similar) although males and females were using different habitats, however the total number of observations of females was low (33) in this month and they may have used a wider range of habitats than recorded. In January, diets were very different between the sexes although similar habitats were used. The greatest degree of dissimilarity of both diet and habitat utilisation was observed in January/February, immediately prior to kidding and may be a strategy to reduce interspecific competition at this time of year.

Overall diet similarity (82.33 %) was lower and more variable than in Cwm Ffynnon (96.41 %) reflecting perhaps the higher diversity of forage available in the Padarn area and the greater segregation of the sexes onto different habitat types.

Figure 9.19 Seasonal change in percentage similarity (KSI values) of male and female diets at the Padarn site.



Chapter 6. Discussion and summary

The aim of the present study was to investigate and describe possible seasonal variations in the diets of two groups of feral goats and to examine any dietary differences between the sexes. Available techniques were limited and faecal analysis was selected to represent the diet in terms of botanical composition. Faecal analysis is laborious to carry out and preparation to produce reference material for cuticle identification is also very time consuming. Experience in using the technique was gained by examining certain aspects including developing prediction equations for hand compounded mixtures, producing keys to identify cuticle fragments and exploring potential misidentification errors. These exercises are discussed below (Section 6.1) and recommendations for further study areas suggested.

Faecal samples from two groups of goats feeding in very different habitats, upland heath (Cwm Ffynnon) and deciduous woodland (Padarn) were analysed. Considerable monthly variations were found in the faecal composition of goats at both sites and significant dietary differences between the sexes were observed for the Padarn group. Dietary variation was low between samples from six individual goats taken over seven months at Cwm Ffynnon. Seasonal and 12-month ranges for males and females were estimated at both sites during fieldwork, these were similar in Cwm Ffynnon but differed in the Padarn. Habitat utilisation and selection also varied throughout the year at both sites and also between the sexes at the Padarn site. Ranges, habitat utilisation and faecal composition are discussed in sections 6.2 to 6.4 and related to theories of optimal foraging, diet selection and resource partitioning.

Information on the diets selected by wild, free-ranging animals can assist in the management decisions for domesticated stock and may help to predict the potential impact on particular types of habitat. Interest has been shown in using goats to manipulate the vegetational composition of ranges, or to use them in mixed grazing regimes with other herbivores to maximise productivity. How results of the present study relate to such aspects of management are discussed briefly in section 6.5.

6.1 Faecal Analysis.

This technique has been used to study the dietary botanical composition of a wide variety of animal species ranging from slugs (Pallant 1969) to waterfowl (Owen 1975) It has frequently been applied to the study of ungulates grazing rangelands in the United States, and many habitat types in Europe (e.g. Hansen & Reid 1975, Taylor & Kothman 1990, Maisels 1988). Despite its repeated use there has been only limited standardisation of methods and the reported precision, especially the degree to which plant species can be identified, varies considerably between researchers. Alongside these issues there remains controversy over the ability of the technique to reflect herbivore diets both quantitatively and, to a much lesser extent, qualitatively (reviewed in Chapter 2). It was beyond the scope of the present study to fully evaluate the technique, but a training period was necessary before dealing with the large number of faecal samples, and a limited number of tests were carried out mainly to gain experience in preparing and enumerating samples.

Several different enumeration and calculation procedures were tested on simple hand compounded mixtures that had been milled and macerated to simulate digestion. Although the number and size of samples was small due to time constraints, there appeared to be little variation in the precision offered by different procedures, actual and estimated compositions correlated well. These results are in agreement with Sparks & Malechek (1968) also working with hand compounded mixtures. Recently, microhistological analysis has been evaluated using known diet mixtures fed to goats and other ruminants (Alipayo *et al.* 1992). Diets of goats were accurately estimated from faecal samples and they attributed this to the systematic training of observers and the use of actively growing plants with a high proportion of epidermal material. Other workers that have had less success (e.g. Slater & Jones 1971, Vavra *et al.* 1978) have suggested that differential digestion and loss of cuticle from delicate herbs caused overestimation of more fibrous plant groups. Such problems are more likely to occur in goats where the diet often contains a mixture of woody browse and forbs. More seriously, it has been suggested that there are associative effects in the gut, and that the degree of differential digestion may vary depending on the particular mixture and proportion of dietary components. In that case development of correction factors to deal with all possible circumstances would be problematic. Until further work is carried out using a wide variety of component species in more complex mixtures similar to those found in natural diets the question of how quantitative faecal analysis can be (and whether correction factors are needed) will remain open.

The advantages of faecal analysis over other diet analysis techniques such as oesophageal or rumen fistulation are that collection of faeces is far cheaper, less disruptive to the animals and, in theory, there are fewer restrictions on the number of samples that can be examined. In this study, attempts were made to collect faeces from as many individuals as possible at both sites but the number of females was limited either due to the small herd size in Cwm Ffynnon or previous culling at the Padarn. Although variation between individual goats appeared small, the number of samples collected each month was lower than preferred and would have been increased if a larger group could have been located. Collection of samples more frequently would have been difficult as location of faeces from identified individuals in mixed-sex groups was very time consuming. Unexpectedly, the herd in Cwm Ffynnon did not segregate into single-sex groups which would have made faecal collection much easier.

The theoretical sample size required for estimating various components of a mixture within certain confidence limits was estimated by assuming that such data would be binomially distributed. Following this assumption a component of 40 % should be estimated to within + 10 % (of that component) at the 90 % confidence interval by examining approximately 400 fragments. Strictly speaking such compositional data may follow a multinomial distribution (Angers 1974) which would require larger sample sizes, but in practice the optimum may be affected by other factors such as observer fatigue (Stevens 1977). A minimum of 400 fragments per month from each sex were identified for the Padarn site and between 457 and 1065 for Cwm Ffynnon. With experience, the time required to accurately identify such large numbers of fragments can be reduced, but this remains a major disadvantage of the technique.

At the outset, difficulties were experienced in identifying certain plant species from their microscopic cuticle/epidermal fragments, and this is an aspect of faecal analysis which has rarely been addressed. Many workers have stressed the need for a training period so that operator error due to observers mis-identifying fragments is reduced (e.g. Holechek & Gross 1982a, Free *et al.* 1970) but information on plant cuticle anatomy is widely dispersed or lacking for many British species, especially dicotyledonous plants. It is known that epidermal anatomy varies not only on different parts of the same plant, but at different seasons and phenological stages and in plants from different locations due to local soil or climatic conditions (Putman *pers comm*.). For these reasons it is important to develop a collection of cuticle reference material containing as many potential dietary constituents as possible, preferably collected from the study area over several seasons. The determination of suitable distinguishing features is also a lengthy process and few authors have published details of how identifications have been made.

The construction of dichotomous keys to aid identification of epidermal fragments was found to be useful in recognising features that could distinguish different plant groups and indicating areas where problems might occur. Following this, an identification test was carried out which showed that certain plant types (especially sedges and ferns) could only be distinguished to species level with difficulty. Such tests can identify the broad diet categories which can be used to minimise mis-identification errors. In other studies such tests have been used to develop correction factors to overcome the problem of some species/taxa being easier to identify than others (Havstad & Donart 1978). Knowledge of the degree of variability in cuticle anatomy and the standardisation of identification methods would shed light on the reliability of faecal analysis and greatly reduce preparation time.

6.2 Group structure, seasonal and 12-month ranges.

Seasonal variations in group size and spatial segregation of the sexes is a common phenomena for many species of ungulate (Geist 1971, Shank 1982), including goats (Munton 1975, Riney & Caughley 1959, O'Brien 1988). This has been viewed as a method of reducing intra-specific competition both between individuals and between the sexes. The basic pattern for seasonal changes in group size and structure for goats is for group size first to decrease in late winter/early spring as pregnant females disperse and become solitary prior to parturition (Rudge 1970). As spring and summer progress, group size tends to increase as association between females renews and males may or may not rejoin the group. By late summer and autumn large mixed-sex groups occur due to the return of related males and itinerants from other areas during the rutting period (Brown 1983, McDougall 1975, Hellawell 1991). Following the rut, which can continue through to early winter, there is a tendency for males and females to form separate herds often feeding in different habitats (Riney & Caughley 1959, Munton 1975, McDougall 1975).

This seasonal pattern of dispersal and re-association was not observed in Cwm Ffynnon but was seen to a greater extent at the Padarn. In Cwm Ffynnon, solitary females were observed in February and March but mixed-sex groups were also seen in these and every other month. This group was much smaller than at the Padarn (9 adults in the main group compared to 29 at the Padarn) and although three kids were seen in March they were not seen again and are assumed to have died in March or early April. The reasons for the loss of these kids is not known, Bullock (1991) considered starvation-related hypothermia to be a likely cause of kid mortality although predation (possibly by foxes) is also a possibility. Weather conditions following kidding though rather wet and windy, were not unusually severe. Hellawell (1991) observed the productivity of goats to be lower at higher altitudes and related this to both increased kid mortality and reduced fecundity. The survival rate of kids was related to the quality of forage available, the severity of weather and the amount of shelter. The mean kidding altitude in Cwm Ffynnon is approximately 450 m, comparable with the highest site studied in the Rhinogau (440 m) which had a kid mortality rate of at least 67 %. Crook (1969) estimated similar numbers of goats in the Cwm Ffynnon area in 1968 and the static population size and high kid mortality rate would suggest that conditions for goats in Cwm Ffynnon are not ideal.

Typically, male goats occupy larger ranges which overlap with the females' (Yocom 1967, O'Brien 1988) and this was seen to be the case for the Padarn group. In Cwm Ffynnon little segregation of the sexes was seen and consequently male and female ranges overlapped considerably. Whilst there may be advantages for the sexes to segregate to reduce competition, not all individuals disperse and there would also appear to be some advantage to remaining in small groups. Clutton-Brock *et al.* (1982a) suggest that grouping is an adaptation against predation as an individual need spend less time alert when in a group than when alone. Behavioural factors may also play a part, Thirgood (1990, quoted in Putman *et al.* 1993) found that for fallow deer the degree of sexual segregation was related to the density of males in the population, being greater where male density was high. In Cwm Ffynnon it is possible that due to the small number of goats concerned, the benefits gained by remaining in a group outweighed those of dispersal and hence no segregation of the sexes took place.

At the Padarn site, mixed-sex groups were seen after kidding in early spring. These groups separated for the summer months, reforming in autumn before splitting again into single-sex groups over the winter. This pattern was complicated by the presence of one female which kidded in August and whose pattern of social behaviour was out of synchrony with other females. The degree of dispersion and size of groups each month was difficult to estimate as not all individuals were located and hence their associations are not known. Seven kids including two sets of twins were observed with five adult females in March 1990 and all survived to the end of the study. The sixth female also gave birth to twins in August but one was still-born. At least one other set of twins was born after the end of the study period in March 1991. Such a high level of productivity is consistent with observations in the Rhinogau (Hellawell 1991) where twin survival was only recorded for the lower hefts where shelter was abundant and food quality highest. It is interesting to note that at several of the Rhinogau sites the incidence of twinning increased following a reduction of numbers by culling. The number of goats in the Padarn group were reduced in 1990 by the removal of 22 individuals from approximately 50 adults. The consequent high level of productivity may therefore be a response to the relatively greater food resources available following a reduction of competition.

Spatial segregation of the sexes has been recorded for many species of ungulate including: Red Deer (Clutton-Brock *et al.* 1982b, Watson & Staines 1978); Fallow Deer (Putman *et al.* 1993, Kerridge & Bullock 1991); White-tailed Deer (Beier 1987, McCullough 1985); Chamois (Shank 1985); Bighorn Sheep (Geist & Petocz 1977); and Goats (e.g. O'Brien 1988, Riney & Caughley 1959, Munton 1975). Various hypotheses have been put forward to account for such behaviour. Geist & Petocz (1977) initially suggested that males should avoid areas preferred by females in order to reduce the amount of competition indirectly imposed on their offspring which the females are carrying. However this would not explain why males which have not bred would find any advantage from avoiding those preferred areas. Recent studies have suggested that in sexually dimorphic species choice of different habitats may be due to the exclusion of males from particular habitats due to morphometric and digestive limitations (Illius & Gordon 1987, 1990).

For both sheep and goats the basic social unit is the female and her most recent offspring (Arnold & Dudzinski 1978) and female herds tend to be more sedentary and demonstrate fidelity to home ranges over consecutive years. Female kids which remain with their mother are presumed to learn their home range from her (O'Brien 1984). Male kids usually join up with other adult males gaining knowledge of both the matrilineal range and the larger range of the males (Munton 1975). Males are known to range widely, especially during the rut (Brown

1983), and for the Padarn group this was particularly obvious, with males moving several kilometres across the valley to join oestrous females during the rut. The effect of these movements was to double the estimated male range size from approximately 3.07 km^{-2} to 6.18 km^{-2}. Female range during the study period was estimated at 1.32 km^{-2}, somewhat smaller than both male and female ranges in Cwm Ffynnon (1.94 km^{-2} and 2.02 km^{-2} respectively).

The size and shape of an animals range is related to the distribution of various requirements for the animals existence (Riney & Caughley 1959) and may also be associated with the degree of "patchiness", particularly of food supplies and shelter (Clutton-Brock *et al.* 1982a). On Rhum, Boyd (1981) found that areas of high quality forage close to shelter caves resulted in small home ranges whilst range sizes in the Southern Uplands (Bullock 1982), where forage quality was poorer and shelter more scattered, were considerably larger . Range size is frequently related to population size but although larger herds tend to have larger ranges, these areas may not increase in proportion and population density may also be high (MacDonald 1987). A relationship between population density and range quality has been observed for other ungulate species (e.g. Hunter 1962, Clutton-Brock *et al.* 1982a) and has also been noted for feral goats (Brown 1983, Hellawell 1991). In this study, overall range size was larger for the more numerous Padarn group and smaller in Cwm Ffynnon where both overall numbers and population density were lower. However, female range at the Padarn site was smaller than in Cwm Ffynnon even though there were more females in the group. This may reflect a greater abundance of high quality forage and shelter at the wooded lowland site or may be related to the lack of kids in Cwm Ffynnon: Munton (1975) observed that mothering females had smaller ranges than females without kids.

Observations of goat range were collected opportunistically and were rather limited in number. A fuller description of true home range would require observations for several years, preferably over the life-span of the animals in question. Seasonal and daily variations in feral goat range have been reported elsewhere (e.g. Riney & Caughley 1959, Gordon 1989, Munton 1975). Daily variations in ranges have been associated with such environmental variables as minimum daily temperature and number of days since rain (O'Brien 1984), wind strength and direction (Hellawell 1991) and added to these, there may be a degree of random movement when other conditions have little effect (Arnold & Dudzinski 1978). Seasonal changes in range may be similarly related to meteorological conditions. An extension of the range to include areas of higher altitude in the summer months and lower areas in winter has frequently been observed and was noted in both Cwm Ffynnon and the Padarn. Seasonal changes in range due to the preference for different vegetation communities has also been observed in many species, including goats (e.g. Bell 1970, Gordon 1989, McCullough *et al.* 1989) and is discussed in section 6.3.

6.3 Habitat utilisation.

In this study, observations of goat group location were recorded during faecal collections each month. These were plotted onto vegetation maps divided into simple vegetation categories for comparison with faecal composition data. Direct comparison with the results of faecal analysis are difficult however, due to the presence of some species in several habitat categories and the fact that faecal composition may relate to the diet ingested perhaps 30 hours or more before collection (Castle 1956).

In Cwm Ffynnon most of the range consisted of dry Calluna heath (approximately 32 %), species-poor Nardus grassland (27 %) and areas of bracken (19 %). However, over 60 % of observations were made on the "Heather" category and it was utilised to some extent in every month. This category covers the central section of the cwm and due to the height of the vegetation and presence of boulders, caves and gullies, it is probably the most sheltered part of the range. On several occasions, goats continued to feed by sheltering from rain and wind in heather-filled gullies and during spells of hot weather they often settled almost out of sight in deep Calluna to ruminate.

"Nardus" grassland covered approximately 27 % of the range but was avoided overall and goats were only observed on this category in two months (September and December). On both occasions, movements onto these areas may have been partly linked to the presence of oestrous females from other groups. This may also apply to use of the "Bilberry" category which occurred only in December when the herd moved out of the cwm towards another group. "Nardus" covers the more open upper and western slopes which are exposed to the prevailing winds, but even in fine weather goats tended to avoid these areas. In contrast, sheep appeared to graze "Nardus" areas in preference to the deep heather in the centre of the cwm. Several studies have noted an increased utilisation of grassland habitats by goats in the summer months even in the presence of sheep (e.g. Bullock 1982, Hellawell 1991). Crook (1969) mentioned that the lack of shelter and the reduced amount of vegetation on open slopes following grazing by sheep may reduce the value of such habitats to goats, especially in winter. As few sheep grazed the central part of Cwm Ffynnon, it is possible that the goats were able to maintain a sufficiently high proportion of monocotyledons in their diet by feeding on grasses and sedges growing amongst the rather heterogeneous "Heather" community.

"Bracken" and "Mire" communities are found at the base of the cwm around the shores of Llyn Ffynnon. These communities were generally avoided but were used to varying degrees mainly in the spring and early summer. One female was observed kidding in a "Bracken" area in March and it is possible that other goats also used these lower altitude communities during poor weather and/or to feed on the fresh growth of grasses and sedges early in the year.

Similarity in habitat utilisation between the sexes was very high (more than 90 %) throughout the year, except in March, due to the greater utilisation of "Bracken" by females. This situation might have been different had the group been larger (making dispersal more likely) or if the kids had survived into the summer months.

At the Padarn site, due to the more complex topography and greater dispersal of the male goats, many distinct habitat types were available within the range. "Deciduous Woodland" and "Quarry Spoil" covered approximately 62 % of the entire range and almost 80 % of all observations were recorded in these habitats. Goats in the Padarn area divided into many small groups, each group often using several different habitats to various extents each month. Consequently any seasonal patterns in habitat utilisation are rather complicated but a few generalisations may be made:

Goats of both sex strongly selected "Deciduous Woodland" throughout the year except in June and September when areas of "Quarry", "Heath" or "Nardus" were used, and in February when all the females seen were using isolated ledges of "Heath" in the Dinorwic Quarry. Sufficient forage is probably available in the woodland areas all year round and movements away may be at least partly explained by social or behavioural factors. Thus, ledges of "Heath" may have been selected in February by females prior to kidding for their isolation rather than the food available. Similarly, selection of a heavily grazed "Nardus" community by males in September occurred because several oestrous females were located there and almost certainly not for dietary reasons. The use of "Quarry" and "Reclaim" areas, especially by females in spring and summer, is less easy to explain but it may be that the need to satisfy certain dietary requirements is partly responsible: Most feeding observations in these "Quarry" areas were made as goats moved away from overnight resting sites, but in the summer months, females were seen in these areas for long periods and were observed eating annual grasses and herbs, potentially a higher quality forage than that available in the woodland in the same period. Faecal analysis shows a higher proportion of herbs, and lower levels of tree leaves, in the female diet compared to the males during this period, but whether selection of such habitats reflects differing nutritional demands is difficult to say without a comparison of the quality and availability of the different forages.

Differences in habitat utilisation between the sexes were highly variable over the year but followed a broadly similar pattern to faecal composition. Discrepancies between the two may reflect the ability of the sexes to eat different foods in the same habitats or to maintain similar diets whilst in different habitats by feeding on the more ubiquitous plant groups. Potential competition between the sexes can be reduced by using different areas, by selecting different diets or, as was the case in February, by doing both. Competition is likely to be highest when resources are least abundant and animal requirements are highest. For females this is likely to be in the last third of pregnancy and during lactation (Clutton-Brock *et al.* 1982c), that is, in late winter and early spring before abundant vegetation growth has taken place. It is interesting to note that at both Padarn and Cwm Ffynnon, this appeared to be the case, the greatest differences in diet and habitat utilisation between the sexes occurring during the kidding periods. However, at neither site were these differences maintained. In Cwm Ffynnon, female dietary needs may have been similar to the males following the loss of the kids and an end to lactation. For the Padarn group this was not the case, but it is possible that forage was sufficiently abundant later in the year that significant partitioning of resources was neither brought about nor essential. On the other hand, larger differences in overall diet and habitat utilisation were observed in the Padarn area than in Cwm Ffynnon. This is probably due to the wider variety of suitable habitats available to the Padarn group, the more extensive movements of the males and the greater sexual segregation.

Habitat selection and diet choice are interdependent and difficult to separate even in relatively simple ecological situations. Observations over a much longer time period would be required to show any consistent seasonal preferences in habitat use and its relationship to diet. Goat distribution did not appear to be explicable solely in terms of dietary requirements and at both sites could be related to other, sometimes rather unpredictable, ecological variables such as local meteorological conditions or social behaviour.

Many studies of large herbivores in a variety of environments have shown predictable seasonal patterns in the utilisation of different habitats or plant communities (e.g. Bell 1970, Gwynne & Bell 1968, Gordon 1989). Differential habitat use by the sexes has also been observed for many species (see section 6.2) and is often associated with sexual dimorphism. Clutton-Brock & Harvey (1983) considered that large animals would be unable to maintain adequate food intake on short swards which would easily support smaller ones. This assumes that bite size (and hence intake rate) is at least partly determined by incisor arcade breadth and that an allometric relationship exists between body weight and bite size such that incisor breadth scales at weight W0.33 (Illius & Gordon 1987). As a consequence of this, larger males might be excluded from swards preferred by females and a weight difference of as little as 20 % between males and females could bring this about (Illius & Gordon 1987). An additional explanation for differential habitat use is the Jarman-Bell principle (Geist 1974) which predicts that the daily energy and protein requirements of mammals are a function of body weight raised to the power 0.75. Thus there is an overall increased food requirement but relatively lower metabolic demands accompanying increased body size. The high metabolism of small animals can only be sustained by a highly digestible diet rich in energy and protein. In sexually dimorphic ungulate species, the larger males may be obliged to shift their foraging style towards bulk rather than concentrate feeding and can tolerate more fibrous diets provided such foods are in large supply (Demment & Van Soest 1985). On Rhum, Gordon & Illius (1989) examined resource partitioning between several ungulate species and concluded that the larger species or sexes were at a disadvantage when feeding on shorter swards and may be competitively excluded. Pronounced sex differences in habitat use have been well documented for Red deer where choice of feeding areas have been related to the underlying geology and vegetation quality (Charles *et al.* 1977, Watson & Staines 1978, Staines *et al.* 1982). Resource partitioning between the sexes can occur by geographical separation, but may also be achieved at a much finer level by the selection of different plants or plant parts in the same area. Putman *et al.* (1993) found that dietary differences existed between male and female Fallow deer even when living sympatrically. Gordon (1989) showed that for goats on Rhum, although ranges were limited by the need for shelter, spatial segregation of the sexes did occur, and males used poorer quality, oligotrophic vegetation communities to a greater extent than females.

If such hypotheses are valid, one might expect some form of resource partitioning between male and female goats to occur, either by spatial segregation, and/or differences in diet associated with dimorphism in body size. Differences in habitat selection and dietary quality have been observed in strongly dimorphic ungulates (Staines *et al.* 1982, Gordon 1989, Clutton-Brock *et al.* 1987, Kerridge & Bullock 1991, Putman *et al.* 1993) but there have been few studies dealing with feral goats. Data from Brown (1977), Hellawell (1991) and Bullock (1991) for British feral goats suggest that the body weight ratio (Females:Males) lies between 1:1.08 and 1:1.44, compared to approximately 1:1.5 for Red deer (Illius & Gordon 1987) and 1:1.6 for Fallow deer (Putman *et al.* 1993). Unfortunately, weight data were not available for goats in this study, however, visual estimation suggested that the sexes in Cwm Ffynnon were similar in body weight, perhaps closer to the 1:1.08 ratio for goats in the Rhinogau. Males (which included hummels) in the Padarn group appeared heavier and in better condition than those in both Cwm Ffynnon or the Rhinogau, also the average female age was lower than the males so that the body weight ratio was probably considerably higher, perhaps more than 1:1.4.

Results in this study are compatible with such models of foraging strategy, differential habitat use was least obvious in Cwm Ffynnon where the two sexes were similar in size and possibly had similar dietary requirements, especially following death of the kids. At the Padarn site where males appeared much heavier than the females, and all kids survived, there was a greater degree of separation of the sexes in both habitat usage and diet. There is also limited evidence to suggest that males selected areas where biomass, and not necessarily food quality, was higher: Females grazed more in the "Quarry" habitat feeding on scattered herbs and sparse annual grasses whilst the males used the woodland areas to a greater extent, browsing on the abundant growth of tree leaves. Possibly males found it difficult to obtain sufficient quantities of forage in the "Quarry" areas and preferred to feed in the woodland where larger quantities of forage was available.

6.4 Faecal composition.

Recently, there have been several longer-term studies looking at the dietary composition of goats on upland sites in Britain, but direct comparisons between these studies are hazardous as different environmental conditions and plant availabilities tend to make results very site-specific. There have been fewer studies in Britain where goats made appreciable use of woodland. Most research has shown large seasonal variations in the diets of goats and these are very obvious at both Cwm Ffynnon and Padarn sites. Goats have been variously described as grazers (Malechek & Leinweber 1972), opportunistic generalists (Coblentz 1977), browsers (Van Dyne *et al.* 1980) or intermediate feeders (Van Soest 1982, Pfister & Malechek 1986). In this study, goats behaved both as grazers (in Cwm Ffynnon) and browsers (Padarn) during certain periods of the year, confirming their versatility and ability to adapt their diets to different conditions.

In Cwm Ffynnon, overall faecal composition was similar to goat diets observed in other areas of upland heath: monocotyledons formed approximately 50 % of the diet, dwarf shrubs approximately 40 % and ferns, herbs and bryophytes made up the remainder. However, within this basic dietary profile monthly variations in the diet were noted, and these did not always accord with those seen at other sites. The proportion of grass species in the faeces fell dramatically in the summer months whereas in most other comparable studies a considerable increase has been recorded. This pattern is partly due to grasses forming a large proportion of the diet in spring which were then replaced by sedge species in the summer months. Selection of sedges in early summer coincided with their flowering and peak nutritional value (Grant & Campbell 1978), and the use of "Mire" habitat, where *Carex* and *Eriophorum* species are abundant. High levels of grass in the diet in March and April are surprising as the most frequent species identified during this period was *Nardus stricta* which was available only as dry leaves and stems and no fresh growth was visible in any of the grasses so early in the year.

Many other similar studies have described an increased use of ericaceous shrubs during the winter months and much lower levels during the summer (e.g. Bullock 1985, Hellawell 1991). This was true to a small extent for males in Cwm Ffynnon but not for the females, and for both sexes the levels of "Heather" generally remained high (approximately 30 %) throughout the year. Utilisation during the summer coincides with the growth of new shoots and higher nutritional values of *Calluna vulgaris* (Trinder 1975), but presumably, in other studies, more preferred species such as grasses replace heather in this season. As mentioned previously, numbers of sheep grazed the open grassland community in the summer months and appeared to avoid the deep heather in the centre of the cwm. In contrast, the goats avoided the "Nardus" community and remained in the "Heather" area where ericaceous shrubs were the most abundant forage category. For morphological reasons, goats may be at a competitive disadvantage to sheep when feeding on heavily grazed swards. Consequently, goats may have found it difficult to feed on sufficient quantities of grasses, and the more optimal diet strategy may be to feed on the new shoots of heathers and sedges which may be of higher nutritional value and are more abundant.

The remaining diet categories (Bilberry, Ferns, Rushes, Bryophytes and Herbs) were relatively minor components, rarely comprising more than 10 % of the diet in any month. Due to their low levels, apparent seasonal patterns may be misleading. However, the higher utilisation of ferns (mainly *Pteridium aquilinum*) in autumn, and rushes (mainly *Juncus effusus*) in late winter and early spring have been noted elsewhere (Bullock 1982). The proportion of rushes in the diet is lower than in many other studies but apart from *Juncus* *squarrosus*, they did not appear to be abundant in the area and there were no extensive areas of *J.effusus*.

No significant difference in overall diet between males and females was observed but a significant sex*month interaction was recorded for sedges, rushes and ferns. Ferns usage differed between the sexes, being consistently more frequent in the female diet, especially in autumn. Sedges were also utilised more in the autumn by females and rushes were eaten more by males in spring and summer. Habitat utilisation was similar between the sexes except in March, so differences in diet may be due to preferential selection of certain diet categories. Whether such preferences are an attempt to meet different nutritional requirements during particular seasons is difficult to say without more detailed information on feeding behaviour, possible nutritional constraints and relative nutritional values of the available foods. Information on the relative availabilities of all species in relation to dietary composition could indicate to what degree any plant category is selected, rejected, or eaten in similar proportions to its abundance.

Similarities between the sexes in habitat utilisation and faecal composition were at there lowest around the time of kidding in March. Grasses formed a large proportion of the female diet in this month, but in April similar high levels were also seen in males, even though the abundance of grass was apparently unchanged. Thus, males did not appear to be excluded from feeding on grasses in March and diets differed because females preferred to move away from the males into sheltered areas for kidding. In Cwm Ffynnon these areas consisted mainly of "Bracken" and "Mire" habitats where more monocotyledonous species and fewer dwarf shrubs were available. Dietary segregation at such a time may simply be a consequence of the spatial separation of the sexes but this may be an instinctive mechanism for reducing competition between males and females at a time when plant resources are low and nutritional requirements are likely to be high.

No significant differences were found in overall diet composition between six individual goats over seven months, although the differences in the proportion of "Sedges" were significant when separate diet categories were investigated. Individual variation in diet is generally considered to be high (Arnold & Dudzinski 1978), higher in sheep than cattle, and lower when herbage is limited (Van Dyne & Heady 1965). The use of broad diet categories may have masked some differences in individual plant species, but the inability to accurately identify fragments precluded more detailed comparisons. It was only possible to compare a small number of goats in Cwm Ffynnon and these individuals were generally seen grazing together on the same areas of hill. The choice of vegetation available to the Cwm Ffynnon goats is rather limited compared to the Padarn site and hence the opportunity for diversification of the diets may be limited. Individual variations in diet would have been higher for the Padarn group when individuals dispersed onto different habitats but even when feeding together, greater diversity of forage species available would have permitted any individual preferences of goats to be expressed.

The overall dietary profile of goats in the Padarn area was very different to that in Cwm Ffynnon: Browse in the form of tree leaves, ericaceous and other woody shrubs constituted approximately 65 % of the diet, monocotyledons (mainly grasses) formed approximately 18 % and ferns, herbs and bryophytes made up the remaining 17 %. Significant differences in the utilisation of almost all diet categories were recorded between the sexes, and the usage of all categories showed different patterns over time.

A wide variety of vegetation communities were available in the range of the Padarn goats and this was reflected in the additional diet categories such as "Tree leaves", "Holly/Ivy" and "Miscellaneous shrubs" not available to the goats in Cwm Ffynnon. Similarly, many more plant species were available to the Padarn goats, over fifty species were identified in the faeces and it is likely that the many more than this were consumed over the year.

The most notable feature of the diet of the Padarn goats after its variety is the large proportion of tree browse (approximately 20 % of the overall diet in females and 25 % in males) which remained a major component from spring through to late autumn. The utilisation of tree browse was highly seasonal, reaching a peak in the summer months coinciding with peak abundance, but even in the winter months some tree leaves were identified, presumably eaten as fallen leaf litter. Although goats were observed feeding on most of the deciduous tree species present, the identification of cuticle fragments to species level was very difficult except in the case of oak (*Quercus petraea*). Approximately 14 % of "Tree" fragments were classified as oak but the composition of the remainder is not known. Variations in the relative percentage of oak within the "Tree" category were observed, this may indicate differing degrees of selection between species which flushed at different times or relate to later 'lammas' growth. Alternatively, it may be a reflection of changes in the identifiability of oak cuticles as leaves senesced.

Many studies have documented feeding by goats on various tannin-rich Quercus spp. browse (e.g. Nastis & Malechek 1981, Villena & Pfister 1990, Cuartas & Garcia-Gonzalez 1992, Papachristou & Nastis 1993). Most tree leaves and particularly oak, contain high levels of secondary metabolites including tannins, which are thought to inhibit digestion by binding to digestive enzymes and dietary protein (Robbins *et al.* 1987a). Recently, attention has been given to the role of these toxic compounds in defining what is an 'optimum' diet and it has been argued that avoiding excessive intake of toxins may be just as important to herbivores as maximising energy or nutrient intake (Westoby 1974).

The ability to deal with diets containing high levels of tannins has been linked to rapid rates of passage through the gut and increased salivary proline content (Robbins *et al.* 1987b, Hume 1989). There is evidence that the rate of passage in goats is relatively rapid (Castle 1956), closer to that in browsing deer than in grazers such as sheep or cattle (McCammon-Feldman *et al.* 1981), and saliva production is greater than in sheep (Devendra 1978, Domingue *et al.* 1991a). Compared to sheep, goats may be better at digesting fibre, especially lignin (Domingue *et al.* 1991b) and hence are able to include in the diet often large quantities of material which would be classified as low quality forage for other animals. Other facilities which allow goats to exploit tree browse are their agility and willingness to climb or stretch upward on their hind legs; a prehensile tongue; narrow mouth and mobile upper lip (McCammom-Feldman *et al.* 1981), all of which allows greater selectivity within the array of available vegetation.

Utilisation of monocotyledons (mainly grasses) showed a distinct reduction in the summer months, coinciding with higher levels of tree browse in the diet. A peak utilisation of various grass species for both sexes in April corresponded with the period of fresh growth, but selection away from monocotyledons to browse occurred shortly after the opening of new tree leaves in April-May. There was little competition for grasses, with very few sheep grazing within the goats' range at this time, and grasses appeared plentiful throughout the summer but were not eaten in large quantities again until autumn. Maximum monocotyledon utilisation occurred for males in September when they moved onto an area of upland heath and "Nardus' grassland. In females, use of monocotyledons was variable, being low in November and December when they were observed only in the woodland areas, but higher in October and January when they were seen feeding in the "Quarry" areas.

McCammon-Feldman *et al.* (1981) concluded that the nutritive strategy of goats appears to be to select grasses when their protein contents are high, but to switch to browse when their overall-nutritive value may be higher. This may explain the dietary pattern recorded in the Padarn, but information on the relative nutritive values of the browse and graze species through the seasons is unavailable. It is known that the levels of secondary metabolites may vary considerably in leaves and twigs as they mature but the data on the timing of peak tannin levels in oak is conflicting (Nastis & Malechek 1981). Goats have been shown to be highly sensitive to bitter-tasting substances, and Provenza & Malechek (1984) showed that goats avoided foods with high tannin contents when given suitable alternatives. It is possible that goats are extremely selective in their choice of browse, not only at the species level but in the choice of material within individual plants, enabling them to minimise their intake of tannins, and maximise the digestive value of their diet. Goats continued to feed on tree browse over the summer period even though apparently high quality grasses were available and in this instance might be classified as animals which prefer to browse but are able to graze when necessary.

Although tree browse was an important component of both male and female diets, ericaceous shrubs ("Heather") formed the single largest category in females and was especially important to females in winter. Males at this time appeared to feed instead on bramble and holly or ivy. All these plant groups are available throughout the year but were only used to any great extent in January and February by the males. Similar seasonal utilisation of bramble and ivy has been observed in Red deer and Roe deer feeding in broadleaved woodlands (Hosey 1981, Hearney & Jennings 1983). Putman *et al.* (1987) showed that free-ranging ponies also showed marked seasonal changes in diet, with increased exploitation of gorse and holly in winter when grasses were scarce. In the Padarn group, the use of evergreen woody shrubs (heathers, bramble, and holly/ivy combined) shows a similar pattern in males and females: peaking in the winter months and declining in summer. These shrubs may play similar roles in the diet and be interchangeable. The inclusion of particular species seemed to relate to their availability and not necessarily a dietary preference: In winter, females used areas in the quarry where heathers were abundant but holly, ivy and bramble were absent or rare, whilst males used woodland and overgrown farmland where bramble and ivy were plentiful.

One exception to this pattern of shrub utilisation was gorse, which formed approximately 30 % of the female diet in June and was little used during the rest of the year. Both sexes were seen feeding as a mixed herd in this month but very little (<5 %) gorse was recorded in the males' faeces, suggesting that females were preferentially feeding on gorse in this month. Alternatively, the two sexes may have fed in different areas during the period before faecal collection, and faecal composition was representing foods ingested from different sites.

The presence of ferns in the diet showed a distinct seasonal pattern, with considerably higher levels in both sexes in November. Increased use of bracken was also seen in Cwm Ffynnon in late autumn and winter and consumption of ferns seems to be related to their stage of maturity and relative toxicity (Cooper-Driver *et al.* 1977). Ferns consistently formed a larger proportion of the Padarn males' diet over several months, suggesting that they were less averse to feeding on this category of plants. However, this situation was reversed in Cwm Ffynnon, though the particular species of fern eaten at each site may have been different.

A wide variety of herb species was available in the Padarn range and they apparently formed a more important component of the diet than in Cwm Ffynnon. At both sites, herb usage peaked in the summer months coinciding with maximum growth and flowering. Herbs may form a much higher percentage of the diet than recorded by faecal analysis due to loss of the more delicate material during digestion. Goats were observed feeding on the flowers of foxglove (*Digitalis purpurea*) but little evidence of this was seen in the faeces. Pfister & Malechek (1986) note that fruits and flowers can be highly nutritious additions to goat diets even when present in relatively small proportions. Thus, their contribution to the diet may be much higher than their levels might suggest.

As in Cwm Ffynnon, bryophytes appeared to form only a small part of the diet and their consumption may be incidental, linked to grazing on short grass swards (as in males in September) or to feeding on tree bark.

A higher percentage of material in the faeces was unidentifiable in the faecal samples from the Padarn site (approximately 43 %). Much of this material was fibrous in nature and may have derived from tree bark which goats were seen to feed on. Casual observations suggested that both males and females were involved in bark-stripping in most months and such material may have formed a substantial part of the diet on occasions. Another potential dietary item was tree mast, particularly acorns. These were not identified in the diet, but may also have been an important component of the diet not revealed by faecal analysis. Goats in the Padarn woodland were observed feeding in leaf litter in the autumn and winter months and acorns may be important to the diet during this period.

Significant differences were found in overall faecal composition between males and females and between months. All major dietary categories also showed variation between the sexes and between months. Seasonal variations in diet are, perhaps, to be expected, reflecting changes in the availability of particular plant categories over the seasons, and segregation of the sexes onto different habitats. Few studies have distinguished between the diets of male and female goats, although Gordon (1989) showed significant differences in vegetation community use which probably resulted in different diets. The results from the Padarn site are in contrast to a study in the Rhinogau (Hellawell 1991) where no significant differences were found in habitat selection between the sexes or in faecal composition from separate-sex groups feeding on similar habitats in February, April, July and November.

Faecal and rumen analyses have been used to study dietary quality (nitrogen content) and/or botanical composition in several species of deer (Staines *et al.* 1982, Beier 1987, Kerridge & Bullock 1991, Putman *et al.* 1993) and all found significant differences between the sexes. Female Red deer (*Cervus elaphus*) appear to select higher quality diets than males in autumn and winter, Fallow deer (*Dama dam*a) females had the highest quality diets in spring and summer and female white-tailed deer (*Odocoileus virginianus*) maintained higher diet quality than males all year round. From the information on botanical faecal composition in the present study, female goats in the Padarn group appeared to have a low quality diet in winter (when they appeared to feed mainly on heather and grasses), and an improved diet in spring and summer (when they fed on early-growing grasses, tree browse, herbs and gorse). Males concentrated on tree browse and ferns during the summer but moved onto poor quality *Nardus stricta* for a period in September during the rut. In winter, males utilised bramble and holly/ivy to a much greater extent than females. These may represent a higher quality diet than heather and grasses during this period but information on their overall digestibility taking into account the presence of inhibitory toxins is lacking. A longer term study which used chemical analyses of diet quality would be more suitable to confirm such a pattern. Crude protein content of faeces can be a good indicator of diet quality in ruminants (Jarrige 1965, Putman 1984), although it may be less accurate when high levels of soluble phenolic compounds (tannins) are present (Wofford *et al.* 1985) which is likely to be the case considering the high levels of browse in goat diets.

Such a description of presumed diet quality is, of course very crude, as botanical faecal analysis does not provide any information on the quantities of food ingested or the nutritional status and metabolic requirements of the goats. Appetite, and the intake of food is known to vary with season, state of pregnancy (Van Dyne *et al.* 1980) and during the rut (Clutton-Brock et al 1982a). Animals may also compensate for the reduced availability of forage in lean periods by feeding less and relying on fat reserves built up during the summer. Consequently, lower nutritional demands may be met by what are apparently poor quality foods.

In sexually dimorphic ungulates, larger males are likely to have higher maintenance requirements than females but comparisons of nutritional requirements are complicated by differences in the extent and timing of the costs of reproduction (Clutton-Brock *et al.* 1982a). In Red deer stags, (and presumably also in male feral goats), the costs of rutting are high (Anderson 1976) and to survive through the winter it would be an advantage to replace depleted fat reserves quickly in autumn and early winter. Bullock (1982) felt that goats in the Southern Uplands would be under the greatest dietary competition in autumn, when forage quality and quantity is declining and goats are attempting to build up their fat reserves. In winter, competition may be lower than expected as animals can utilise these fat reserves instead of the scarce and poor quality forage. In the Padarn group, males used the same habitats and had similar diet compositions to females immediately following the rut, though the diets diverged considerably in January. The milder climate, longer growing season and more abundant forage at the Padarn site may mean that competition in autumn is less critical than in the Southern Uplands and may only be important for a short period in late winter.

For females, nutritional requirements are probably highest from late pregnancy to peak lactation (Moen 1973). The diet of the Padarn females appeared to consist mainly of old heather and grasses in late pregnancy but improved with the growth of early grasses from March onwards. Similarity between male and female diets fell to its lowest in January and February, partly due to the separation of the females from the rest of the group and use of different habitats. Selection of ledges in the quarry around the time of kidding may represent a compromise between an instinctive preference for isolation during this period and diet optimisation. Alternatively, these ledges may have provided the best dietary opportunities available to the females within their more restricted range.

Differences in body size between males and females in the Padarn group were conspicuous, and one might predict such dimorphism to lead to different dietary choices. Larger males can compensate for lower quality diets by eating larger amounts, whereas females may need to maintain diet quality by being more selective. Male and female diets did differ over time and overall, females appeared to prefer more monocotyledons and heather and less tree leaves, holly/ivy and ferns than males. Whether such differences are a product of morphometric, physiological, or other differences between the sexes is uncertain. Information on both the chemical composition of the different forage types and the extent they are selected could help to clarify the question.

For goats in both Cwm Ffynnon and Padarn areas, a wide variety of plant species were included in the diet in every month and as more were available, more were eaten. Simple optimal foraging models would predict that foods are selected on the basis that the net rate of energy intake is maximised, foods are ranked, and the most profitable foods always chosen first. Thus, in any given environment an animal should always forage in the same way (Stephens & Krebs 1986). Contrary to this basic theory, the diets of large herbivores are typically composed of many plant species, and include apparently sub-optimal choices (Crawley 1983), goat diet being a good example.

Crawley (1983) gave several reasons why an animal might find it necessary or advantageous to maintain a mixed diet: 1) a preferred food may not be abundant enough to maintain the animal by itself; 2) foods may be so similar in quality that it isn't worth spending effort to be selective; 3) factors other than energy maximisation may be more important, such as the supply of vitamins, minerals or essential amino acids; 4) in a changeable and varied environment, food quality may change rapidly in time and space. As the nutritional value of one plant rises, or its toxicity falls, it may then become the preferred species, it may be necessary to ingest such vegetation in order to track these changes; 5) Some plants may be nutritious but toxic if eaten at high doses, whereas small quantities of several different plants may be eaten safely; 6) foods may be so similar in quality that the animal isn't able or doesn't need to choose between them.

In addition, there may be synergistic, associative effects of feeding on a mixed diet such that the digestibility of one food is improved when present in the rumen with another, hence increasing overall dietary quality. Baker & Hobbs (1987) found that increased levels of browse in the diet prolonged the retention time of grass which resulted in higher fibre digestion in the grass component.

All these factors may partly explain the maintenance of highly varied diets by goats in Both Cwm Ffynnon and Padarn areas. Westoby (1978) considered that sampling of the vegetation to keep up with seasonal changes in nutritional value is the best explanation for varied diets. However, although strong selectivity for certain habitats was observed, the degree of selection for particular components of the diet was not measured: Faecal analysis may not be the most appropriate technique to compare the diet selected and the diet available, especially considering the long period between ingestion of foods and their excretion (Norbury & Sanson 1992).

Goats are considered to be selective feeders (Malechek & Leinweber 1972, Wilson *et al.* 1975, McCammon-Feldman *et al.* 1981), and their unique morphological, physiological and behavioural traits renders then particularly well adapted to utilizing ephemeral plants in botanically diverse environments (Malechek & Provenza 1983). The results of the present study are in accord with the description of goats as highly opportunistic intermediate feeders which may prefer to browse but are capable of grazing under certain conditions.

6.5 Management implications.

Feral goats have the potential to cause considerable damage to vegetation in fragile environments, and examples of their destructive abilities are numerous (e.g. Sykes 1969, Coblentz 1978, Parkes 1984). In a position statement from the IUCN Caprinae Specialist Group, Rudge (1989) recommended that feral Caprinae should be exterminated unless there are defensible reasons to make an exception. In North Wales, the feral goat has attained a special historical value which may offer some protection in the short term.

Information on dietary composition and habitat utilisation in free-ranging feral goats can prove valuable in understanding their relationship with the environment and lead to more rational management decisions for both wild and domesticated animals. Due to their ability to feed selectively and their willingness to exploit vegetation which other large herbivores avoid, interest has been shown in the use of goats to control unwanted plant species. Feral goats have been successfully used in Britain to remove invading Betula and Salix species on dune slacks (Bullock & Kinnear 1988). They have been used for some time to control scrub (Batten 1979) and gorse (Radcliffe 1986) in New Zealand, and Oakbrush (*Quercus gambelii*) in the United States. Feral goats tend to eat more fibrous material, browse more and graze less than cattle or sheep (Squires 1982, Bullock 1985) and this distinction has been exploited in experiments to modify the floristic composition of hill sheep pastures. Grant *et al.* (1984) found that *Eriophorum vaginatum*, *Calluna vulgaris,* and especially *Juncus effusus* were all grazed to a greater degree by goats than sheep. Studies of mixed stock grazing have shown that herbivores can show complementary diet selection and vegetation can be managed by manipulating the ratios of different herbivores grazing together or by strategic grazing at different times (Harrington 1978, Clark *et al.* 1982, Lippert *et al.* 1987).

In Cwm Ffynnon, feral goats do not appear to be seriously damaging the existing vegetation, though the present plant community may in part be a result of considerably higher goat stocking densities in the past (Roberts 1959). Lippert *et al.* (1984) showed that high goat densities (14.7 ha^{-1}) could be detrimental to heather, especially where it forms only a small percentage of grass-heather mosaics, and in most scrub control projects similarly high (>10 ha^{-1}) stocking levels have been used (Smith & Bullock 1993). The number of goats regularly using Cwm Ffynnon is very low, usually only nine adults, but increasing to approximately thirty during the rut. The goats' range over 12 months covered approximately 2 km^2, leading to a density of between 0.045 to 0.15 goats per hectare, though goats were not evenly distributed over the whole range and selected the "Heather" vegetation class more than the others. Sheep numbers were also low in the goats' range, approximately 100 were counted in June, most grazed on the open "Nardus" areas, and generally less than 25 were seen in the central "Heather" section. Bullock & Grabrovaz (1990) commented that in tall heather, goats tended to show a preference for woody tissue of the previous years growth. this has implications for the regeneration of grazed heather but at such low goat densities in Cwm Ffynnon it is unlikely that any long-term damage is being done, especially as grazing did not appear to be concentrated on any small areas.

At the moment there appears to be a small level of complementary grazing, with goats eating species such as *Pteridium aquilinum*, *Nardus stricta*, and *Juncus effusus* which would otherwise not be grazed by sheep. Unfortunately, faecal analysis cannot provide any information on the actual quantities of material eaten, but it seems unlikely that these species are eaten in sufficient quantities to substantially improve the quality of sheep grazing. Whether an increase in the numbers of domesticated goats would reap any benefits is difficult to predict but may be unlikely: Feral goat numbers in Cwm Ffynnon are comparable with estimates made in 1968 (Crook 1969), and the low reproductive rate observed here and in other high altitude areas suggests that maintaining large numbers of goats on such sites would be difficult without supplementary feeding and the provision of shelter (Hellawell 1991).

Management issues are slightly different in the Padarn area where a considerable part of the goats' range is broadleaved woodland with high conservation status. Ratcliffe (1977) considered the Allt Wen woodland to be important due to its unusual status as ungrazed upland sessile oakwood. Several interesting field communities were noted, including areas of *Luzula sylvatica* and rarer Atlantic ferns and mosses in block screes. At the time of this survey, feral goats did not seem to be making use of the woodland to any degree and are believed to have arrived in the late 1970's.

Large herbivores have been implicated in the lack of natural regeneration in semi-natural woodland (Coed Cymru 1985, Tilghman 1989, Mitchell & Kirby 1990) and concern was raised about the possible effect on regeneration of the Padarn woodland by excessive browsing on seedlings and saplings and the amount of damage goats were inflicting on the trees by bark-stripping. Smith (1989) observed a two metre browse line and extensive patches of bark-stripping and these were equally obvious during the present study. The impact of goats on trees can be divided into three main areas: grazing on seed, seedlings or young saplings; browsing on buds, leaf and twig material of more mature trees; and the stripping of bark. Hellawell (1991) found that whilst sheep had little impact on established Oak and Rowan saplings, goats caused considerable damage, and this could have a major effect on the woodlands age structure. Goats in the Padarn were regularly seen feeding on small saplings, often bending them to the ground in order to feed on the terminal buds and leaves and may have consumed acorns over the winter months.

Tree leaves formed a major component of the diet for the Padarn goats, though this may not always be the case for goats feeding in woodlands and was not observed to any great extent in the Rhinogau (Hellawell 1991). Cuartas & Garcia-Gonzalez (1992) used faecal analysis to study the diet of domestic and wild Caprini feeding on Holm oak (*Quercus ilex*) in Spain. They estimated the effects of browsing and found that domestic herbivores may seriously affect the biomass of *Q.ilex* by the removal of leaf and twig material, altering the growth form of the trees to prostrate cushions. However, the stocking densities of feral goats and sheep involved, were much higher (18.2 km^{-2} and 171.3 km^{-2} respectively) than those recorded in this study (less than 1 km^{-2}) and the same level of damage was not apparent in the Padarn woodland.

Bark-stripping was a conspicuous feature of the behaviour of the Padarn goats and took place in all seasons. Hellawell (1991) noted a preference by goats for certain tree species and girth sizes, and found considerable variation in the amount of bark-stripping between different goat groups. Bark-stripping reduces tree health and may cause death due to fungal infections or by ring-barking. A considerable proportion of trees in the Padarn area were affected, and although certain species, older, or coppiced forms were damaged less, it is likely that the species balance would eventually be modified.

Other plant groups in the woodland which formed large proportions of the diet included bramble, holly/ivy and ferns. Putman *et al.* (1989) found large differences in the herb and shrub layers in mixed woodland following the cessation of grazing by deer and horses. In adjacent grazed areas, unpalatable species such as Hyacinthoides non-scripta, *Oxalis* *acetosella* and *Pteridium aquilinum* remained common, whereas in the ungrazed areas there was an initial increase in the abundance of many shrub species followed by thinning due to shading by regenerating trees. During the period of study, grazing intensity in the Padarn woodland could be described as moderate using the scheme of Mitchell & Kirby (1990), but species which goats feed upon, such as bramble, holly and ivy, may increase in abundance if grazing were ended.

Goats were not observed feeding on the dense areas of *Luzula sylvatica*, and rushes apparently formed only a small part of the diet. Other species of high conservation value such as Atlantic filmy ferns and bryophytes are also unlikely to be affected adversely. There is some evidence that low levels of grazing in woodlands may benefit the conservation of rare bryophyte species (Mitchell & Kirby 1990) by reducing excessive shading by tall vegetation.

Females in the Padarn group showed a high rate of twinning and low kid mortality, giving every indication that the population size would rapidly increase. Several studies have shown that on high quality ranges, goat populations can have high annual growth rates (Watts & Conley 1984, Hellawell 1991). Although the level of grazing was not high during the study period, without intervention it is likely that bark-stripping damage and perhaps further reduction of tree regeneration would occur in a short period of time.

Concern over the possible levels of damage by the goats led to the removal in January 1990 of 22 individuals from an estimated group size of 32. This may have been an underestimate of the original number present, as 20 adults were counted in a single group in February 1991, and during the study 29 adult individuals were identified regularly in the area. There is little evidence of goats making permanent moves from existing hefts to new areas (Bullock 1982) but the question of whether weakly associated males joined the original Padarn group following the cull is an important one. Management of goat populations by the removal of groups to other areas is expensive and time-consuming but which may be more appropriate than other alternatives provided it is successful. At both the Cwm Ffynnon and Padarn sites, goats showed strong selectivity for certain habitats and the possibility exists that a reduction in herbivore numbers would not necessarily affect the utilisation of such regions, but simply lead to the abandonment of poorer, less preferred areas (Crawley 1983).

In October 1992 most of the remaining Padarn group were captured and removed from the site, leaving three adult males, two hummels and one kid remaining of the original group. An adjacent group of goats whose range occasionally overlapped with the main Padarn group during the study have been observed feeding in parts of the Dinorwic quarry since the cull. It would be useful to monitor the range of these and the remaining individuals from the Padarn group, to reveal the long-term effectiveness of removing goats from selected areas in Snowdonia.

Chapter 7. Summary and Conclusions.

7.1 Background

Feral goats have a special place in the culture of North Wales and have become a symbol of the regions mountain wildlife. At times their existence has also been controversial, mainly due to their perceived destructive feeding habits. This study sought to extend the knowledge of the annual diet of feral goats in two very different habitats in northern Snowdonia, and to describe any evidence for diet differences between the sexes. Feral goats are sexually dimorphic in body size and are generally known to segregate into separate sex herds. Such traits have been described for other ungulates and are thought to be a strategy for reducing intra-specific competition at critical times of the year. Close observation of the goats was difficult due to their shyness, and techniques for studying their diet were limited. Faecal analysis was considered the most appropriate to compare the botanical composition of goat diets on a monthly basis and between the sexes.

7.2 Use of faecal analysis.

The analysis of fragments of plant cuticle/epidermis in the faeces of herbivores is a frequently used technique despite criticisms over its ability to represent an animals diet. Recent research has shown that in certain circumstances faecal analysis can accurately depict the dry weight composition of foods ingested. However, until the technique is tested using complex diets as are found in goats, faecal composition should not be assumed to represent the actual diet consumed, but may be used to show trends or comparisons between samples.

Faecal analysis is time consuming, but the most lengthy aspect is the collection and preparation of plant reference material and the training needed to identify cuticle fragments accurately. There is very little published information on plant cuticle anatomy which can be used directly for faecal analysis. Although every situation is different, and a reference collection is essential for each study site, it would be useful to collate information on the identification of cuticles of common forage species. This would reduce the time required for training, highlight problem areas, and indicate possible limitations of the technique.

In this study, problems were encountered with the separation of several species. The cuticles of tree leaves, sedges and rushes are all potentially identifiable provided fragments are of good quality, large, and possess sufficient diagnostic features, however, frequently this is not the case. Correct identification of all fragments is essential to the accuracy of faecal analysis, so to gain experience before samples collected in the field were examined, certain aspects of the method were investigated, dichotomous keys constructed to identify fragments, and an identification test was carried out. Simple mixtures of hand-compounded plant material were digested with acid and then examined using different enumeration and calculation procedures. A good correlation was found between the estimated and actual dry weight composition of these mixtures, and there was little difference between methods. Dichotomous keys were developed to assist the identification of common species from the Cwm Ffynnon and Padarn areas. These were tested on hand compounded material from the two sites. Problems were found in identifying some material down to species level and more success was achieved when larger taxonomic groupings were used. Although a higher rate of success may be possible using different diagnostic features or when dealing with different sets of species, caution is advised when attempting to analyse diets containing certain species.

7.3 Fieldwork

Feral goats at two study sites, an upland heath (Cwm Ffynnon) and a deciduous woodland at lower altitude (Padarn). Collection of faecal samples were carried out on a monthly basis and information on other aspects of goat ecology were recorded during these field visits. The faeces of goats are not distinguishable from those of sheep and as the goats were often in mixed sex herds, to collect samples from males and females necessitated identifying individuals and observing them for long periods. Data on the location of the group, its size and the individuals present were recorded and used to define the male and female range during the study period.

In Cwm Ffynnon the male and female ranges were similar in location and size, approximately 2 km^2. This group was small in number and although kids were seen in March, these died early in the year. These factors may have contributed to the lack of sexual segregation and the consequently similar ranges that were observed. Females in the Padarn group had a smaller range than in Cwm Ffynnon, approximately 1.3 km^2, but the males ranged widely. During the rut in September, most males moved approximately 6 km away from their normal area to join other goats further up the valley. A much greater degree of sexual segregation was observed in the Padarn herd and this may have been connected to the larger group size, much larger number of males, and the survival of most kids.

7.4 Habitat utilisation

The location of goats recorded during faecal collections were related to the habitats available within their ranges to estimate the degree of selectivity for particular vegetation communities. At both sites, strong selection was shown for certain vegetation types, whilst others were avoided. In Cwm Ffynnon the most common vegetation type was upland Calluna heath ("Heather", approximately 32 % of range) and over 60 % of all observations were recorded on this class. "Bilberry", "Nardus", and "Mire" communities were all avoided overall and "Bracken" was used in proportion to its area. Although observations were recorded opportunistically, "Mire" and "Bracken" areas appeared to be used more in the winter and in poor weather conditions. These vegetation types covered the lowest altitude areas and were generally more sheltered. Both sexes used similar vegetation types throughout the year, except in early spring when females used "Bracken" areas more than males. This may have been connected to the preference for more sheltered areas as kidding sites.

At the Padarn site several major habitat types were identified and males and females used different areas in different seasons. "Deciduous Woodland" formed over 34 % of the female range and almost 40 % of the males' and was selected overall by both sexes. "Quarry/Spoil", and "Reclaim" also covered a large part of both ranges but was mostly avoided, except by females in the summer months. "Semi-improved Grassland" and "Nardus" grassland were avoided, although a large number of males were seen on a "Nardus" area in September. "Heath" areas were used only occasionally by both sexes but in February all females observed were feeding on heather covered ledges.

Optimal foraging models predict that animals will select feeding areas to maximise their net intake of energy within the constraints laid down by their morphometric and physiological limitations. The greater utilisation of "Quarry" and "Reclaim" habitats may be explained by the ability of the females to feed on relatively sparse but possibly higher quality vegetation (grasses and herbs) that the larger males might find it difficult to maintain themselves on. However, selection of other habitats during the year seemed to be explained by other factors such as social behaviour rather than for dietary reasons. Selection of "Heath" areas by females coincided with kidding when they appeared to move to more isolated areas, and use of "Nardus" seemed to be determined by the location of oestrous females during the rut. Further information is needed on seasonal habitat preferences over a longer period and the relative nutritional qualities and availability of vegetation.

7.5 Diet analysis

Faecal samples were collected from males and females at both sites, and from Cwm Ffynnon samples from individual goats were analysed separately. A total of 30 species were identified in the diet of goats from Cwm Ffynnon and 51 from the Padarn. These species were group into eight plant categories most of which were represented in the diet in every month.

In Cwm Ffynnon, overall diet (as expressed by faecal composition) comprised approximately 50 % monocotyledons (30 % grasses, 14 % sedges, 4 % rushes) and 40 % dwarf shrubs, the remaining 10 % consisting of ferns, herbs and bryophytes. No significant differences between the overall diets of males and females were apparent. This is in contrast to the Padarn site where male diet consisted of only 15 % monocotyledons (mostly grasses), 67 % tree browse and dwarf shrubs, and the remaining 18 % of ferns (10 %), herbs (5 %) and bryophytes (3 %). Female diet over the 12 months contained a higher percentage of monocotyledons (21 %), less browse material (62 %) and similar proportions of other forage (6 % ferns, 7 % herbs and 3 % bryophytes).

Seasonal variations in dietary components were noted at both sites. In Cwm Ffynnon, ericaceous shrubs were a major component throughout the year, but were more important in the male diet during the winter. Monocotyledons were most important in late spring and early summer when grasses, especially *Nardus stricta* were eaten. In late spring, grasses were replaced by sedges which remained an important component over the summer months. Other studies on goat diet in similar areas have noted greater utilisation of grasses during the summer at the expense of dwarf shrubs. However, the range of grass species available in Cwm Ffynnon was rather low, *Nardus stricta* being prevalent, and sedges such as *Eriophorum vaginatum* seemed to be preferred. Use of both grasses and sedges coincided with early growth, when their nutritional values are likely to be highest. Bilberry, rushes and mosses were not major components of the diet, nor were herbs, although these may have been underestimated due to the loss of cuticle and difficulty of identification. Ferns (mainly *Pteridium aquilinum*) were used more by females and mainly in autumn and winter.

Differences in overall diet between individuals were not a significant factor in the dietary variation of six goats compared over seven months. Significant variation between individual animals has been noted elsewhere but because faecal samples may represent the diet consumed over a long period, any differences over time may be evened out. Also, the variety of forage available in Cwm Ffynnon was low, and the expression of individual preferences may have been limited.

Faecal composition at the Padarn site varied considerably with the seasons, reflecting the greater variety of habitats that the goats used and the wider selection of forage classes available. Woody browse was very important: ericaceous shrubs were used throughout the year and tree leaves formed a significant part of the diet from spring through to late summer. Other shrub material eaten included bramble (*Rubus fruticosus* agg.) and holly/ivy (*Ilex aquifolium*/*Hedera helix*) which were eaten mainly in winter. The proportion of monocotyledons in the diet fluctuated greatly over the year and was made up mostly of grasses with few sedges or rushes. Grass utilisation peaked in spring but decreased rapidly following the growth of tree leaves before peaking again in autumn. Although grasses were available throughout the summer it appeared that goats preferred to browse on trees and shrubs over this period. Other diet categories followed a similar pattern to Cwm Ffynnon. Ferns were more important for the Padarn goats but were used at a similar time of year, in autumn, possibly linked to reduced levels of toxins. Herbs also formed a larger part of the diet than in Cwm Ffynnon and utilisation followed a similar pattern, increasing over the spring and summer coinciding with growth and flowering. Bryophytes (mosses and lichens) formed only a small proportion of the diet at both sites, higher levels in the Padarn males in September appeared to be linked to grazing on short grasses.

The sex of the goats was not a significant factor influencing overall faecal composition for the Cwm Ffynnon group, although ferns appeared to be utilised more by females. Diet composition was compared using Kulzynski's similarity index, and male and female diets corresponded closely over the much of the year (>90 % similarity), but was markedly different in March (approximately 60 % similarity). Habitat utilisation followed a similar pattern, males and females using similar habitats for most of the year but females using different areas around kidding in March.

For the Padarn group, the overall diet differed significantly between males and females, and for all plant categories used except "herbs" and "moss". Males had a greater proportion of "tree leaves", "ferns" and "holly/ivy" in their diet than females and a smaller proportion of "heather" and "monocotyledons". Male and female diets also showed slightly different seasonal patterns, with females selecting ericaceous shrubs and monocotyledons in the winter, whilst males selected bramble and holly/ivy over the same period. Overall diet similarity (82 %) was lower than in Cwm Ffynnon and again was very low (34 %) in late winter.

Much of the disparity between male and female diets can be related to the use of different habitats where different proportions and types of forage species are available. However, it is interesting to note that for whatever cause, diets at both areas were least similar between the sexes in late winter, when one might expect resources to be most limited and the potential competition for food high.

The partitioning of food resources between males and females has been described for several species of sexually dimorphic ungulate, and has been associated with differing physical and physiological limitations imposed by body size. Larger males may tolerate poor quality diets better than females because of their greater gut capacity in relation to their weight. In addition, due to the allometric scaling of mouth size, one would also expect smaller animals to be able to feed more selectively than larger ones. Thus, if the sexes are different enough in size one might expect females to prefer to feed on high quality diets, while males could tolerate areas where quality was low, provided sufficient food was available.

Although the existence of different diets between male and female goats does not necessarily indicate evidence of resource partitioning, the results of this study are in broad agreement with such theories. The greatest segregation of diet and habitat utilisation was observed in late winter when competition for food may be high, and in the Padarn group where the greatest sexual dimorphism was apparent. It also appeared that males preferred to feed on the abundant tree browse during spring and summer whilst females and kids utilised the "Quarry" and "Reclaim" areas, feeding on widely scattered herbs and grasses. However, at both sites the population density of goats was low, and food resources, certainly in the Padarn area, did not appear limiting. Without such stresses one might expect choice of habitat and diet to be easily overridden by other factors such as social behaviour or the need for shelter in poor weather.

Data on the botanical composition of diets from faecal analysis can indicate how individuals of each sex use the food resources available to them. With increasing interest in the use of goats for habitat manipulation and in mixed grazing with other herbivores, such details provide a background to improve the management of both feral and domesticated herds.

Appendix 1.

1.1 Keys to assist in identification of plant cuticle fragments found in faeces.

As mentioned in Chapter 4, dichotomous keys were developed to assist in identifying plant cuticle fragments found in faecal material and these are presented below. (Sections 1.2 and 1.3.) Information on the methods for distinguishing the different plant species found at the study sites was rather scattered, a list of references that provided useful examples of plant cuticle characteristics is given in section 1.4.

Other workers employing faecal analysis have also developed keys (Croker 1959, Bhadresa 1981, Riegert & Singh 1982, Matrai et al. 1986) and their use can have several advantages: Identification of fragments can be speeded up, particularly in the early stages before experience is gained; Identification is made more consistent throughout a single study and between individual workers and different studies; Keys can suggest cuticle characters that might be used for distinguishing other plant species; Construction of such keys prior to faecal analysis provides experience in preparing and examining cuticle material and highlights the limitations of the technique in distinguishing certain species.

Plant taxonomists have been reluctant to rely entirely on cuticular features for plant classification for several reasons: Some species simply cannot be easily separated by their cuticle characteristics alone; Rules that may apply to a limited range of species growing in one area may not apply to all the species in that taxon; Cuticle characters can be very plastic and may vary between parts of the same plant, between different growth stages and times of the year, and between locations with different growing conditions. However, Stace (1965) concluded that cuticular characters could be of equal or greater value than other features for identification and taxonomy.

Whilst keys can be valuable in faecal analysis studies, the use of keys from other areas must be strongly cautioned against. Most studies are restricted to a small number of plant species growing in particular habitats, use of published keys in other areas with different combinations of species may be impossible or may produce mis-identification errors. In addition, as conditions at different sites are unique, it is recommended that large plant reference collections are always made (using permanent slides, photomicrographs, drawings and notes), keys specific to the area are developed, and the limitations to cuticle identification are explored. Development of keys that are robust enough to distinguish all species found in a wide variety of habitats would be a major task requiring wide botanical and taxonomic experience. In the present study two keys were developed for selected species from the Cwm Ffynnon and Padarn areas. Due to time limitations, the number of cuticle samples used were small and limited in times of collection, locations and plant parts used. Both keys were tested on a range of species from both study areas with some success (see Chapter 4, Table 4.9) but some problems may still exist and improvements could be made. Identification of cuticle fragments from material digested in vitro was found to be somewhat easier than from faecal material and again it must be stressed that such keys cannot replace a large, well prepared cuticle reference collection combined with experience.

A selection of colour photomicrographs of common species identified in the faeces are shown in Figures A1 and A2. The complete collection of reference material including approximately 400 photomicrographs, drawings, notes and permanent slides are held at:

The School of Agriculture and Forest Sciences
University of Wales,
Bangor,
Gwynedd LL57 2UW

The techniques used to prepare cuticle and epidermal material are described in Chapter 3, section 3.4. The terminology used to describe cuticular features followed Van Cotthem (1973) for stomata and Radford et al. (1974) for trichomes.

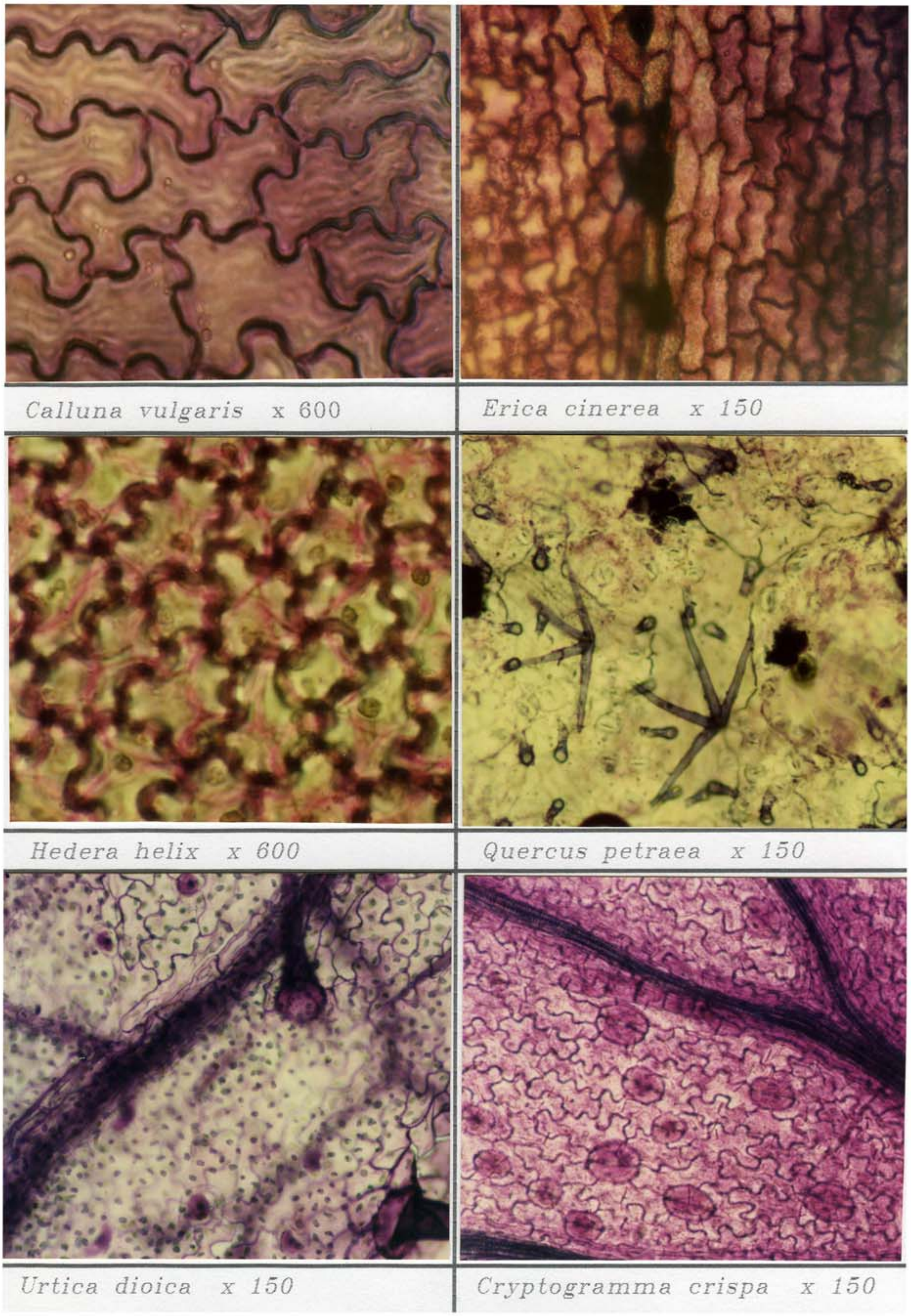


Figure A1. Examples of plant cuticle found in goat faeces. Colours are artificial due to staining.

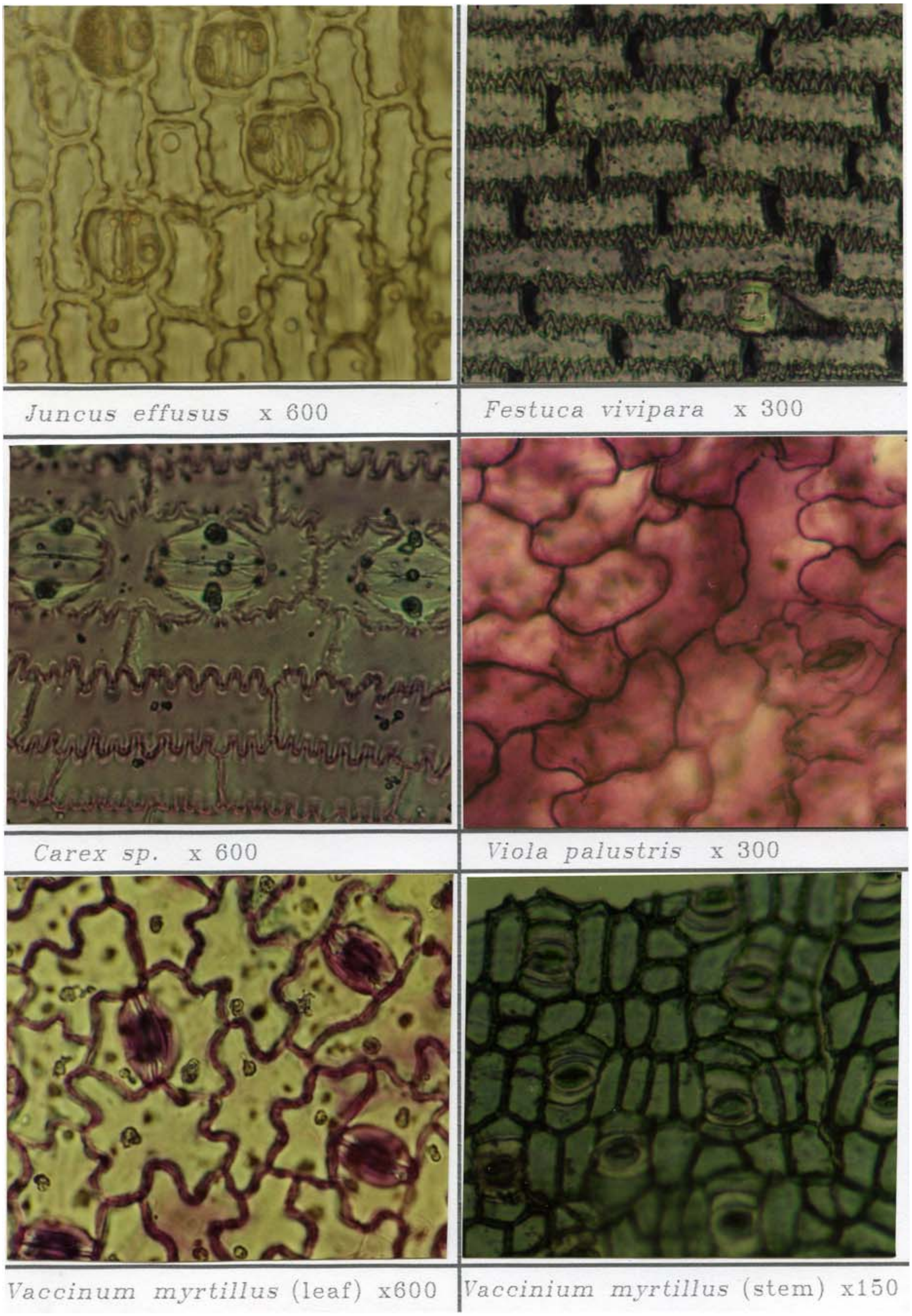


Figure A2. Examples of plant cuticle found in goat faeces. Colours are artificial due to staining.

1.2 Key to Epidermal Fragments of common plant taxa found in Cwm Ffynnon.

Cells regularly shaped and arranged in parallel rows, stomata alligned in row. see....**Monocotyledonous Plants.**
Cells not regularly shaped or arranged in parallel rows, cell walls wavy or lobed see....**Misc. Groups & Dicotyledons**.

Monocotyledonous Plants.

a) Cells differentiated into long & short cells, silica bodies may be visible. see....**Gramineae A**.
Cells never differentiated **b**)

b) Cells with thick, double-walled appearance, sometimes greenish, with sinuous or straight walls, no trichomes. Stomata often round with large subsidiary cells. see....**Juncales B**.

Cells with generally thin walls, deeply & regularly corrugated, trichomes may be present at edges. Stomata oval-shaped. Cells variable in size or large (>50µm x >12µm), squarish and regular see....**Cyperaceae C**.

A. Gramineae (Grasses)

A1. Distinct dense, blunt papillae ***Nardus stricta***
No papillae, plain sheet of differentiated cells **A2**.

A2. Trichomes present. **A7**.
No trichomes visible **A3**.

A3. Cells large (>200µm long), smooth-walled, tapering ***Poa/Deschampsia*** spp.
Cells with deeply corrugated walls, parallel & regular. **A4**.

A4. Silica bodies distinct (stain darkly), very regular arrangement (like brickwork), cells medium sized ***Festuca* spp**.
Silica bodies not so distinct, cells not distinctly regular. **A5**.

A5. Silica bodies dumbell-shaped, found on veins ***Molinia caerulea***
Silica bodies squarish, rectangular or rounded **A6**.

A6. Stomata wider than adjacent cell ends. Cells large (>200µm long), silica bodies rectangular & crenellated ***Agrostis* spp**.
Stomata not as above ***Nardus stricta***

A7. Large macro-hair(s) present. **A8**.
Small or medium trichomes present, including bicellular trichomes (often with apical cell lost) **A9**.

A8. Cells small (50-140µm), regular, parallel, bicellular trichomes may be present or small papillae ***Nardus stricta***
Cells large (>200 µm long), smooth walled, tapering. ***Deschampsia* spp**.

A9. Bicellular trichomes (often broken) present **A10**.
Bicellular trichomes absent **A11**.

A10. Silica bodies dumbell-shaped on veins, edge trichomes sharp, dense but irregularly shaped.
Cross veins may be present. ***Molinia caerulea***
Silica bodies squarish, or rounded, cells medium sized (but variable), regular, corrugated ***Nardus stricta***

11. Medium sized prickle trichomes, bulbous at base. Stomata wider than ends of adjacent cells.
Large (>200 µm) regular corrugated cells ***Agrostis* spp.**
Small-medium sized prickle trichomes with small tapering cells on ribs or edges **A12**.

A12. Prickle trichomes conical and slightly hooked. ***Deschampsia* spp**.
Prickle trichomes large(30µm x 66µm) bent, dense ***Festuca* spp**.

B. Juncales (Rushes).

B1. Regular "brickwork" or "chicken-wire" pattern of thick-walled cells.
May be associated with distinctive structural cells.). ***Juncus* spp**. B2.
Irregular pattern of cells, stomata with large subsidiaries. ***Juncus squarrosus***.

B2. Cells long, walls , straight or slightly sinuous ***Juncus articulosus***
Cell rectangular, regular, sinuous or corrugated ***Juncus effusus***

C. Cyperaceae (Sedges)

C1. No trichomes visible **Sedge**
Trichomes visible at leaf edge **C2**

C2. Trichomes at edge thorn-like and regularly spaced, end walls of cells oblique and thickened ***Carex echinata***
Trichomes irregular, end walls corrugated ***Eriophorum angustifolium***
Trichomes irregular, many dense papillae visible at edge ***Carex* spp**.

Miscellaneous Groups, Ferns & Dicotyledonous Plants,

1. Indistinct mass with hyphae and rounded algal cells. **Lichens (not identified further)**

2. Undifferentiated small elongated cells (stain red-pink); Hyaline cells with septa & pores; thin-walled cubical cells with distinct toothed profile, possibly with thorn-like projection see....**Mosses. E**

3. Cells distinctly lobed & "amoeboid" in shape, veins dichotomously branching, stomata anomocytic or polocytic. Sporangia may be present. see....**Ferns. F**

4. Cells roughly rectangular, with sinuous walls or extremely thick-walled cells with visible pores or irregularly branched veins. see....**Dicotyledons. D**

D: Dicotyledonous Shrubs & Herbs

D1. Whole leaflet or petiole with central groove and papillae **Shrub D2**.
Fragment/sheet of cells; branched vein or thick-walled fruit cell. **D3**.

D2. Glandular trichomes present, cells small, squarish. ***Erica tetralix***
Conical trichomes near base of leaflet. Cells large, rectangular but sinuous and thick-walled. ***Calluna vulgaris***
Cells squarish, small to medium sized. ***Erica* spp**.
Cells squarish with crystalline bodies. ***Empetrum nigrum***

D3. Fragment or sheet of cells. **D4.**
Branched vein with club-shaped glands ***Vaccinium myrtillus***
Branched vein, no club-shaped glands visible **Bilberry/Herb**
Large thick-walled angular cells with distinct pores (stains deep blue-purple). (Fruit) ***Vaccinium myrtillus***

D4. Cells thick-walled, often brownish in colour. **D5**.
Cells thin walled. **D7**.

D5. Sheet of squarish or polygonal cells. (Stem) **D8**.
Amoeboid cells thick-walled, often brownish, with dense papillae. **D6**.

D6. Cells large, elongated with conical trichomes. ***Calluna vulgaris***
Cells smaller, squarish ***Erica* spp**.
Cells squarish with crystalline bodies. ***Empetrum nigrum***

D7. Small amoeboid or polygonal cells with warty appearance and long lanceolate &/or medium sized curly trichomes ***Polygala vulgaris***
Long lanceolate trichomes, club-shaped glandular trichomes six cells long. ***Tormentilla erecta***
Small amoeboid or polygonal cells without trichomes or glands. **Herb**

D8. Rough trichomes (papillose) present (Stem). **Shrub**
No trichomes present. **D9**.

D9. Stomata with distinctive parallel subsidiary cells (with differential

staining). (Stem). ***Vaccinium myrtillus***
Stomata without distinctive associated cells. (Stem). **Shrub.**

E. Mosses

E1. Hyaline cells with distinct septa & pores; or mass of undifferentiated cells forming branches, possibly with retort cells. ***Sphagnum* spp**.

E2. Leaf lamellae made of columns of cubical cells with distinct toothed profile, trichome-teeth may be present ***Polytrichum* spp**.

E3. Simple reticulate sheet of cells with irregular dark bodies **Moss**

F. Ferns

F1. Numerous large (100-500 µm) jointed trichomes. Stomata polocytic ***Pteridium aquilinum***
Unjointed club-like trichomes present near veins.
Stomata anomocytic/polocytic ***Cryptogramma crispa***

F2. No trichomes present. **Fern**

1.3 Key to epidermal fragments from common plant taxa found in the Padarn area

Cells Regularly shaped and arranged in parallel rows,
stomata alligned in rows see....**Monocotyledons**.

Cells not regularly arranged or shaped. Smooth, wavy or lobed walls
see....**Misc. Taxa & Dicotyledons**.

Miscellaneous Taxa & Dicotyledonous Plants.

Indistinct mass with hyphae and rounded algal cells ....**Lichen** (not identified further).

Undifferentiated small elongated cells (stain red-pink); Hyaline cells with septa & pores; thin-walled cubical cells with distinct toothed profile,possibly with thorn-like projection see....**Mosses E**.

Cells distinctly lobed & "amoeboid" in shape. Veins dichotomously branching, stomata alligned, often in dense patches, stomata anomocytic or polocytic, Sporangia may be present see....**Ferns F.**

Cells basically rectangular in shape, but may be lobed see....**Dicotyledons D**.

Monocotyledonous Plants.

a) Cells differentiated into long & short cells, silica bodies may be visible see....**Gramineae C.**
Cells never differentiated **b)**

b) Cells with thick, double- walled appearance, sometimes greenish with sinuous or straight walls, no trichomes. Stomata often round with large subsidiary cells see....**Juncales A**.

Cells with generally thin walls, deeply & regularly corrugated, trichomes may be present at edges. Stomata oval-shaped. Cells variable in size or simple, squarish and regular see....**Cyperaceae B.**

Stomata without subsidiary cells. Cell walls not corrugated, end walls oblique ***Endymion non-scriptus***

A. Juncales (Rushes)

A1. Interstomatal cell walls smooth, stomata in rows 2-3 wide ***Luzula pilosa***
Cell walls in interstomatal regions corrugated, stomata round **A2**

A2. Cells long, (40-75µm) and wide(13-20 µm), veins 3-5 cells wide, intercostal zones 10-15 cells wide. Cells corrugated at 12 per 100µm ***Juncus effusus***

Cells short, (15-56 µm) long by 10-15 µm wide. End walls sinuous, cells irregular near stomata. Cells corrugated at 15 per 100 µm ***Juncus squarrosus***

B. Cyperaceae (Sedges)

B1.	No trichomes visible	**Sedge**
	Trichomes visible at leaf edge	**B2**
B2.	Trichomes at edge thorn-like and regularly spaced, end walls of cells oblique and thickened	***Carex echinata***
	Trichomes irregular, end walls corrugated	***Eriophorum angustifolium***
	Trichomes irregular, many dense papillae visible at edge	***Carex* spp**.

C. Gramineae (Grasses)

C1.	Cells tapering, ends much narrower than mid-section	**C2**
	Cells rectangular in shape, not tapering at ends	**C4**
C2.	Cell walls corrugated	**C3**
	Cell walls smooth or only very finely corrugated	**C14**
C3.	Macrohairs present	***Brachypodium sylvaticum***
	No trichomes present	***Agrostis capillaris***
C4.	Cell walls corrugated	**C5**
	Cell walls smooth or only very finely corrugated	**C9**
C5.	Papillae present	***Nardus stricta***
	Papillae absent, short cells regularly arranged	**C8**
	Papillae absent, not as above	**C6**
C6.	Medium sized (50-120 µm) trichomes common	**C7**
	Medium sized trichomes absent	**C8**
C7.	Large macrohairs also present	***Holcus mollis***
	Silica bodies rectangular, smooth side	***Aira praecox***
C8.	Cells large (80-170 µm), short cells regularly arranged, prickle trichomes may be very common	***Festuca* spp**.
	Cells not large (50-140 µm), macrohairs may be present	***Nardus stricta***
C9.	Cells very large (>200 µm), finely corrugated	**C13**
	Cells not very large	**C10**
C10.	Medium trichomes common	***Holcus mollis***
	Medium trichomes not common	**C11**
C11.	Silica bodies dumbbell shaped	***Molinia caerulea***
	Silica bodies not dumbbell shaped	**C12**
C12.	Stomatal subsidiary cells dome-shaped, cross-veins may be present	***Anthoxanthum odoratum***
	Stomatal subsidiaries not dome-shaped	***Brachypodium sylvaticum***

C13. Stomatal subsidiary cells dome-shaped, cross veins present, cell walls finely corrugated — ***Anthoxanthum odoratum***
Not as above — ***Deschampsia flexuosa***

C14. Medium trichomes common — ***Poa* spp**.
No medium trichomes — **C15**

C15. Cells small (80-170 µm), prickle trichomes may common — ***Festuca* spp.**
Cells not small (>170 µm) — **C16**

C16. Short cells distinctly cuboid (stain well) — ***Poa* spp.**
Short cells not distinct — **C17**

C17. Stomata in single distinct rows — ***Glyceria* spp**.
Stomata in double rows — ***Poa* spp**.

D: Dicotyledonous Shrubs & Herbs.

D1. Whole leaflet or petiole with central groove and papillae or sheet of thick-walled squarish cells with warty trichomes or stomata with distinctive parallel subsidiary cells — see....**Ericaceous shrubs & Bilberry G.**

D2. Sheet of "waxy" cuticle cells with very dense stomata — see....**Waxy Plants H.**

D3. Fragments of cuticle with squarish or amoeboid cells, branching veins, trichome-hairs, or glands — see....**Trees, Shrubs & Herbs I.**

E: Mosses

E1. Hyaline cells with distinct septa & pores; or mass of undifferentiated cells forming branches possibly with retort cells — ***Sphagnum* spp**

E2. Leaf lamellae columns of cubical cells with distinct toothed profile, trichome-teeth may be present — ***Polytrichum* spp**

E3. Simple reticulate sheet of cells with irregular dark bodies — **Moss**

F: Ferns

F1. Numerous large (100-500 µm) jointed trichomes. Cell walls thick, Stomata polocytic — ***Pteridium aquilinum***
Unjointed clublike trichomes present near veins. Stomata anomocytic/polocytic — ***Cryptogramma crispa***

F2. Trichomes absent — **Fern**

G. Ericaceous Shrubs and Bilberry (including stems & fruit).

G1.	Whole leaflet or petiole with central groove and papillae	**Shrub..G2.**
	Fragment/sheet of cells; branched vein or thick-walled fruit cell	**G3.**
G2.	Glandular trichomes present, cells small, squarish	***Erica tetralix***
	Conical trichomes near base of leaflet. Cells large, rectangular but sinuous and thick-walled	***Calluna vulgaris***
	Cells squarish, small to medium sized	***Erica* spp.**
	Cells squarish with crystalline bodies	***Empetrum nigrum***
G3.	Fragment or sheet of thick-walled brownish cells	**G4.**
	Branched vein with club-shaped gland	***Vaccinium myrtillus***
	Branched vein	**Bilberry/Herb**
	Large thick-walled angular cells with distinct pores (stains deep blue-purple). (Fruit)	***Vaccinium myrtillus***
G4.	Sheet of squarish or polygonal cells. Stem	**G6**.
	Amoeboid cells thick-walled, often brownish, with dense papillae	***Calluna vulgaris***
G5.	Cells large, elongated with conical trichomes	***Calluna vulgaris***
	Cells smaller, squarish	***Erica* spp.**
	Cells squarish with crystalline bodies	***Empetrum nigrum***
G6.	Rough trichomes (papillose) present. (Stem)	**Shrub**
	No trichomes present	**G7.**
G7.	Stomata with distinctive parallel subsidiary cells (with differential staining). (Stem)	***Vaccinium myrtillus***
	Stomata without distinctive associated cells. (Stem)	**Shrub**.

H. Waxy-leaved trees & Shrubs

H1.	Cell walls very thick, stomata arranged in regular rows	**H5.**
	Stomata not arranged in regular rows	**H2.**
H2.	Cell walls distinctly angular/polygonal	**H6.**
	Cell wall amoeboid or only slightly polygonal	**H3.**
H3.	Large glandular pores & oil bodies	***Rhododendron* spp.**
	No large glandular pores	**H4.**
H4.	No stomata present	**Ivy/Holly/Rhododendron**
	Stomata with dark radial subsidiary cells, epidermal cells weakly amoeboid	***Ilex aquifolium***
	Stomata clear with "annular" appearance, epidermal cells freely amoeboid, granular bodies (7µm diameter)	***Hedera helix***
H5.	Cell walls extremely corrugated	***Picea abies***
	Cell walls smooth, dark granular bodies	***Taxus baccata***

H6.	Cell walls thick, stomata alligned	***Ulex* spp**.
	Cell walls thin, no stomata, trichome bases	***Cotoneaster* spp.**

I. Miscellaneous Trees, Shrubs and Herbs.

1.	Cells massive (>150 µm), or stomata in aniso-/dia-cytic.	**75.**
	Cells not massive stomata solitary, subsidiary cells not clustered as above	**2.**
2.	Cells squarish, small. No amoeboid or deeply lobed cells.	**36.**
	Cells deeply lobed or amoeboid and large	**3.**
	Cells deeply lobed but very small & few distinguishing features	***Fagus sylvatica***
3.	Cells deeply lobed and large.	**70**.
	Cells amoeboid	**4.**
4.	No trichome hairs present	**20.**
	Trichome hairs present	**5.**
5.	Trichomes tufted (multangulate) with 2-4 rays	***Quercus petraea***
	Trichomes large prickles (70 µm long)	***Melampyrum pratense***
	Trichomes massive with swollen base (sting)	***Urtica dioica***
	Trichomes jointed, in sections	**7.**
	Trichomes unjointed, simple, lanceolate or filiform	**6.**
6.	Curly trichome hairs present, often numerous (Trees)	**50.**
	No curly trichomes present	**10.**
7.	Trichomes thick and sac-like	**8.**
	Trichomes many jointed, thin and stick-like	**9.**
	Trichomes inflated sacs, bicellular	***Oxalis acetosella***
8.	Trichomes with warty texture and rounded tip, stomata indistinct	***Digitalis purpurea***
	Trichomes usually smooth, stomata dia-cytic, clear	***Origanum vulgaris***
9.	Stomata dia-cytic, within large clear subsidiary cells	***Origanum vulgare***
	Trichomes brightly staining, bicellular club-glands, no circular glands	***Teucrium scorodonia***
10.	Cell walls thick, trichomes usually long, straight or filiform	**11.**
	Trichomes not stiff or long and filiform, cell walls not thick	**12.**
	Inflated sac-like trichomes, club glands, circular glands	***Oxalis acetosella***
11.	Circular glands, dark glandular bodies and small stomata present	***Rubus fruticosus***
	Medium stomata, no circular glands or dark bodies, trichomes stiff	***Lonicera periclymenum***
12.	Circular glands present	***Crataegus monogyna* 13.**
	No circular glands	**14.**

13. Large dark glands, large stomata (50 x 20µm) — ***Betula*** **spp.**
Dark glands, small dark-staining stomata — ***Rubus fruticosus***
No dark glands, medium sized oval stomata — ***Crataegus monogyna***

14. No stomata present — **18.**
Stomata present — **15.**

15. Stomata large (70 x 35µm), large club-shaped glands — ***Corylus avellana***
Stomata medium or small in size — **16.**

16. Stomata small (15 x 12µm), club-shaped glands, trichomes warty or inflated — ***Oxalis acetosella***
Stomata medium sized — **17.**

17. Stomata oval in shape, distinct — ***Crataegus monogyna***
Stomata not distinct — ***Quercus petraea***

18. No club-shaped gland present — **Unidentifiable Dicotyledon**
Club-shaped gland present — **19.**

19. Small gland trichomes like oval balloons — ***Oxalis acetosella***
Small gland trichomes blunt-headed clubs — ***Quercus petraea***
Large club-shaped glands — ***Rubus fruticosus***

20. Stomata large or annular (Tree) — **25.**
Stomata not large or annular, or no stomata present — **21.**

21. Cell walls thick (Shrubs) — **22.**
Cell walls not thick (Trees/Herbs) — **28.**

22. Multicellular club-shaped glands present — ***Vaccinium myrtillus***
No multicellular club-shaped glands — **23.**

23. Circular- and/or dark- glands present — ***Rubus fruticosus***
No circular or dark glands present (Shrub) — **24.**

24. Cells squarish, distinct walls — ***Lonicera periclymenum***
Stomata medium-sized (27 x 17µm) — ***Vaccinium myrtillus***
Stomata small (18 x 15µm) dark-staining — ***Rubus fruticosus***

25. Club-shaped glands present — ***Corylus avellana***
No club-shaped glands present — **26.**

26. Dark glandular bodies present — ***Betula*** **spp.**
No dark glandular bodies (Tree) — **27.**

27. Stomata annular, with radial subsidiary cells — ***Fagus sylvatica***
Stomata very large (70 x 35µm-outer) — ***Corylus avellana***
No distinctive stomata — **Birch/Hazel/Beech**

28.	No club-shaped glands present	**31.**
	Large (120 µm) club-shaped gland present, circular glands	***Corylus avellana***
	Medium or small sized club-shaped glands present	**29.**
29.	Blunt club-shaped gland trichomes	***Quercus petraea***
	Long balloon-shaped gland trichomes	***Oxalis acetosella***
	Small bicellular club-gland trichomes	***Teucrium scorodonia***
	Club-shaped gland trichomes	**30.**
30.	Large circular glands present	***Origanum vulgaris***
	No large circular glands	**Foxglove/Marjoram**
31.	No circular glands present	**35.**
	Circular glands present	**32.**
32.	No stomata present	**Unidentifiable Tree or Herb**
	Stomata present	**33.**
33.	Stomata medium sized	**Hawthorn/Rowan**
	Stomata small (<20 x 10 µm)	**34.**
34.	Cell walls thin, large holes of broken trichome bases	***Teucrium scorodonia***
	Stomata within amoeboid clear subsidiary cells	***Origanum vulgaris***
	Stomata with clear squarish subsidiary cells	***Salix capra***
	Stomata dark-staining, with amoeboid subsidiary cells	***Rubus fruticosus agg.***
35.	Dark glands present	**Rowan/Birch**
	No dark glands present	**Unidentifiable Tree or Herb**
36.	Tufted trichomes present	***Quercus petraea***
	No trichomes present	**40.**
	Non-tufted trichome hairs present	**37.**
37.	Curly trichomes (may be numerous) present	**50.**
	No curly trichomes present	**38.**
38.	Dark glandular bodies present	***Betula* spp.**
	No dark glandular bodies present	**39.**
39.	Stomata not distinct	**Oak/Willow**
	Stomata oval, distinct (dark staining)	***Crataegus monogyna***
	Stomata annular (cyclocytic)	***Fagus sylvatica***
40.	Circular glands present	**50.**
	No circular glands present	**41.**
41.	No club-shaped glands present	**43.**
	Club-shaped glands present	**42.**

42.	Large (70 x 35 µm) stomata present	***Corylus avellana***
	Medium (25 x 20 µm) stomata present	***Quercus petraea***
	No stomata present	**Hazel/Oak**
43.	No dark glands present	**45.**
	Dark glands present	**44.**
44.	Large stomata present	***Betula* spp.**
	Medium stomata present	***Sorbus aucuparia***
	No stomata present	**Birch/Rowan**
45.	No stomata present	**Unidentifiable Tree**
	Large stomata present	**46.**
	Medium or small stomata present	**47.**
46.	Stomata annular	***Fagus sylvatica***
	Stomata large (50 x 20 µm), not annular	***Betula* spp.**
	Stomata very large (70 x 35 µm), not annular	***Corylus avellana***
47.	Stomata small (10 x 8.5 µm)	***Salix capra***
	Stomata medium sized	**48.**
48.	Stomata oval, distinct	***Crataegus monogyna***
	Stomata lemon-shaped, not distinct	**Rowan/Oak**
50.	No stomata present	**58.**
	Stomata present	**51.**
51.	Circular glands present	**55.**
	No circular glands present	**52.**
52.	Club-shaped glands present	***Corylus avellana***
	No club-shaped glands	**53.**
53.	Dark glands present	**57.**
	No dark glands present	**54.**
54.	Stomata large (>50 µm x >20 µm)	**Birch/Hazel**
	Stomata small (10 x 8.5 µm)	***Salix capra***
	Stomata medium-sized	***Sorbus aucuparia***
55.	Dark glands present	**Birch/Rowan**
	No dark glands present	**56.**
56.	Stomata small (10 x 8.5 µm)	***Salix capra***
	Stomata large (50 x 20 µm)	***Betula* spp.**
	Stomata medium-sized	***Sorbus aucuparia***
57.	Stomata large (>50 x >20 µm)	**Birch/Hazel**
	Stomata medium-sized	***Sorbus aucuparia***

58.	Circular glands present	**59.**
	No circular glands	**61.**
59.	Dark glands present	**Birch/Rowan**
	No dark glands present	**Birch/Rowan/Willow**
60.	Cell walls thick, darkly staining	***Sorbus aucuparia***
	Cell walls not thick	***Betula* spp.**
61.	Club-shaped glands present	***Corylus avellana***
	No club-shaped glands present	**62.**
62.	Dark glands present	**Birch/Hazel/Rowan**
	No dark glands	**Birch/Hazel/Rowan/Willow**
70.	Waxy, large circular glands (bubble-like cells) & prickles	***Melampyrum pratense***
	Elongated cells, multicelled stalked glands	***Achillea millefolium***
	Blunt-ended lobed cells, clear oval stomata	71.
71.	Large, thick, jointed trichome-hairs	***Geranium robertianum***
	No jointed trichomes present (Herb)	**Herb Robert/Celandine/etc.**
75.	Stomata grouped in distinct clusters, aniso/helo-cytic	***Umbilicus rupestris***
	Stomata solitary, stomata aniso-cytic	***Sedum anglicum***
	Stomata solitary, stomata dia-cytic & numerous	***Origanum vulgarum***

1.4 References used in development of keys to plant cuticle / epidermal material.

Arber, A. (1934) **The Gramineae: A study of Cereal, Bamboo & Grass.** Cambridge University press.

Barnard, C. (ed.), (1964) **Grasses & Grasslands**. pp 58-61. Publs: MacMillan & Co. Ltd. London

Baumgartner, L.L. & Martin, A.C. (1939) **Plant histology as an aid in squirrel food-habit studies**. J. Wildlife Management 3:3.

Bhadresa, R. (1981) I**dentification of leaf epidermal fragments in Rabbit faeces.** Rogate Papers 4,. pp 1-27.

Booth, W.E. (1964) **Agrostology**. Publs: Edwards Bros Inc. Michigan USA.

Bower, F.O. (1923) **The Ferns**. Vol 1. Publs: Cambridge University Press.

Burr, S.M. & Turner, D.M. (1933) **British Economic Grasses: Their identification by leaf anatomy**. Publs: E. Arnold & Co. London.

Chapuis, J.L. (1980) **Methodes d'etude du regime alimentaire du lapin de Garenne, Oryctolagus cuniculus (L.) par l'analyse micrographique dees feces.** Terre et Vie 34, pp 159-198.

Cherouvrier, A., Gueguen, A. & LeFeuvre, J.C. (1975) **Essai de determination du regime alimentaire d'animaux herbivores a l'aide des phytolithes siliceux des Graminees et de Cyperacees**. C.R. Acad. Sc. Paris 281, pp 839-842.

Clarke, J. (1960) **Preparation of leaf epidermis for topographic study**. Stain Technology 35 pp 35-39.

Clifford, H.T. & Watson, L. (1977) **Identifying Grasses: Data, methods & illustrations.** Publs:University of Queensland Press Australia.

Croker, B.H. (1959) **A method of estimating the botanical composition of the diet of sheep**. N.Z. J. Ag. Research 2, pp 72-85.

Cutler, D.F. (1969) **Anatomy of the Monocotyledons. IV Juncales.** Publs: Clarendon Press Oxford.

Daniels, R.E. & Eddy, A. (1985) **Handbook of European Sphagna.** Publs: NERC Institute of Terrestrial Ecology ISBN 0 904282 82 1.

Davies, I. (1959) **The use of epidermal characteristics for the identification of grasses in the leafy stage.** J. Br. Grassland Soc. 14, pp 7-16.

Dusi, J.L. (1949) **Method for the determination of food habits by plant microtechniques and histology and their application to Cottontail Rabbit food habits**. J. Wildlife Management 13: 3.

Goebel, K. (1887) **Outlines of Classification & Special Morphology of Plants.** Publs: Clarendon Press.

Gueguen, A., Cherouvrier, A. & Lefeuvre, J.C. (1975) **Essai de determination du regime d'animaux herbivores a l'aide des phytolithes siliceux des Graminees et des Cyperacees**. C.R.Acad.Sci. Paris 281, pp 929-932.

Hercus, B.H. (1960) **Plant Cuticle as an aid to determining the diet of grazing animals**. Proc. 8th Int. Grassland Congress. pp 443-447.

Jermy, A.C., Chater, A.O. & David, R.W. (1982) **British Sedges**. Publs: Botanical Soc. of the Brit. Isles.

Martin, D.J. (1955) **Features on Plant Cuticle. As an aid to the analysis of the natural diet of grazing animals, with especial refernces to Scottish hill sheep.** Trans. Bot. Soc. Edin. 36: IV, pp 278-288.

Martin, D.J. (1964) **Analysis of sheep diet utilizing plant epidermal fragments in faeces samples. in: Crisp, D.J. (ed.) Grazing in terrestrial and marine environments**. Publs: Blackwell Scientific Publications, Oxford.

Matrai, K, Koltay, A. & Vizi, G. (1986) K**ey based on leaf epidermal anatomy for food habits studies of herbivores.** Acta Botanica Hungarica 32 (1-4), pp 255-271.

Metcalfe, C.R. (1960) **Anatomy of the Monocotyledons. I Graminae.** Publs: Oxford University Press.

Metcalfe, C.R. (1971) **Anatomy of the Monocotyledons. V Cyperacae**. Publs: Clarendon Press. Oxford.

Metcalfe, C.R. & Chalk, L. (1979) **Anatomy of the Dicotyledons. Vol. 1**. Publs: Clarendon Press. Oxford.

Metcalfe, C.R. & Chalk, L. (1983) **Anatomy of the Dicotyledons. Vol. 2**. Publs: Clarendon Press. Oxford.

Nugent, G.(1983) **Deer diet estimation by rumen or faecal analysis: An evaluation of available techniques**. F.R.I Bulletin 24.

Prat, H. (1932) **L'Epiderme des graminees. Etude Anatomique et Systematique.** Ann. des Sci. nat. Series 10: 14, pp 117-324.

Prat, H. (1959) **Emploides caracteres epidermiques dans la classification des graminees**. 9th Int. Bot. Congress. in: Recent Advances in Botany 1, pp 99-101.

Priestley, J.H. (1943) **The Cuticle in Angiosperms**. Botanical Review 9, pp 593-616.

Radford, A.E. & Smith, B.W. (1974) **Vascular plant systematics.** Publs. Harper Row. London.

Riegert, P.W. & Singh, N. (1982) **A Key to identify epidermal fragments of Saskatchewan Rangeland plants.** Can. J. Bot. 60, pp 2461-2468.

Rogerson, S.J, Stevens, E.J. & Hughes, J.G. (1976) **An improved preparation technique for identification of plant cuticle in animal faeces.** N.Z. J. Botany 14, pp 117-119

Scott, D.H. & Ingold, C.T. (1955) **Flowerless Plants**. Publs: A.C. Black.

Sleper, D.A. & Roughan, P.G. (1984) H**istology of several cool-season forage grasses digested by cellulase**. N.Z. J. Agric. Res. 27, pp 161-166.

Smith, A.J.E. (1978) **The Moss Flora of Britain & Ireland**. Publs: Cambridge University Press.

Smith, A.J.E. (1978) **The Moss flora of the British Isles.** Publs: Cambridge University Press. ISBN 0 521 21648 6.

Smith, A.J.E. (1990) **The Liverworts of Britain & Ireland**. Publs: Cambridge University Press. ISBN 0 421 23834 X.

Smith, J.E. (1989) **Aspects of the foraging ecology & management of feral goats (Capra hircus) at Coed Allt Wen and Dinorwic Quarries, N. Wales: A Pilot Study.** MSc Thesis UCNW Bangor.

Stace, C.A. (1965) **Cuticular studies as an aid to plant taxonomy**. Bulletin of the Brit. Mus. Nat. Hist: Botany 4:1, pp 1-87.

Stainsby, C.B. (1973) **A Study of Welsh Mountain Ponies.** MSc Thesis UCNW, Bangor.

Stevens, E.J. (1977) **A comparison of three methods of sheep diet determination and the field application of faecal cuticle analysis**. Thesis for Master of agricultural science. University of Canterbury. New Zealand.

Van Cotthem, W.R.J. (1973) **Stomatal types and Systematics. in: The Phylogeny & Classification of the Ferns**. Eds.: A.C. Jermy, J.A. Crabbe & B.A. Thomas. Bot. J. Linnean Soc. Supp. No. 1 to vol. 67. Publs: Academic Press. London.

Watson, E.V. (1981) **British Mosses & Liverworts.** 3rd edition. Publs: Cambridge University Press. ISBN 0 521 2404 2.

Winton, A.L. (1906) **Microscopy of Vegetable Foods**. Publs: John Wiley & Sons.

Appendix 2. Field data.

Observations on the location, group structure and numbers of goats seen feeding were recorded during fieldwork between March 1991 and February 1992. The positional data were used to define seasonal and annual ranges and habitat utilisation described in Chapters 3 and 5. Times are all GMT, LONG and LAT refer to grid locations on Ordnance Survey sheet SH (Snowdonia National Park, 1:25 000 sheet 17). The sex of kids (<1 year old) and hummels were not recorded.

2.1 Cwm Ffynnon

* Denotes groups of goats seen at the two sites but which were not associated with the main groups studied.

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
MARCH										
3:3:91	7:30	6500	5710		3	1		4		3
	8:00	6503	5710		3	1		4		
	8:30	6506	5711		3	2		5		3
	9:00	6508	5710		3	2		5		
	9:30	6510	5711		4	2		6		3
	10:00	6510	5711		4	2		6		2
	10:00	6509	5737	3	1			4		
	10:30	6510	5729	3	3			6		4
	11:00	6513	5734	3	3			6		6
	11:00	6513	5711		2	2		4		2
	11:30	6520	5740	3	3			6		1
	11:30	6520	5713		2	2		4		2
	12:00	6530	5748	3	3			6		3
	12:00	6522	5732		2	2		4		2
4:3:91	13:00	6520	5720	1				1		1
	15:00	6520	5720		2			2		2
	15:30	6520	5720	1	2			3		
	16:00	6520	5720	1	2			3		
	16:30	6520	5720	1	2			3		
	17:00	6520	5720	1	2			3		
5:3:91	13:00	6500	5650	3	2	1		6		2
	13:00	6510	5690		1			1		1
	13:30	6506	5667	3	3	1		7		1
	13:30	6510	5690		1			1		1
	14:00	6513	5687	2	2	1		5		2
	14:00	6510	5690	1	2			3		1
	14:30	6518	5701	3	2			5		1
	14:30	6500	5650		1	1		2		
	15:00	6530	5720	4	2			6		3
	15:00	6500	5650		1	1		2		
	15:30	6500	5650		1	1		2		
	15:30	6500	5730	3	3			6		2
	16:00	6500	5650		1	1		2		
	16:00	6510	5730	4	2	1		7		3
	16:30	6500	5650		1	1		2		
	16:30	6507	5728	3	2			5		1
	17:00	6500	5650		1	1		2		1
	17:00	6520	5720		1			1		
	17:00	6513	5732	3	1	1		5		1
APRIL										
7:4:91	5:30	6485	5717	2	3			5		2

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
	6:00	6505	5725	3	5			8		3
	6:30	6517	5739	3	5			8		7
	7:00	6523	5748	3	4			7		7
	7:30	6528	5753	1	3			4		1
	8:00	6524	5758	1	3			4		4
	8:00	6515	5760	2	2			4		4
	8:30	6517	5750	3	5			8		8
	9:00	6519	5745	1	2			3		6
	9:00	6518	5750	2	1			3		
	9:00	6516	5756		2			2		
	9:30	6519	5742	1	2			3		5
	9:30	6517	5750	2	3			5		
	10:00	6521	5744		3			3		1
	10:00	6517	5750	2	1			3		3
	10:30	6515	5744	2	1			3		
	10:30	6515	5737		3			3		
	11:00	6514	5729	2	1			3		
	11:30	6514	5729	1	2			3		
	12:00	6514	5729	1	2			3		
8:4:91	12:00	6527	5718		2			2		2
	12:00	6532	5748	1				1		
	12:30	6527	5719		2			2		5
	12:30	6540	5752	3	2			5		
	13:00	6527	5721		2			2		3
	13:00	6540	5752	3	2			5		
	13:30	6526	5722		2			2		6
	13:30	6541	5754	3	2			5		
	14:00	6525	5723		2			2		6
	14:00	6544	5754	3	2			5		
	14:00	6532	5741		1			1		
	14:30	6525	5723		2			2		
	14:30	6544	5754	3	2			5		2
	14:30	6519	5755		1			1		
	15:00	6525	5723		2			2		
	15:00	6521	5755		1			1		
	15:30	6525	5730		2			2		2
	15:30	6521	5755	2	3			5		3
	16:00	6520	5756	2	4			6		4
	16:30	6511	5747	3	5			8		2
	17:00	6511	5747	2	4			6		1
	17:30	6511	5747	2	3			5		
	18:00	6511	5747	2	3			5		
	18:00	6519	5757		2			2		
	18:00	6520	5754	1				1		1
	18:30	6511	5747	2	3			5		
	18:30	6513	5752		2			2		2
	18:30	6521	5762	1				1		
	19:00	6511	5747	3	5			8		
9:4:91	12:00	6533	5749	1	3			4		4
	12:30	6533	5749	1	3			4		3
	13:00	6533	5749	1	3			4		
	13:30	6532	5747	1	3			4		
	14:00	6527	5743	1	3			4		4
	14:30	6524	5740	1	3			4		4
	15:00	6526	5723	1	3			4		3
	15:00	6509	5727	1	1			2		
	15:30	6520	5729	2	4			6		
MAY										
13:5:91	4:30	6478	5722	1	2			3		
	5:00	6478	5722	1	2			3		

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
	5:30	6478	5721		3			3		
	6:00	6478	5721	1	3			4		
	6:30	6478	5721	1	3			4		
	7:00	6478	5721	1	3			4		
	7:30	6478	5721	1	3			4		
	8:00	6478	5721	3	5			8		3
	8:30	6478	5721	3	5			8		
	9:00	6478	5718	3	5			8		
	9:30	6486	5708	3	4			7		5
	10:00	6500	5694	3	4			7		4
	10:30	6506	5684	3	5			8		8
	11:00	6513	5674	3	5			8		8
	11:30	6513	5674	3	5			8		8
	12:00	6513	5675	3	5			8		5
14:5:91	13:00	6534	5736		3			3		1
	13:30	6518	5749	3	3			6		5
	13:30	6534	5736		2			2		2
	14:00	6523	5752	3	4			7		7
	14:30	6521	5751	3	5			8		8
	15:00	6519	5750	1	3			4		2
	15:00	6517	5750	1	2			3		
	15:30	6519	5750	1	3			4		2
	15:30	6517	5750	1	2			3		
	16:00	6519	5750	2	5			7		
	16:30	6519	5750	3	2			5		3
	16:30	6527	5751		3			3		
	17:30	6540	5748	3	2			5		8
	17:30	6518	5749		3			3		
	18:00	6519	5749	3	2			5		2
	18:00				3			3		
	18:30	6547	5746	3	2			5		2
	18:30				3			3		
	19:00	6548	5747	3	2			5		5
	19:00	6516	5751		3			3		3
	19:30	6550	5748	3	2			5		4
	19:30	6516	5751		3			3		3
	20:00	6550	5748	3	2			5		
	20:00	6516	5750		3			3		3
	20:30	6550	5748	3	2			5		
	20:30	6516	5750		3			3		
15:5:91	11:00	6515	5697	3	5			8		5
	11:30	6527	5698	3	5			8		8
	12:00	6525	5700	3	5			8		8
	12:30	6517	5717	3	5			8		4
	13:00	6517	5717	3	5			8		
	13:30	6515	5719	3	5			8		
JUNE										
16:6:91	3:30	6485	5714	3	5			8		2
	4:00	6497	5716	3	5			8		6
	4:30	6524	5726	3	5			8		4
	5:00	6528	5727	3	2			5		1
	5:00	6528	5725		3			3		3
	5:30	6541	5723	3	2			5		3
	5:30	6529	5728	0	3			3		3
	6:00	6536	5727	3	2			5		7
	6:00	6532	5729		3			3		
	6:30	6536	5727	3	5			8		6
	7:00	6532	5729	3	2			5		4
	7:00	6544	5729		3			3		1
	7:00	6545	5677	3	3	1		7	*	2

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
	7:30	6532	5729	3	2			5		
	7:30	6544	5729		3			3		2
	7:30	6550	5672	3	3	1		7	*	6
	8:00	6507	5722	3	2			5		2
	8:00	6550	5671	3	3	1		7	*	2
	8:30	6507	5722	3	2			5		1
	8:30	6550	5671	3	3	1		7	*	2
17:6:91	11:00	6576	5668	3	3	1		7	*	5
	11:30	6617	5669	3	3	1		7	*	7
	12:00	6619	5672	3	3	1		7	*	5
	12:30	6632	5670	3	3	1		7	*	4
	13:00	6636	5668	3	3	1		7	*	2
	13:30	6640	5665	3	3	1		7	*	6
	14:00	6645	5661	3	3	1		7	*	6
	14:30	6647	5660	3	3	1		7	*	3
	15:00	6645	5667	3	3	1		7	*	
	15:30	6645	5667	3	3	1		7	*	2
	16:00	6645	5668	3	3	1		7	*	2
	16:30	6646	5674	3	3	1		7	*	7
	17:30	6507	5688	3	4			7		2
	18:00	6508	5689	3	4			7		2
	18:30	6508	5689	3	4			7		1
	19:00	6508	5689	3	4			7		
	19:30	6508	5689	3	5			8		3
	20:00	6517	5696	3	4			7		7
	20:30	6500	5700	3	4			7		7
	21:00	6494	5707	3	4			7		
19:6:91	14:00	6509	5687	3	5			8		4
	14:30	6515	5686	3	5			8		2
	15:00	6516	5684	3	5			8		2
	15:30	6519	5684	3	5			8		7
	16:00	6526	5682	3	5			8		5
	16:30	6528	5684	3	5			8		
	18:00	6537	5690	3	5			8		6
	18:30	6538	5690	3	5			8		5
	19:00	6544	5692	3	5			8		5
	19:30	6544	5692	3	5			8		
	20:00	6560	5694	3	5			8		6
JULY										
19:7:91	4:30	6494	5717	3	4	1		8		
	5:00	6494	5717	3	4	1		8		
	5:30	6494	5717	3	4	1		8		
	6:00	6495	5716	3	4	1		8		
	6:30	6495	5716	3	4	1		8		1
	7:00	6495	5716	3	4	1		8		1
	7:30	6496	5715	3	4	1		8		2
	7:30	6507	5732		3	1		4	*	
	8:00	6494	5715	3	4	1		8		2
	8:00	6508	5731		3	1		4	*	
	8:30	6494	5710	3	4	1		8		1
	8:30	6508	5730		3	1		4	*	4
	9:00	6491	5706	3	4	1		8		3
	9:00	6508	5730		3	1		4	*	
	9:30	6489	5704	3	4	1		8		1
	9:30	6508	5730		3	1		4	*	1
	10:00	6478	5688	3	4	1		8		4
	10:00	6508	5730		3	1		4	*	
	10:30	6475	5688	3	4	1		8		8
	10:30	6509	5731		3	1		4	*	2
	11:00	6473	5685	3	4	1		8		7

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
	11:00	6508	5730		3	1		4	*	1
	11:30	6472	5683	3	4	1		8		8
	11:30	6513	5731		3	1		4	*	4
	12:00	6487	5686	3	4	1		8		5
	12:00	6518	5732		3	1		4	*	2
	12:30	6487	5686	3	4	1		8		4
	12:30	6520	5732		3	1		4	*	1
20:7:91	13:00	6559	5693	5	4	1		10		
	13:00	6574	5767	8	6	1		15	*	
	13:00	6550	5683	1	3	1		5	*	
	13:30	6559	5693	5	4	1		10		
	13:30	6574	5766	8	6	1		15	*	8
	13:30	6563	5693	1	3	1		5	*	
	14:00	6550	5694	5	4	1		10		6
	14:00	6558	5765	8	6	1		15	*	
	14:30	6529	5711	3	4	1		8		5
	14:30	6539	5761	8	6	1		15	*	
	14:30	6550	5694	2				2		
	15:00	6525	5713	3	4	1		8		7
	15:00	6538	5761	8	6	1		15	*	
	15:00	6556	5695	2				2		2
	15:30	6518	5713	3	4	1		8		8
	15:30	6538	5762	8	6	1		15	*	15
	15:30	6562	5693	2				2		2
	16:00	6513	5712	3	4	1		8		5
	16:00	6538	5762	8	6	1		15	*	12
	16:00	6575	5693	2				2		2
	16:30	6500	5712	3	4	1		8		7
	16:30	6538	5762	8	6	1		15	*	8
	16:30	6583	5693	2				2		2
	17:00	6515	5713	3	4	1		8		6
	17:00	6540	5765	8	6	1		15	*	12
	17:00	6598	5695	2				2		2
	17:30	6508	5714	3	4	1		8		8
	17:30	6553	5768	8	6	1		15	*	7
	18:00	6505	5715	3	4	1		8		7
	18:00	6572	5768	8	6	1		15	*	7
	18:30	6495	5718	3	4	1		8		7
	18:30	6578	5768	8	6	1		15	*	5
	19:00	6496	5718	3	4	1		8		7
	19:00	6588	5768	8	6	1		15	*	7
	19:30	6496	5718	3	4	1		8		5
	20:00	6497	5718	3	4	1		8		6
	20:30	6497	5718	3	4	1		8		6
	21:00	6500	5718	3	4	1		8		5
21:7:91	14:00	6547	5750	3	4	1		8		5
	14:00	6553	5750	1	4	1		6	*	6
	18:30	6514	5750	3	4	1		8		8
AUGUST										
20:8:91	5:00	6543	5752	2	1	1		4		4
	5:00	6549	5762	4	2			6	*	6
	5:30	6548	5752	2	1	1		4		4
	5:30	6551	5762	4	2			6	*	6
	6:00	6554	5752	4	3	1		8		8
	6:00	6552	5762	4	2			6	*	6
	6:30	6555	5752	3	4	1		8		7
	6:30	6573	5767	4	2			6	*	6
	6:30	6567	5757	1	1			2	*	2
	7:00	6559	5755	3	4	1		8		8
	7:00	6573	5767	4	2			6	*	6

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
	7:00	6559	5758	1	1			2	*	2
	7:30	6555	5753	4	5	1		10		9
	7:30	6574	5766	4	2			6	*	6
	7:30	6559	5758	1	1			2	*	2
	8:00	6551	5752	4	5	1		10		6
	8:00	6574	5766	4	2			6	*	6
	8:00	6536	5755	2	2	1		5	*	5
	8:30	6548	5752	3	1			4		1
	8:30	6574	5766	4	2			6	*	2
	8:30	6540	5758	3	3	1		7	*	1
	9:00	6548	5752	3	1			4		
	9:00	6574	5767	4	2			6	*	2
	9:00	6540	5758	3	3	1		7	*	3
	9:30	6548	5752	3	1			4		
	9:30	6574	5767	4	2			6	*	3
	9:30	6542	5757	3	3	1		7	*	4
	10:00	6548	5752	4	5	1		10		9
	10:00	6552	5758	2	2	1		5	*	4
	10:30	6549	5752	4	5	1		10		7
	10:30	6559	5760	2	2	1		5	*	5
	11:00	6549	5752	4	5	1		10		6
	11:00	6560	5760	2	2	1		5	*	4
	11:30	6549	5753	4	5	1		10		6
	11:30	6563	5760	2	2	1		5	*	
21:8:91	13:30	6530	5745	4	5	1		10		5
	14:00	6532	5746	4	5	1		10		
	14:00	6576	5765	1	1			2	*	1
	14:30	6540	5751	4	5	1		10		6
	14:30	6573	5768	1	1			2	*	
	15:00	6540	5751	4	5	1		10		4
	15:00	6569	5773	1	1			2	*	1
	15:30	6540	5751	4	5	1		10		3
	15:30	6569	5773	1	1			2	*	
	16:00	6540	5751	4	5	1		10		6
	16:00	6569	5773	1	1			2	*	
	16:30	6541	5751	4	5	1		10		9
	17:00	6542	5752	4	5	1		10		7
	17:30	6543	5752	4	5	1		10		8
	17:30	6576	5766	2	1			3	*	3
	18:00	6544	5755	4	5	1		10		7
	18:00	6576	5771	4	2			6	*	6
	18:30	6542	5757	4	5	1		10		7
	18:30	6576	5776	5	4			9	*	8
	19:00	6538	5757	4	5	1		10		3
	19:00	6573	5773	5	4			9	*	3
	19:30	6538	5756	4	5	1		10		6
22:8:91	10:30	6495	5724	4	5	1		10		6
	10:30	6554	5771	5	3			8	*	
	11:00	6495	5724	4	5	1		10		3
	11:00	6554	5771	5	3			8	*	3
	11:30	6495	5724	4	5	1		10		
	12:00	6495	5724	4	5	1		10		
	12:30	6499	5727	4	5	1		10		8
	13:00	6499	5727	4	5	1		10		9
	13:30	6498	5727	4	5	1		10		2
	14:00	6493	5719	3	2			5		
	14:00	6497	5727	1	3	1		5		
SEPTEMBER										
8:9:91	5:30	6501	5781	2	5	1		8		8
	5:30	6525	5764	5	3	1		9	*	7

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
	5:30	6538	5760	2	7			9	*	11
	6:00	6501	5781	2	5	1		8		8
	6:00	6524	5764	5	3	1		9	*	9
	6:00	6537	5760	2	7			9	*	9
	6:30	6501	5781	2	5	1		8		6
	6:30	6523	5764	5	2	1		8	*	8
	6:30	6536	5760	2	7			9	*	8
	7:00	6501	5781	2	5	1		8		7
	7:00	6523	5764	5	2	1		8	*	2
	7:00	6531	5762	2	8	1		11	*	6
	7:30	6501	5781	2	5	1		8		6
	7:30	6523	5764	5	2	1		8	*	4
	7:30	6529	5763	2	8	1		11	*	6
	8:00	6511	5783	2	5	1		8		4
	8:00	6521	5768	5				5	*	
	8:00	6521	5763		2	1		3	*	3
	8:00	6530	5763	2	8	1		11	*	3
	8:30	6511	5783	2	5	1		8		3
	8:30	6521	5763	2	2	1		5	*	2
	8:30	6530	5763	2	8	1		11	*	
	9:00	6511	5783	2	5	1		8		3
	9:00	6521	5763	2	2	1		5	*	4
	9:00	6530	5763	2	8	1		11	*	
	9:30	6501	5785	2	5	1		8		
	9:30	6521	5763	2	2	1		5	*	
	9:30	6530	5763	1	8	1		10	*	
	10:00	6501	5785	2	5	1		8		1
	10:00	6521	5763	2	2	1		5	*	1
	10:00	6530	5763	1	8	1		10	*	4
	10:30	6501	5785	2	5	1		8		3
	10:30	6519	5772	5				5	*	2
	10:30	6515	5764	2	2	1		5	*	3
	10:30	6530	5763	1	8	1		10	*	4
	11:00	6501	5785	2	5	1		8		3
	11:00	6518	5772	5				5	*	3
	11:00			2	2	1		5	*	1
	11:00	6530	5763	1	8	1		10	*	1
	11:30			2	5	1		8		
	11:30	6518	5772	5				5	*	3
	11:30			2	2	1		5	*	
	11:30	6530	5763	1	8	1		10	*	2
9:9:91	12:00	6518	5767		2	1		3		3
	12:00	6525	5795	1	3	1		5		5
	12:30	6518	5767		2	1		3		3
	12:30	6525	5795	1	3	1		5		4
	13:00	6515	5747			1		1		1
	13:00	6523	5795		2			2		2
	13:00	6553	5759	3	3			6	*	
	13:30	6515	5747			1		1		1
	13:30	6521	5796	3	2	1		6		6
	13:30	6553	5758	3	4	1		8	*	4
	14:00	6520	5796	3	2	1		6		1
	14:00	6556	5758	3	4	1		8	*	5
	14:00	6436	5722	2				2	*	
	14:30	6520	5796	3	2	1		6		2
	14:30	6556	5758	3	4	1		8	*	2
	15:00	6520	5796	3	2	1		6		3
	15:00	6556	5758	3	4	1		8	*	3
	15:30	6520	5796	3	2	1		6		3
	15:30	6556	5758	3	4	1		8	*	3

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
	16:00	6524	5781	1	2			3		3
	16:30	6516	5748		2	1		3	*	2
	16:30	6527	5778	4	6	1		11		2
	17:00	6516	5748		2	1		3	*	3
	17:00	6527	5778	4	6	1		11		4
	17:30	6526	5779	4	7	2		13		8
	18:00	6526	5779	4	7	2		13		7
	18:30	6524	5778	4	7	2		13		8
	18:30	6551	5746	3	4	2		9	*	7
	18:30	6494	5733	2				2	*	
10:9:91	10:00	6526	5795	12	8	1		21	*	
	10:00	6506	5787	6	5	1		12		
OCTOBER										
13:10:91	6:30	6505	5744	3	7	1		11		3
	7:00	6508	5744	3	7	1		11		4
	7:30	6513	5749	3	7	1		11		8
	8:00	6517	5747	3	7	1		11		4
	8:30	6525	5747	3	7	1		11		6
	9:00	6526	5755	3	8	1		12		11
	9:30	6533	5762	3	8	1		12		11
	10:00	6540	5768	3	8	1		12		10
	10:30	6536	5772	3	8	1		12		
	11:00	6536	5772	3	8	1		12		
14:10:91	11:30	6558	5718	1	2			3		3
	12:00	6558	5718	1	2			3		3
	12:30	6558	5718	1	2			3		
	13:00	6558	5718	2	3			5		3
	13:00	6564	5769	2	2			4		4
	13:30	6556	5717	4	5			9		6
	14:00	6556	5717	3	5			8		8
	14:00	6564	5718	1				1		
	14:30	6552	5721	3	5			8		8
	14:30	6569	5719	1				1		1
	15:00	6552	5723	3	5			8		6
	15:30	6555	5726	3	5			8		7
	16:00	6557	5729	3	5			8		8
	16:30	6564	5726	3	5			8		8
	17:00	6566	5727	3	5			8		8
	17:30	6566	5727	3	5			8		
15:10:91	11:30	6547	5752	3	5			8		8
	11:30	6485	5727	2	1	1		4		2
	12:00	6546	5753	5	5			10		
NOVEMBER										
16:11:91	8:30	6456	5715	4	5			9		8
	9:00	6455	5725	4	5			9		9
	9:30	6451	5721	2	3			5		3
	9:30	6459	5726	2	2			4		4
	10:00	6451	5721	2	3			5		2
	10:00	6459	5726	2	2			4		2
	10:30	6465	5733	1	2			3		3
	10:30	6461	5727	2	2			4		4
	10:30	6453	5722	1	1			2		2
	11:00	6456	5723	1	2			3		1
	11:00	6475	5738	3	3			6		1
	11:30	6456	5723	1	2			3		
	11:30	6470	5730	3	3			6		6
	12:00	6452	5728	1	2			3		
	12:00	6470	5730	3	3			6		6
18:11:91	16:00	6472	5724	4	5			9		9
	16:30	6473	5723	4	5			9		9

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
19:11:91	10:00	6509	5704	2	2			4		1
	10:00	6492	5711	2	3			5		
	10:30	6502	5710	2	2			4		3
	10:30	6495	5718	2	3			5		4
	11:00	6503	5717	2	2			4		4
	11:00	6493	5717	2	3			5		
	11:30	6499	5722	2	2			4		4
	11:30	6493	5717	2	3			5		3
	12:00	6499	5722	2	2			4		4
	12:00	6494	5722	2	3			5		5
	12:30	6493	5724	4	5			9		8
	13:00	6492	5725	4	5			9		9
	13:30	6489	5725	4	5			9		9
	14:00	6488	5726	4	5			9		9
	14:30	6485	5725	4	5			9		9
	15:00	6485	5724	4	5			9		9
	15:30	6484	5723	4	5			9		9
	16:00	6486	5722	4	5			9		9
DECEMBER										
14:12:91	9:00	6455	5714	3	4			7		2
	9:00	6486	5727	2	3	2		7	*	4
	9:00	6523	5765		3	1	1	5	*	3
	9:30	6443	5711	3	4			7		4
	9:30	6481	5727	2	3	2		7	*	5
	9:30	6529	5769		3	1	1	5	*	5
	10:00	6435	5704	3	4			7		6
	10:00	6478	5719	1	1			2		
	10:00	6476	5724	2	3	2		7	*	4
	10:00	6534	5769		3	1	1	5	*	5
	10:30	6440	5705	3	4			7		1
	10:30	6465	5722	3	4	2		9		8
	10:30	6538	5772		3	1	1	5	*	1
	11:00	6441	5705	3	4			7		7
	11:00	6453	5723	3	4	2		9		6
	11:00	6542	5773		3	1	1	5	*	5
	11:30	6446	5707	3	4			7		4
	11:30	6453	5723	3	4	2		9		5
	11:30	6544	5773		3	1	1	5	*	5
	12:00	6448	5712	1	4			5		2
	12:00	6450	5717	5	4	2		11		4
	12:00	6539	5773		3	1	1	5	*	1
	12:30	6441	5712	6	8	2		16		9
	12:30	6539	5773		3	1	1	5	*	1
	13:00	6436	5708	1	5			6		5
	13:00	6433	5702	5	3	2		10		
	13:00	6539	5775		3	1	1	5	*	5
	13:30	6431	5707	1	5			6		6
	13:30	6431	5703	5	3	2		10		6
	13:30	6528	5772		3	1	1	5	*	
	14:00	6412	5693	1	7			8		
	14:00	6431	5703	5	1	2		8		6
	14:00	6527	5772		3	1	1	5	*	5
	14:30	6405	5686	6	8	2		16		6
	14:30	6526	5771		3	1	1	5	*	4
	15:00	6389	5684	6	8	2		16		
	15:30	6379	5688	6	8	2		16		
	15:30	6370	5685	1	2		1	4	*	3
	16:00	6371	5695	6	8	2		16		3
	16:00	6518	5763		3	1	1	5	*	4
	16:00	6361	5688	1	2		1	4	*	2

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
15:12:91	11:00	6359	5699	2	3			5		
	11:00	6365	5725	3	3	2		8		
	11:00	6359	5699	1	2		1	4	*	
JANUARY										
15:1:92	8:00	6511	5738	4	7	1	1	13		9
	8:30	6513	5739	4	7	1	1	13		10
	9:00	6515	5739	4	7	1	1	13		10
	9:30	6523	5741	4	7	1	1	13		8
	10:00	6526	5744	4	7	1	1	13		9
	10:30	6528	5746	4	7	1	1	13		10
	11:00	6535	5755	4	6	1	1	12		6
	11:00	6531	5753		2			2		2
	11:30	6543	5752	4	7	1	1	13		13
	12:00	6546	5748	4	7	1	1	13		9
	12:30	6548	5747	1	4			5		4
	12:30	6550	5745	3	2	1	1	7		5
	13:00	6548	5747	1	5			6		
	13:00	6550	5745	3	2	1	1	7		4
	13:30	6548	5747	3	4			7		5
	13:30	6553	5741	1	3	1	1	6		3
	14:00	6554	5745	4	7	1	1	13		11
	14:30	6551	5751	3	5			8		8
	14:30	6554	5750	1	2	1	1	5		4
15:1:92	15:00	6548	5759	3	5			8		6
	15:00	6551	5758	1	2	1	1	5		2
	15:30	6546	5760	4	7	1	1	13		13
	16:00	6551	5766	3	5			8		7
	16:00	6547	5760	1	2	1	1	5		2
	16:30	6551	5766	3	5			8		
	16:30	6547	5760	1	2	1	1	5		1
17:1:92	11:30	6540	5744	4	7	1		12		12
	12:00	6536	5743	4	7	1		12		12
	12:30	6533	5742	4	7	1	1	13		13
	13:00	6531	5741	4	7	1	1	13		8
	13:30	6527	5739	4	7	1	1	13		
FEBRUARY										
17:2:92	9:00	6566	5665	1	3		1	5	*	4
	9:00	6542	5668		2			2		2
	9:30	6565	5665	1	3		1	5	*	2
	9:30	6542	5667		2			2		2
	9:30			3	2			5		
	10:00	6565	5665	1	3		1	5	*	1
	10:00	6545	5673	3	4			7		2
	10:30	6565	5665	1	3		1	5	*	4
	10:30	6545	5673	3	4			7		4
	11:00	6564	5664	1	3		1	5	*	5
	11:00	6545	5677	3	2			5		4
	11:00	6541	5663		2			2		1
	11:30	6556	5670	1	2		1	4	*	3
	11:30	6545	5665	3	3			6		6
	11:30	6546	5656		1			1		1
	11:30	6545	5664		1			1		1
	12:00	6561	5677	1	3		1	5	*	5
	12:00	6544	5688	3	3			6		2
	12:00	6543	5666		1			1		
	12:30	6571	5679	1	3		1	5	*	4
	12:30	6544	5690	3	3			6		4
	12:30	6564	5667		1			1		1
	13:00	6571	5679	1	3		1	5	*	2
	13:00	6542	5698	3	4			7		4

Date	Time	LONG	LAT	Male	Female	Kid	Hummel	Total	*	Number observed feeding
	13:30	6571	5679	1	3		1	5	*	
	13:30	6542	5698	3	4			7		
	14:00	6571	5679	1	3		1	5	*	
	14:00	6542	5698	3	4			7		2
	14:30	6542	5698	3	4			7		3
	15:00	6542	5697	3	4			7		2
	15:30	6542	5697	3	4			7		
	16:00	6544	5698	3	4			7		6
	16:30	6543	5699	2	4			6		4
	17:00	6544	5699	2	2			4		4
	17:30	6544	5699	2	2			4		4

2.2 Padarn area.

* Denotes groups of goats seen at the site but which were not associated with the main group studied.
? Denotes goats that were counted and located but not immediately sexed.

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
MARCH											
6:3:91	7:00	5869	6041		2	3	1		6		1
	7:30	5882	6023		2	3	1		6		3
	8:00	5895	6015	6	1	1	3		11		
	8:30	5910	6000	4	2	1	3		10		8
	9:00	5910	6000	5	3	1	2		11		6
	9:30	5885	6000	4	2	1			7		
	10:00	5880	6015	4	1	1	2		8		5
	10:30	5890	6015	5	3	1	1		10		3
	11:00	5888	6027	4	3	1	3		11		6
	11:30	5888	6027	7	4	1	3		15		12
	12:00	5888	6027	4	3	1	3		11		11
	12:30	5910	6009	6	3	1	3		13		
	13:00	5910	6009	6	2	1	2		11		
7:3:91	13:30	5921	6020					15	15		
	14:00	5921	6020					15	15		9
	14:30	5921	6020					15	15		
	15:00	5921	6020					15	15		
	15:30	5921	6020					15	15		
	16:00	5921	6020					15	15		
	16:30	5910	6011					15	15		
	17:00	5885	6023					15	15		10
	17:30	5883	6027					15	15		13
	18:00	5870	6040				2	13	15		2
	18:30	5880	6030					15	15		15
	19:30	5870	6046		2	2			4		2
APRIL											
10:4:91	5:00	5867	6046		2	2			4		1
	5:30	5867	6046		2	2			4		
	5:30	5870	5980		3	2			5	*	3
	6:00	5862	6046		2	2			4		
	6:00	5870	5980		3	2			5	*	4
	6:30	5862	6047		2	2			4		
	7:00	5861	6051		2	1			3		
	7:00	5867	6048			1			1		
	9:00	5817	6097	3			1		4		4
	9:30	5817	6097	1			2		3		2
	10:00	5820	6090	4	2	3	2		11		8
	10:30	5821	6089	4	2	1	2		9		9
	11:00	5826	6098	5		1	2		8		4
	11:30	5828	6098	7	2	3	2		14		5
	12:00	5828	6098	8	2	2	2	3	17		3
	12:30	5828	6098	8	2	3	4		17		
	13:00	5828	6098	8	2	2	5		17		6
	13:30	5828	6098	9	3	2	3		17		1
	14:00	5823	6092	7	3	1	1		12		3
11:4:91	14:00	5807	6102	5	4	1	4		14		10
	14:30	5808	6099	9	5	4	4	1	23		19
	15:00	5808	6099	11	4	4	4		23		18
	15:30	5807	6101	4	3	2	1		10		5
	16:00	5807	6101	10	3	4	1		18		12
	16:30	5828	6098	3	2	2			7		3

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
	17:00	5832	6082	6	2	2	1		11		8
	17:30	5839	6071	9	2	2	3	1	17		14
	18:00	5845	6064	9	2	2	3		16		
	18:00	5867	6046		1	1			2		
	18:30	5857	6068	11	3	3	4	2	23		2
	18:30	5867	6046		1	1			2		
	19:00	5871	6067	11	3	3	4	2	23		2
	19:00	5867	6046		1	1			2		
12:4:91	11:00	5807	6103	6	3	1		1	11		3
	11:30	5807	6103	6	3	1	2	1	13		
	12:00	5807	6103	8	1		1		10		
	12:30	5807	6103	8	1		1		10		
	13:00	5825	6097	4		1	2		7		2
	13:30	5825	6097	8	2		2		12		4
	14:00	5825	6097	4	4	1	1		10		4
	14:30	5808	6106	4	2	1	3	1	11		7
	15:00	5808	6106	13	5	4	4		26		
	15:30	5832	6084	13	2	1	4		20		15
	16:00	5834	6080	5	2	1	1		9		9
MAY											
15:5:91	18:30	5875	6061				1		1		
16:5:91	4:00	5875	6061	1	1		1		3		
	4:30	5875	6061	1	1		1		3		
	5:00	5798	6113	5			1	2	8		1
	5:30	5798	6113	4	1	1	3		9		6
	6:00	5797	6115	6	4	1	3		14		8
	6:30	5795	6120	6	5	3	3		17		2
	7:00	5781	6119	7	5	4	4		20		5
	7:30	5724	6151	5	1	1	1	1	9		
	7:30	5736	6146	2			3		5		
	7:30	5774	6119		5	5			10		5
	8:00	5708	6166	7	1	1	4		13		3
	8:00	5778	6111		4	3			7		5
17:5:91	9:00	5697	6185	5					5		
	9:30	5697	6185	5					5		
	10:00	5887	6012	1	3	2	2		8	*	3
	10:30	5886	6009	1	3	2	2		8	*	8
	11:00	5885	6008	1	3	2	2		8	*	7
	11:30	5880	6003	1	3	2	2		8	*	8
	12:00	5880	6003	1	3	2	2		8	*	2
	13:30	5697	6174	7	1	1	3		12		
	14:00	5697	6174	7	1	1	3		12		
	14:30	5697	6175	7	1	1	3		12		5
	16:30	5697	6176	7	1	1	3		12		7
	17:30	5754	6133		2	5	3		10		5
	18:00	5754	6133		2	5	3		10		8
	19:00	5696	6183	3	1	1	1		6		2
	20:00	5696	6184					3	3		1
JUNE											
24:6:91	3:30	5952	6018	13	1	1	5		20		
	4:00	5935	6043	13	1	1	5		20		
	4:30	5922	6046	13	1	1	5		20		5
	4:30	5934	5988		2	2			4		2
	5:00	5922	6049	13	1	1	5		20		1
	5:00	5932	5978		2	2			4		
	5:30	5922	6049	14	1	1	5		21		3
	5:30	5931	5969		2	2			4		
	6:00	5905	6034	14	1	1	5		21		
	6:30	5910	6074	14	1	1	5		21		4
	7:00	5932	6065	14	1	1	5		21		

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
	7:00	5956	5927		5	4			9		
	7:30	5932	6065	14	1	1	5		21		
	7:30	5956	5927		5	4			9		
	8:00	5956	5927		5	4			9		
	8:00	5940	6079					3	3		
	8:30	5960	5922		5	4			9		9
	9:00	5964	5921		5	4			9		9
	9:30	5969	5920		5	4			9		7
	10:00	5963	5928		5	4			9		5
	10:00	5912	6103	14	1	1	5		21		
	10:30	5906	6095	14	1	1	5		21		11
25:6:91	13:00	5965	6040	14	1	1	5		21		7
	13:00	5930	6015		5	4			9		9
	13:30	5965	6040	14	1	1	5		21		7
	14:00	5965	6040	14	1	1	5		21		1
	14:00	5945	6016		5	4			9		
	14:30	5965	6040	14	1	1	5		21		
	14:30	5955	6012		5	4			9		
	15:00	5965	6040	14	1	1	5		21		
	15:00	5965	5969		4	2			6		1
	15:00	5968	5973		1	2			3		3
	15:30	5955	5964		4	2			6		4
	15:30	5965	5969		1	2			3		3
	16:00	5951	6039	9	1	1	3		14		7
	16:30	5951	6039	11		1	4		16		8
	17:00	5951	6039	14	1	1	5		21		7
	17:30	5951	6039	5		2			7		
	17:30	5943	6062	8	1	1	3		13		
	17:30	5942	6048	1					1		
	18:00	5951	6039	5		2			7		
	18:00	5943	6062	8	1	1	3		13		
	18:00	5940	6054	1					1		
	18:30	5953	6060	5		2			7		
	18:30	5935	6070	9	1	1	3		14		2
	19:00	5931	6062	14	1	1	5		21		6
	19:30	5946	6060	14	1	1	5		21		5
	20:00	5949	6044	14	1	1	5		21		
	20:30	5927	6031	14	1	1	5		21		4
26:6:91	12:00	5949	6041	3			1		4		
	12:00	5965	6041				1		1		
	12:30	5949	6041	3			1		4		
	13:00	5930	5970		5	4			9		
	13:30	5930	5970		5	4			9		
	14:00	5930	5970		5	4			9		
JULY											
15:7:91	4:00	5920	6020	13	1	1	4		19		
	4:00	5920	6015		2	1			3		
	4:30	5920	6020	13	1	1	4		19		
	4:30	5920	6015		2	1			3		3
	5:00	5920	6020	13	1	1	4		19		
	5:00	5920	6015		2	1			3		
	5:30	5920	6020	13	1	1	4		19		
	5:30	5920	6015		2	1			3		
	6:00	5920	6020	13	1	1	4		19		
	6:00	5920	6015		2	1			3		
	6:30	5920	6020	13	1	1	4		19		
	6:30	5920	6015		2	1			3		3
	7:00	5890	6016	13	1	1	4		19		
	7:00	5920	6018		2	1			3		3
	7:30	5883	6032	13	1	1	4		19		10

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
	7:30	5882	6016		2	1			3		
	8:00	5875	6049	13	6	5	4		28		9
	8:30	5875	6049	13	6	5	4		28		3
	9:00	5880	6054	11			2		13		
	9:00	5873	6048	2	6	5	2		15		6
	9:30	5880	6048	11			2		13		
	9:30	5873	6054	4	6	5			15		6
	10:00	5873	6055	3	6	5	1		15		5
	10:30	5873	6055	2	6	5	1		14		1
	11:00	5873	6055	2	6	5	1		14		2
16:7:91	11:30	5874	6056		3	3			6		
	12:00	5874	6056		3	3			6		
	12:30	5874	6056		3	3			6		
	13:00	5874	6056		3	3			6		2
	13:30	5804	6093	2	2	1			5		
	14:00	5835	6085	7	2	1	3		13		7
	14:30	5860	6078	14	3	2	4		23		14
	14:30	5877	6060		3	3			6		
	15:00	5865	6077	14	3	2	4		23		2
	15:30	5865	6077	14	3	2	4		23		
	16:00	5865	6077	14	3	2	4		23		
	16:30	5865	6077	14	3	2	4		23		
	17:00	5865	6077	14	3	2	4		23		3
	17:30	5838	6091	13	1	1	3		18		
	17:30	5863	6074	1	2	1	1		5		5
	18:00	5823	6096	13	1	1	3		18		15
	18:00	5863	6074	1	2	1	1		5		3
	18:30	5831	6089	13	1	1	3		18		15
	18:30	5863	6074	1	2	1	1		5		
	19:00	5845	6079	13	1	1	3		18		
	19:00	5863	6074	1	2	1	1		5		
	19:30	5859	6071	14	3	2	4		23		16
	20:00	5863	6065	14	3	2	4		23		7
	20:30	5870	6066	14	1	1	4		20		2
	20:30	5873	6064		2	1			3		2
	21:00	5870	6066	14	3	2	4		23		
17:7:91	13:30	5835	6085	14	3	2	4		23		15
	14:00	5846	6082	14	3	2	4		23		16
	14:30	5855	6080	14	3	2	4		23		10
	15:00	5863	6078	14	3	2	4		23		3
	15:30	5863	6078	14	3	2	4		23		
	16:00	5863	6078	14	3	2	4		23		
	16:30	5863	6078	14	3	2	4		23		
	17:00	5855	6084	14	3	2	4		23		12
	17:30	5957	5997		3	3			6		2
	18:00	5958	6002		3	3			6		2
	18:30	5958	6004		3	3			6		6
	19:00	5955	5991		3	3			6		3
	19:30	5957	5997		3	3			6		2
AUGUST											
12:8:91	4:30	5874	6065		6	4			10		
	5:00	5874	6065		6	4			10		
	5:30	5874	6065		6	4			10		3
	6:00	5874	6065		6	4			10		3
	6:30	5875	6070		5	4			9		4
	6:30	5874	6065		1				1		
	7:00	5878	6075		5	4			9		3
	7:00	5874	6063		1				1		
	7:30	5878	6075		5	4			9		5
	7:30	5874	6063		1				1		1

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
	8:00	5878	6075		5	4			9		2
	8:00	5872	6064		1				1		
	8:30	5876	6062		5	4			9		7
	8:30	5873	6064		1				1		1
	9:00	5876	6062		5	4			9		9
	9:00	5875	6062		1				1		1
	9:30	5876	6062		5	4			9		9
	9:30	5875	6062		1				1		1
	10:00	5876	6062		5	4			9		6
	10:00	5874	6068		1				1		1
	10:30	5877	6063		5	4			9		1
	10:30	5874	6068		1				1		
	11:00	5877	6063		5	4			9		2
	11:00	5874	6068		1				1		1
	11:30	5877	6063		5	4			9		1
	11:30	5874	6068		1				1		1
	12:00	5877	6063		5	4			9		1
	12:00	5874	6068		1				1		1
13:8:91	12:00	5875	6066		1	1			2		
	12:30	5875	6066		1	1			2		
	13:00	5801	6097	13			3		16		
	13:30	5801	6097	13			3		16		
	14:00	5801	6097	13			3		16		3
	14:30	5801	6097	13			3		16		4
	15:00	5800	6100	13			3		16		13
	15:30	5802	6107	13			3		16		16
	16:00	5803	6107	13			3		16		10
	16:30	5802	6106	13			3		16		14
	16:30	5875	6066		1	1			2		
	17:00	5803	6106	13			3		16		12
	17:00	5875	6066		1	1			2		
	17:30	5801	6106	13			3		16		15
	18:00	5802	6105	13			3		16		13
	18:00	5875	6066		1	1			2		
14:8:91	12:00	5953	6041		5	5			10		
	12:30	5923	6041		5	5			10		
	13:00	5923	6041		5	5			10		
	13:30	5923	6041		5	5			10		
	14:00	5923	6041		5	5			10		
	14:30	5940	6033		5	5			10		5
	15:00	5945	6029		5	5			10		8
SEPTEMBER											
11:9:91	5:30	5942	5993	5		1			6		
	5:30	5945	6005		5	6	1		12		2
	5:30	5937	6008		1	1			2		
	5:30	5970	5865	9	1		5		15		
	6:00	5949	5997	3		1			4		
	6:00	5941	6003	2	5	5	1		13		1
	6:00	5937	6008		1	2			3		3
	6:00	5970	5865	9	1		5		15		
	6:30	5956	5997	3		1			4		
	6:30	5933	6006	1	5	5	1		12		6
	6:30	5943	5991		1	2			3		3
	6:30	5912	6012	1					1		
	6:30	5970	5865	9	1		5		15		
	7:00	5980	5877	3		1			4		
	7:00	5933	6006	1	5	5	1		12		2
	7:00	5940	5986		1	2			3		
	7:00	5970	5865	9	1		5		15		
	7:30	5933	6006	1	5	5	1		12		2

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
	7:30	5940	5986		1	2			3		
	7:30	5970	5865	12	1	1	5		19		3
	8:00	5933	6006	1	5	5	1		12		2
	8:00	5940	5986		1	2			3		
	8:00	5970	5865	12	1	1	5		19		3
	8:30	5933	6006	1	5	5	1		12		4
	8:30	5940	5986		1	2			3		3
	8:30	5970	5865	12	1	1	5		19		2
	9:00	5933	6006	1	5	5	1		12		
	9:00	5940	5986		1	2			3		3
	9:00	5970	5865	12	1	1	5		19		1
	9:30	5933	6006	1	5	5	1		12		
	9:30	5940	5986		1	2			3		
	9:30	5970	5865	12	1	1	5		19		2
	10:00	5933	6006	1	5	5	1		12		
	10:00	5940	5986		1	2			3		
	10:00	5970	5865	12	1	1	5		19		3
	10:30	5933	6006	1	5	5	1		12		
	10:30	5940	5986		1	2			3		
	10:30	5970	5865	12	1	1	5		19		
	11:00	5933	6006	1	5	5	1		12		3
	11:00	5940	5986		1	2			3		3
	11:00	5970	5865	12	1	1	5		19		3
12:9:91	11:30	5921	6003		4	4	1		9		
	12:00	5921	6003		4	4	1		9		
	12:30	5921	6003		4	4	1		9		
	12:30	5865	5880	1	2	2	1		6	*	6
	12:30	5990	5830	4	1		1		6	*	1
	13:00	5921	6003		4	4	1		9		
	13:00	5865	5880	1	2	2	1		6	*	5
	13:00	5990	5830	4	1		1		6	*	2
	13:30	5921	6003		4	4	1		9		
	13:30	5865	5880	1	2	2	1		6	*	4
	13:30	5990	5830	4	1		1		6	*	4
	14:00	5921	6003		4	4	1		9		
	14:30	5923	6004		4	4	1		9		7
	15:00	5921	6003		4	4	1		9		5
	15:00	5990	5829	3	1		1		5	*	1
	15:30	5921	6003		4	4	1		9		
	15:30	5990	5829	3	1		1		5	*	
	16:00	5921	6003		4	4	1		9		
	16:00	5990	5829	3	1		1		5	*	2
	16:30	5921	6003		4	4	1		9		
	16:30	5990	5829	3	1		1		5	*	2
	17:00	5923	6004		4	4	1		9		6
	17:00	5860	5870	1	2	2	1		6	*	2
	17:00	5980	5915	3	1		1		5	*	2
	17:00	6001	5900		1	1			2	*	2
	17:30	5933	5993		4	4	1		9		
	17:30	5860	5870	1	2	2	1		6	*	
	17:30	5980	5915	3	1		1		5	*	2
	17:30	6001	5900		1	1			2	*	2
	18:00	5933	5993		4	4	1		9		1
	18:00	5860	5870	1	2	2	1		6	*	
	18:00	5980	5795	3	1		1		5	*	2
	18:00	6001	5900		1	1			2	*	2
	18:30	5933	5993		4	4	1		9		3
	18:30	5980	5795	3	1		1		5	*	2
13:9:91	12:00	5934	6014		6	7	1		14		2
	12:00	6001	5798	1	1	1	1		4	*	4

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
17:9:91	14:00	5886	6062		3	2	2		7		6
	14:00	5941	6003		2	3			5		
23:9:91	10:00	6305	5665	13	5	2	1	1	22		
	11:00	6305	5665	3	2	2	1		8		
	11:00	6350	5645	6					6		2
OCTOBER											
16:10:12	14:45	5826	6087	1	6	7			14		14
19:10:91	7:30	6105	5840	1	2	1			4		4
	7:30	6170	5780		1	1			2		
	8:00	6280	5635	1	2	1			4		1
	8:00	6170	5780		2	1			3		3
	9:30	5864	6086		2	3			5		5
	10:00	5862	6086		2	3			5		5
	10:00	5875	6069	4	4	2			10		
	10:30	5861	6082		2	3			5		5
	10:30	5875	6069	4	4	2			10		
	11:00	5861	6082		2	3			5		
	11:00	5875	6069	4	4	2			10		
	11:30	5859	6085	1	2	3	1		7		6
	11:30	5875	6069	2	4	4			10		
	11:30	5865	6076	3					3		
20:10:91	12:30	5869	6048				1		1		1
	13:00	5865	6076	4			1		5		
	13:00	5864	6086	1	4	5		1	11		11
	13:30	5865	6076	4			1		5		
	13:30	5864	6086	1	4	5		1	11		8
	14:00	5865	6076	4					4		
	14:00	5864	6086	1	4	5	1		11		10
	14:30	5851	6081	4					4		4
	14:30	5859	6085	1	4	5	1		11		6
	15:00	5844	6085	4			1		5		5
	15:00	5856	6085	1	4	5			10		7
	15:30	5842	6085	4			1		5		
	15:30	5855	6084	1	4	5			10		6
	16:00	5842	6084	4			1		5		
	16:00	5855	6084	1	4	5			10		5
	16:30	5842	6084	4			1		5		3
	16:30	5855	6084	1	4	5			10		5
	17:00	5857	6082	5	4	5	1		15		4
	17:30	5865	6076	5	1	1	1		8		
	17:30	5869	6068		4	5			9		
NOVEMBER											
20:11:91	10:30	5883	6067	6	5	4	1		16		16
	11:00	5883	6067	6	5	4	1		16		16
	11:30	5884	6064	6	5	4	1		16		16
	12:00	5881	6065	1	5	4	1		11		6
	12:30	5881	6065	1	4	4	1		10		5
	13:00	5882	6064		4	4			8		
	13:30	5882	6064		4	4			8		
	14:00	5881	6067		3	4			7		3
	14:30	5881	6069		3	1			4		4
	15:00	5881	6069		3	1			4		4
	15:00	5883	6072	11	2	3	3		19		10
	15:30	5881	6069		3	1			4		
	15:30	5883	6072	11	2	3	3		19		5
	16:00	5887	6061	11	5	4	3		23		6
	16:30	5887	6061	5	3	2	3		13		13
DECEMBER											
16:12:91	9:00	5876	6042	1	3	5			9		8
	9:00	5854	6054					4	4		4

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
	9:30	5872	6042	1	2	4		1	8		8
	9:30	5862	6066		1	3			4		
	10:00	5872	6045	1	3	5			9		7
	10:30	5872	6044	1	3	5			9		7
	11:00	5872	6044	1	3	5			9		2
	11:30	5872	6044	1	3	5			9		
	12:00	5872	6044	1	3	5			9		5
	12:30	5873	6043	1	3	5			9		8
	12:30	5863	6068		1	3			4		4
	13:00	5874	6042	1	3	5			9		8
	13:00	5863	6068		1	3			4		4
	13:30	5875	6035	1	4	4	1		10		10
	14:00	5877	6033	1	4	4	1		10		10
	14:30	5878	6032	1	4	4	1		10		9
	15:00	5876	6035	1	4	4	1		10		6
	15:30	5874	6043	1	4	4	1		10		10
	16:00	5873	6044	1	4	4	1		10		8
	16:30	5872	6048	1	4	4	1		10		10
17:12:91	11:00	5877	6061	1	4	4	1		10		6
	11:00	5866	6067		1	2			3		3
	11:30	5877	6061	1	4	4	1		10		6
	11:30	5866	6067		1	2			3		3
	12:00	5808	6102	11	1	1	4		17		
	12:30	5808	6102	11	1	1	4		17		
	13:00	5808	6103	11	1	1	4		17		2
	13:30	5808	6103	11	1	1	4		17		3
JANUARY											
19:1:92	9:30	5831	6084	1	1	3			5		5
	10:00	5833	6085	1	4	4			9		5
	10:30	5845	6085	1	4	4			9		9
	11:00	5847	6083	1	5	5			11		9
	11:30	5841	6085	1	5	5			11		11
	12:00	5835	6086	1	5	5			11		8
	12:30	5836	6089	1	5	5			11		11
	13:00	5830	6094	1	5	7			13		13
	13:30	5830	6094	1	5	7			13		
	14:00	5830	6094	1	5	7			13		1
	14:30	5827	6097	1	5	7			13		3
	15:00	5876	6072	1	5	7			13		
	15:30	5876	6072	1	5	7			13		
	16:00	5876	6072	1	5	7			13		7
	16:30	5877	6064	1	3	2			6		6
	16:30	5869	6068		2	5			7		4
	17:00	5876	6065	1	3	2			6		6
	17:00	5874	6068		2	5			7		3
24:1:92	13:00	5782	6157	10	1		4		15		5
	13:30	5782	6157	10	1		4		15		
	14:00	5782	6157	10	1		4		15		
	14:30	5782	6157	10	1		4		15		3
	15:00	5771	6161	10	1		4		15		5
	15:30	5767	6162	10	1		4		15		8
FEBRUARY											
17:2:92	18:00	5864	5959	1	3	2	3	3	12	*	7
18:2:92	12:00	5750	6150	5			2	2	9		
	15:00	5870	6047		1	2			3		1
	15:30	5930	6020		3	2			5		
	16:00	5880	6065	1		4	1		6		5
	17:30	5877	6074	1		4	1		6		2
19:2:92	9:30	5962	6010		3	2			5		1
	10:00	5962	6010		3	2			5		2

DATE	Time	LONG	LAT	Male	Female	Kid	Hummel	?	Total	*	Number observed Feeding
	10:30	5962	6010		3	2			5		3
	11:00	5961	6008		3	2			5		4
	11:30	5959	6009		3	2			5		3
	12:00	5966	6001		3	2			5		4
	12:00	5818	6094	1		4	1		6		6
	12:30	5811	6096	1		4	1		6		5
	13:00	5811	6095	1		5	1		7		1
	13:30	5811	6095	1		5	1		7		5
	14:00	5870	6047		1	1			2		1
	14:30	5870	6047		1	1			2		
	15:00	5710	6165	1					1		
	17:00	5865	5960	1	1	2	3	2	9	*	7
20:2:92	12:00	5874	6051		1	1			2		
	13:00	5960	6005		1	2			3		
25:2:92	12:30	5743	6164	11	1	4	6		22		10

Appendix 3. Summary of Faecal composition data.

3.1 Faecal composition data for individual goats in Cwm Ffynnon

Species included in the broad plant categories are given in Chapter 5, section 5.2. Abbreviations for the individual grass species are as follows: M.c: Molinia caerulea; A.sp: Agrostis spp.; F.sp: Festuca spp.; D.sp: Deschampsia spp.; N.s: Nardus stricta; P.sp: Poa spp.

Monthly summaries for males, females and combined totals for Cwm Ffynnon are given in Appendix 3.1.1

Collection										Total	Non -	%	Grass Species Identified						
Date	Goat	Shrubs	Herbs	Bilberry	Mosses	Ferns	Grasses	Sedges	Rushes	Identified	Identified	Identified	M.c	A.sp	F.sp	D.sp	N.s	P.sp	Sum
March																			
04/03/91	F1	23	0	4	4	8	83	21	19	162	52	75.70	1	2	5	4	40	3	55
03/03/91	F2	22	0	4	3	11	82	18	12	152	56	73.07	2	1	4	4	34	2	47
03/03/91	F3	35	0	7	3	17	62	18	10	152	55	73.42	3	3	1	2	26	2	37
05/03/91	M1	81	0	20	1	3	31	21	17	174	70	71.31	2	1	4	2	8	1	18
05/03/91	M2	77	0	15	1	3	17	7	30	150	63	70.42	1	2	2	1	9	1	16
05/03/91	M3	64	0	17	4	13	25	23	10	156	66	70.27	1	2	3	1	9	2	18
April																			
08/04/91	F1	40	0	12	0	7	79	4	6	148	67	68.83	0	1	1	0	72	1	75
08/04/91	F2	38	1	8	0	5	90	6	3	151	68	68.94	1	0	2	2	74	1	80
09/04/91	Y1	45	0	5	1	2	92	8	5	158	62	71.81	1	1	2	3	78	0	85
09/04/91	M1	52	0	6	0	4	70	15	19	166	65	71.86	0	3	6	1	45	1	56
08/04/91	M2	50	0	6	1	0	80	10	4	151	62	70.89	2	1	3	1	46	2	55
08/04/91	M3	47	1	10	0	5	82	10	10	165	63	72.36	2	2	1	2	53	1	61
May																			
14/05/91	F1	29	2	2	0	2	88	15	18	156	66	70.27	6	1	6	1	51	1	66
15/05/91	F2	37	3	1	2	0	82	14	12	151	70	68.32	2	2	1	2	39	2	48
15/05/91	F3	54	1	4	1	1	72	29	7	169	69	71.00	2	1	4	1	28	1	37
14/05/91	Y1	37	1	4	5	0	49	26	28	150	63	70.42	1	1	2	2	22	1	29
15/05/91	M1	28	0	4	3	0	101	19	15	170	65	72.34	1	1	2	2	84	3	93
15/05/91	M2	36	2	2	0	0	85	22	9	156	64	70.90	3	1	2	2	57	1	66
15/05/91	M3	30	2	1	2	0	88	24	17	164	66	71.30	1	2	1	1	55	1	61
June																			
19/06/91	F1	41	4	7	5	0	32	54	7	150	66	69.44	3	1	2	2	5	2	15
17/06/91	F2	63	6	3	3	12	13	52	2	154	94	62.09	6	1	1	1	2	1	12
19/06/91	F4	46	4	0	2	1	55	36	6	150	66	69.44	14	2	5	1	9	2	33
19/06/91	Y1	55	0	2	2	0	17	68	6	150	63	70.42	4	1	2	1	4	1	13
17/06/91	M1	31	1	0	1	1	26	76	14	150	61	71.09	5	1	1	1	12	1	21
19/06/91	M3	33	5	7	2	0	32	62	10	151	60	71.56	15	1	1	2	5	1	25
17/06/91	M2	45	6	5	4	0	21	63	6	150	67	69.12	8	1	1	1	5	1	17
17/06/91	MX	65	4	3	2	0	24	45	9	152	59	72.03	6	1	1	1	5	1	15
July																			

Collection										Total	Non -	%	Grass Species Identified						
Date	Goat	Shrubs	Herbs	Bilberry	Mosses	Ferns	Grasses	Sedges	Rushes	Identified	Identified	Identified	M.c	A.sp	F.sp	D.sp	N.s	P.sp	Sum
21/07/91	FA	42	12	13	3	2	34	43	2	151	71	68.01	12	1	3	3	4	1	24
20/07/91	F1	33	8	9	4	30	33	36	7	160	62	72.07	4	5	6	1	17	1	34
21/07/91	F3	57	7	8	2	9	31	36	4	154	66	70.00	12	2	2	1	2	1	20
21/07/91	F4	36	10	8	1	30	22	48	5	160	70	69.56	6	1	1	2	2	1	13
21/07/91	F5	36	12	9	1	21	29	39	3	150	63	70.42	5	1	4	1	8	1	20
21/07/91	M1	45	6	10	2	15	37	32	3	150	66	69.44	10	2	1	1	6	1	21
21/07/91	M2	54	5	12	1	11	37	28	7	155	71	68.58	8	1	2	2	6	1	20
20/07/91	M3	39	1	15	2	5	43	35	10	150	66	69.44	10	4	1	2	3	1	21
21/07/91	MX	35	6	2	0	4	48	52	6	153	60	71.83	10	2	3	2	11	1	29
August																			
21/08/91	F1	39	16	13	0	8	25	47	3	151	80	65.36	1	3	2	3	7	1	17
22/08/91	FB	55	15	5	2	12	12	50	1	152	68	69.09	1	3	2	3	2	1	12
22/08/91	F2	68	10	10	0	6	39	19	0	152	71	68.16	1	1	7	4	14	1	28
22/08/91	F4	37	15	15	1	2	15	60	6	151	75	66.81	1	1	2	4	3	1	12
22/08/91	F3	63	1	14	2	7	41	24	2	154	72	68.14	2	2	2	3	7	2	18
22/08/91	M1	59	7	9	4	6	16	51	6	158	71	68.99	3	1	1	2	10	1	18
22/08/91	M2	52	12	13	0	5	20	44	6	152	76	66.66	2	4	2	1	6	1	16
21/08/91	M4	52	5	7	3	2	23	57	11	160	69	69.86	2	1	3	2	5	3	16
September																			
09/09/91	F1	45	0	3	5	2	90	9	0	154	65	70.31	1	7	13	1	32	1	55
10/09/91	F2	55	1	4	4	2	81	10	0	157	64	71.04	1	1	13	2	23	1	41
09/09/91	F3	51	0	1	10	2	81	8	1	154	67	69.68	1	10	13	2	11	2	39
10/09/91	F4	44	1	1	11	4	78	15	0	154	62	71.29	1	7	11	2	26	1	48
10/09/91	Y1	49	2	2	6	9	71	11	1	151	59	71.90	1	3	12	3	29	2	50
09/09/91	M1	36	0	6	6	1	87	14	1	151	66	69.58	1	1	7	13	22	2	46
10/09/91	M2	53	0	0	4	1	85	7	1	151	56	72.94	1	6	14	5	18	1	45
09/09/91	M3	50	0	6	4	4	55	28	4	151	77	66.22	2	3	7	9	7	2	30
10/09/91	MD	50	2	5	4	7	74	8	2	152	58	72.38	1	3	11	4	19	2	40
October																			
14/10/91	F1	57	0	14	1	2	64	12	0	150	64	70.09	1	3	2	11	14	1	32
14/10/91	F2	45	1	14	3	9	58	19	1	150	66	69.44	1	1	5	6	11	1	25
14/10/91	F3	61	1	9	4	11	54	14	0	154	65	70.31	1	4	4	3	14	1	27
14/10/91	F4	79	0	13	1	19	24	15	1	152	71	68.16	1	3	3	2	6	1	16
15/10/91	Y1	55	1	9	3	10	51	22	0	151	57	72.59	1	6	5	2	13	2	29
15/10/91	M1	67	4	8	3	4	54	11	1	152	87	63.59	3	2	7	10	7	2	31
15/10/91	M4	57	0	8	3	6	67	13	1	155	59	72.42	1	1	4	5	19	1	31
15/10/91	M2	63	2	16	3	31	32	3	1	151	60	71.56	1	3	7	1	8	2	22
14/10/91	M3	52	3	11	3	8	59	13	1	150	64	70.09	2	1	8	7	17	1	36
November																			
19/11/91	F1	32	0	13	4	26	48	16	13	152	56	73.07	8	1	5	1	16	1	32
19/11/91	F2	50	1	28	5	17	47	5	6	159	62	71.94	3	2	7	3	7	3	25
19/11/91	F3	36	1	28	13	21	44	7	1	151	65	69.90	2	1	10	3	16	1	33
19/11/91	F4	43	5	24	5	30	30	10	6	153	66	69.86	1	1	6	3	10	2	23
19/11/91	M3	50	25	6	7	2	55	4	0	149	70	68.03	4	1	7	3	9	3	27
19/11/91	M1	49	6	31	15	8	57	7	9	182	62	74.59	3	1	13	7	19	1	44
19/11/91	M2	67	5	17	4	7	45	4	5	154	60	71.96	1	2	8	3	6	1	21
December																			
15/12/91	F2	48	2	30	8	8	38	15	1	150	64	70.09	1	1	14	8	5	1	30

Collection										Total	Non -	%	Grass Species Identified						
Date	**Goat**	**Shrubs**	**Herbs**	**Bilberry**	**Mosses**	**Ferns**	**Grasses**	**Sedges**	**Rushes**	**Identified**	**Identified**	**Identified**	**M.c**	**A.sp**	**F.sp**	**D.sp**	**N.s**	**P.sp**	**Sum**
15/12/91	F4	62	3	6	2	13	34	37	0	157	67	70.08	2	2	4	5	16	2	31
15/12/91	Y1	42	3	10	11	25	45	14	0	150	59	71.77	1	3	14	6	7	2	33
15/12/91	F3	41	1	11	12	33	41	16	1	156	55	73.93	1	2	9	10	8	1	31
15/12/91	M2	34	1	15	11	13	63	11	3	151	66	69.58	0	6	8	4	19	1	38
15/12/91	MA	31	4	14	9	15	74	5	0	152	70	68.46	1	2	7	4	22	0	36
15/12/91	MX	29	2	11	16	7	71	14	0	150	60	71.42	2	4	3	3	33	1	46
15/12/91	M1	31	2	12	9	7	84	8	2	155	67	69.81	0	1	12	3	28	0	44
15/12/91	M3	38	0	25	7	9	61	11	3	154	69	69.05	1	4	9	4	23	2	43
January																			
16/01/92	FA	60	2	16	7	13	52	5	2	157	67	70.08	1	0	3	6	20	2	32
16/01/92	FB	61	1	16	4	20	37	9	2	150	68	68.80	1	3	4	1	18	1	28
16/01/92	F1	52	2	14	4	15	54	4	5	150	65	69.76	1	3	7	1	22	1	35
16/01/92	F2	62	0	10	7	7	52	5	7	150	68	68.80	3	4	4	4	16	1	32
16/01/92	F3	42	2	18	7	21	47	5	14	156	67	69.95	1	4	1	5	12	2	25
16/01/92	F4	59	0	9	3	9	57	6	7	150	63	70.42	0	2	2	5	27	1	37
16/01/92	Y1	33	1	15	0	30	56	16	1	152	70	68.46	0	1	7	5	12	1	26
16/01/92	M3	57	1	23	5	14	47	6	4	157	70	69.16	1	6	7	3	12	0	29
16/01/92	MB	73	0	6	7	6	50	7	3	152	66	69.72	0	1	7	2	18	2	30
16/01/92	M1	69	0	13	8	13	33	10	5	151	66	69.58	2	2	4	4	14	1	27
16/01/92	M2	59	2	12	1	12	54	10	5	155	61	71.75	1	1	2	3	23	1	31
February																			
17/02/92	F1	70	0	25	2	16	13	30	9	165	73	69.32	1	1	3	1	4	1	11
17/02/92	F2	40	1	12	1	19	43	24	10	150	61	71.09	3	2	2	6	17	1	31
17/02/92	F4	39	0	6	6	35	29	25	14	154	71	68.44	2	1	1	2	18	1	25
17/02/92	Y1	48	2	15	6	17	28	30	11	157	74	67.96	3	2	2	4	4	3	18
17/02/92	M1	75	2	8	4	30	18	14	3	154	68	69.36	2	2	2	0	9	1	16
17/02/92	M2	64	1	13	2	18	25	20	8	151	69	68.63	0	1	2	2	11	1	17
17/02/92	M3	51	0	8	2	9	35	31	14	150	73	67.26	2	3	2	1	21	0	29
17/02/92	MX	62	0	17	3	11	32	18	8	151	77	66.22	1	1	2	1	18	2	25

3.1.1 Monthly summaries of faecal composition data for Cwm Ffynnon.

Males (M), females (F) and combined totals for all goats (sum). Abbreviations are as in Appendix 3.1.

													Grass Species Identified						
Month	**Goat**	**Shrubs**	**Herbs**	**Bilberry**	**Mosses**	**Ferns**	**Grasses**	**Sedges**	**Rushes**	**Total Identified**	**Non-Identified**	**% Identified**	**M.c**	**A.sp**	**F.sp**	**D.sp**	**N.s**	**P.sp**	**Sum**
March	M	222	0	52	6	19	73	51	57	480	199	70.69	4	5	9	4	26	4	52
	F	80	0	15	10	36	227	57	41	466	163	74.08	6	6	10	10	100	7	139
	Sum	302	0	67	16	55	300	108	98	946	362	72.32	10	11	19	14	126	11	191
April	M	149	1	22	1	9	232	35	33	482	190	71.72	4	6	10	4	144	4	172
	F	123	1	25	1	14	261	18	14	457	197	69.87	2	2	5	5	224	2	240
	Sum	272	2	47	2	23	493	53	47	939	387	70.81	6	8	15	9	368	6	412
May	M	94	4	7	5	0	274	65	41	490	195	71.53	5	4	5	5	196	5	220
	F	157	7	11	8	3	291	84	65	626	268	70.02	11	5	13	6	140	5	180
	Sum	251	11	18	13	3	565	149	106	1116	463	70.67	16	9	18	11	336	10	400
June	M	174	16	15	9	1	103	246	39	603	247	70.94	34	4	4	5	27	4	78
	F	205	14	12	12	13	117	210	21	604	289	67.63	27	5	10	5	20	6	73
	Sum	379	30	27	21	14	220	456	60	1207	536	69.24	61	9	14	10	47	10	151
July	M	173	18	39	5	35	165	147	26	608	263	69.80	38	9	7	7	26	4	91
	F	204	49	47	11	92	149	202	21	775	332	70.00	39	10	16	8	33	5	111
	Sum	377	67	86	16	127	314	349	47	1383	595	69.91	77	19	23	15	59	9	202
August	M	163	24	29	7	13	59	152	23	470	216	68.51	7	6	6	5	21	5	50
	F	262	57	57	5	35	132	200	12	760	366	67.49	6	10	15	17	33	6	87
	Sum	425	81	86	12	48	191	352	35	1230	582	67.88	13	16	21	22	54	11	137
September	M	189	2	17	18	13	301	57	8	605	257	70.18	5	13	39	31	66	7	161
	F	244	4	11	36	19	401	53	2	770	317	70.83	5	28	62	10	121	7	233
	Sum	433	6	28	54	32	702	110	10	1375	574	70.54	10	41	101	41	187	14	394
October	M	239	9	43	12	49	212	40	4	608	270	69.24	7	7	26	23	51	6	120
	F	297	3	59	12	51	251	82	2	757	323	70.09	5	17	19	24	58	6	129
	Sum	536	12	102	24	100	463	122	6	1365	593	69.71	12	24	45	47	109	12	249
November	M	166	36	54	26	17	157	15	14	485	192	71.63	8	4	28	13	34	5	92
	F	161	7	93	27	94	169	38	26	615	249	71.18	14	5	28	10	49	7	113
	Sum	327	43	147	53	111	326	53	40	1100	441	71.38	22	9	56	23	83	12	205
December	M	163	9	77	52	51	353	49	8	762	332	69.65	4	17	39	18	125	4	207
	F	193	9	57	33	79	158	82	2	613	245	71.44	5	8	41	29	36	6	125
	Sum	356	18	134	85	130	511	131	10	1375	577	70.44	9	25	80	47	161	10	332
January	M	258	3	54	21	45	184	33	17	615	263	70.04	4	10	20	12	67	4	117
	F	369	8	98	32	115	355	50	38	1065	468	69.47	7	17	28	27	127	9	215
	Sum	627	11	152	53	160	539	83	55	1680	731	69.68	11	27	48	39	194	13	332
February	M	252	3	46	11	68	110	83	33	606	287	67.86	5	7	8	4	59	4	87
	F	197	3	58	15	87	113	109	44	626	279	69.17	9	6	8	13	43	6	85
	Sum	449	6	104	26	155	223	192	77	1232	566	68.52	14	13	16	17	102	10	172
12 Months	M	2242	125	455	173	320	2223	973	303	6814	2911	70.07	125	92	201	131	842	56	1447
	F	2492	162	543	202	638	2624	1185	288	8134	3496	69.94	136	119	255	164	984	72	1730
	Sum	4734	287	998	375	958	4847	2158	591	14948	6407	70.00	261	211	456	295	1826	128	3177

3.2. Summary of faecal composition data for goats in the Padarn area 1991-92.

Details of individual species included in each plant category are given in Chapter 5, Section 5.5.

Males																	
Collection Date	**Oak**	**Conifer**	**Other Trees**	**Holly / Ivy**	**Heather**	**Bramble**	**Gorse**	**Misc. Shrubs**	**Fern**	**Herb**	**Moss**	**Grass**	**Sedge**	**Rush**	**Total ID'd**	**Non-ID'd**	**% ID'd**	**No. of Goats**
07-08/03/91	15	0	37	24	165	26	80	22	8	12	3	5	0	3	400	275	59.25	6
10-12/04/91	23	3	50	71	57	28	9	17	8	8	11	100	7	8	400	356	52.91	7
16-18/05/91	22	0	160	11	71	10	1	4	3	14	26	73	1	4	400	367	52.15	7
24-26/06/91	7	0	150	1	126	4	17	15	38	28	11	2	1	0	400	282	58.65	7
15-16/07/91	31	0	197	35	41	9	8	13	26	21	2	17	0	0	400	319	55.63	9
12-14/08/91	34	0	164	7	34	5	12	12	45	15	6	56	1	9	400	327	55.02	11
11-12/09/91	0	0	3	0	65	0	0	7	40	28	52	193	8	4	400	167	70.54	7
19-20/10/91	8	1	94	9	131	12	0	18	50	18	1	49	5	4	400	313	56.10	5
20/11/91	14	0	56	7	65	7	12	3	137	52	4	43	0	0	400	247	61.82	5
16/12/91	1	8	49	17	129	6	3	23	58	8	10	80	5	3	400	357	52.84	10
18-20/01/92	10	0	24	111	23	130	20	8	29	27	1	16	0	1	400	367	52.15	10
24-25/02/92	6	0	19	143	38	128	16	4	32	9	2	3	0	0	400	305	56.73	5
12 Months	171	12	1003	436	945	365	178	146	474	240	129	637	28	36	4800	3682	56.59	89
Females																		
07-08/03/91	18	0	36	23	121	23	56	13	33	19	9	47	0	2	400	292	57.80	3
10-12/04/91	3	0	34	34	45	10	21	41	4	16	14	143	19	16	400	328	54.94	3
16-18/05/91	20	1	113	37	66	7	7	16	10	26	39	55	2	1	400	383	51.08	7
24-26/06/91	6	0	107	5	73	4	118	2	10	52	5	14	1	3	400	289	58.05	3
15-16/07/91	14	0	145	39	44	10	14	6	13	19	3	93	0	0	400	286	58.30	3
12-14/08/91	25	0	104	4	92	15	5	4	18	60	11	60	2	0	400	286	58.30	5
11-12/09/91	27	0	58	7	88	43	0	5	11	60	11	90	0	0	400	316	55.86	5
19-20/10/91	9	0	82	15	53	7	1	13	29	10	10	170	1	0	400	350	53.33	4
20/11/91	13	0	60	6	130	23	3	1	81	48	7	26	2	0	400	217	64.82	3
16/12/91	4	1	23	5	202	5	9	7	56	15	6	64	0	3	400	226	63.89	4
18-20/01/92	2	0	22	16	148	8	2	8	19	5	16	126	9	19	400	385	50.95	4
24-25/02/92	0	2	15	10	216	17	24	17	25	6	5	63	0	0	400	323	55.32	4
12 Months	141	4	799	201	1278	172	260	133	309	336	136	951	36	44	4800	3681	56.59	48

Appendix 4. Notes on Statistical Analysis.

Differences between males, females and individuals were assessed by Multivariate Analysis of Variance (MANOVA) and Univariate Analysis of Variance (ANOVA) following the methods of Putman (1993). All analyses were carried out using "SYSTAT" statistical software (SYSTAT 1986) and results were accepted as significant at the 5 % probability level (P=<0.5).

Fragments identified in the faeces were initially identified to species level where possible but classified into larger groups for ease of presentation. The Species identified in these groupings are given in Chapter 5, (Tables 5.3 and 5.13). For statistical analysis the plant groupings defined for Cwm Ffynnon were unchanged but the numerous groups identified in the Padarn data were reduced to eight categories as follows:

"Heather"	All ericaceous shrubs.
"Tree"	All tree species including Oak and Conifers but excludingn Holly
"Holly"	Holly and/or Ivy (as these species could not be distinguished)
"Shrub"	All non-ericaceous shrubs including Bramble, Gorse and Bilberry
"Ferns"	All fern species.
"Herbs"	All herb species.
"Moss"	All Bryophytes including mosses and lichens.
"Monocots"	All monocotyledonous species including Grasses, Sedges and Rushes

Statistical analysis of dietary data is complicated when the total relative composition is to be assessed rather than analysing a single plant category and ignoring all others. Faecal fragments represent quantitative numerical values rather than true frequencies and with a finite number of fragments counted in any sample, values recorded are not strictly independent: Within a sample, observations of various categories are negatively correlated, an increase in the value of one category is necessarily accompanied by a decrease in one or more of the others. Thus the collection of proportions of each category must be analysed taking this negative correlation into account, by using multivariate statistical methods (Stroup & Stubbendieck 1983). One of the assumptions that must be met to validly apply MANOVA is that the data is normally distributed. Normalisation of the raw faecal composition data was carried out using the additive logistic transformation (Aitchison 1986) by which the values for fragment number in any diet category are divided by the number in the most frequently recorded category, one added, and then logged. For data from both sites, all categories were divided by the value for "Heather" which was the most consistently major category. Consequently, the new categories are effectively analysed in relation to "Heather" and cannot be directly compared to the original values.

In analysis by MANOVA these transformed categories are used as dependent variables and tested against the categorical variables "Sex", "Month" and Sex * Month" interaction. Repeated slide sample counts and individual sample data (from separate goats in Cwm Ffynnon) were used as replicates, with individual goat data nested within "Sex". MANOVA hypotheses were tested using Wilks' Lambda (likelihood ratio criterion) calculated using SYSTAT (SYSTAT 1986). Univariate analyses were carried using the same categorical variables but using single plant categories as dependent variables.

MANOVA's and univariate tests were carried out on all data from each site and also for selected individuals from Cwm Ffynnon. Individual variation between goats was examined using data from six goats which were all present in each of seven months to achieve a completely orthogonal design. Results presented by SYSTAT for all these analyses are summarised in the text (Chapter 5..) and are given in full below:

Abbreviations: SS Sums of squares; DF Degrees of freedom; MS Mean squares; F F statistic; P Probability value

4.1 Multivariate Test Statistics

4.1.1 Cwm Ffynnon (All data)

Model = Goats(M) + Goats(F) + Sex + Month + Sex * Month

Variable	Wilks' Lambda	DF	F	P
Sex	.879	7,52	1.020	.429
Month	.001	77,319	8.756	.000
Sex * Month	.109	77,319	1.863	.000

4.1.2 Cwm Ffynnon (Selected Individuals)

Model = Goats(M) + Goats(F) + Sex + Month + Sex * Month

Variable	Wilks' Lambda	DF	F	P
Goats (Males)	.410	14,36	1.443	.184
Goats (Females)	.394	14,36	1.527	.151
All Individuals	.179	28,66	1.446	.111

4.1.3 Padarn (All data)

Model = Replicate + Sex + Month + Sex * Month

Variable	Wilks' Lambda	DF	F	P
Sex	.207	7,63	34.563	.000
Month	.000	77,384	26.929	.000
Sex * Month	.001	77,384	11.274	.000

4.2 Univariate Tests

4.2.1 Cwm Ffynnon Data

Model = Goats(M) + Goats(F) + Sex + Month + Sex*Month

Test for effect = Sex

Variable	SS	DF	MS	F	P
Grass	.000	1	.000	0.001	.977
Error	.322	58	.006		
Sedge	.004	1	.014	1.195	.279
Error	.197	58	.003		
Rush	.000	1	.000	0.331	.567
Error	.079	58	.001		
Bilberry	.002	1	.002	1.347	.251
Error	.081	58	.001		
Moss	.000	1	.000	0.101	.751
Error	.034	58	.001		
Fern	.015	1	.015	5.448	.023
Error	.162	58	.003		
Herb	.000	1	.000	0.580	.449
Error	.034	58	.001		

Test for effect = Month

Variable	SS	DF	MS	F	P
Grass	.924	11	.084	15.142	.000
Error	.322	58	.006		
Sedge	.733	11	.067	19.588	.000
Error	.197	58	.003		
Rush	.169	11	.015	11.264	.000
Error	.079	58	.001		
Bilberry	.134	11	.012	8.700	.000
Error	.081	58	.001		
Moss	.055	11	.005	8.584	.000
Error	.034	58	.001		
Fern	.197	11	.018	6.387	.000
Error	.162	58	.003		
Herb	.051	11	.005	8.017	.000
Error	.034	58	.001		

Effect = Sex * Month

Variable	SS	DF	MS	F	P
Grass	.457	11	.042	7.489	.000
Error	.322	58	.006		
Sedge	.091	11	.008	2.443	.014
Error	.197	58	.003		
Rush	.029	11	.003	1.956	.050
Error	.079	58	.001		
Bilberry	.021	11	.002	1.341	.226
Error	.081	58	.001		
Moss	.009	11	.001	1.385	.205
Error	.034	58	.001		
Fern	..56	11	.005	1.831	.069
Error	.162	58	.003		
Herb	.013	11	.001	2.047	.040
Error	.034	58	.001		

4.3 Cwm Ffynnon Data - Individual Goats

Model = Male Individuals + Female Individuals + Sex + Month + Sex*Month

Test for effect = Male Individuals

Variable	SS	DF	MS	F	P
Grass	.009	2	.004	0.656	.528
Error	.156	24	.007		
Sedge	.013	2	.006	3.665	.041
Error	.042	24	.002		
Rush	.007	2	.004	3.503	.046
Error	.025	24	.001		
Bilberry	.003	2	.001	1.625	.218
Error	.020	24	.001		
Moss	.001	2	.000	1.126	.341
Error	.007	24	.000		
Fern	.000	2	.000	0.089	.915
Error	.055	24	.002		
Herb	.001	2	.000	1.797	.187
Error	.003	24	.000		

Test for effect = Female Individuals

Variable	SS	DF	MS	F	P
Grass	.005	2	.002	0.355	.705
Error	.156	24	.007		
Sedge	.011	2	.005	3.100	.063
Error	.042	24	.002		
Rush	.001	2	.001	0.652	.530
Error	.025	24	.001		
Bilberry	.001	2	.001	0.790	.465
Error	.020	24	.001		
Moss	.000	2	.000	0.442	.648
Error	.007	24	.000		
Fern	.004	2	.002	0.943	.403
Error	.055	24	.002		
Herb	.000	2	.000	0.529	.596
Error	.003	24	.000		

Test for effect = Males Individuals & Female Individuals

Variable	SS	DF	MS	F	P
Grass	.013	4	.003	0.505	.732
Error	.156	24	.007		
Sedge	.024	4	.006	3.382	.025
Error	.042	24	.002		
Rush	.008	4	.002	2.077	.115
Error	.025	24	.001		
Bilberry	.004	4	.001	1.207	.333
Error	.020	24	.001		
Moss	.001	2	.000	0.784	.547
Error	.007	24	.000		
Fern	.005	4	.001	0.516	.725
Error	.055	24	.002		
Herb	.001	4	.000	1.163	.352
Error	.003	24	.000		

4.4 Padarn Data

Model = Replicate + Sex + Month + Sex * Month

Test for effect = Sex

Variable	SS	DF	MS	F	P
Tree	.156	1	.156	17.144	.000
Error	.628	69	.009		
Holly	.309	1	.309	113.937	.000
Error	.187	69	.003		
Shrub	.168	1	.168	17.011	.000
Error	.680	69	.010		
Fern	.270	1	.270	84.110	.000
Error	.222	69	.003		
Herb	.001	1	.001	0.123	.726
Error	.293	69	.004		
Moss	.000	1	.000	0.135	.715
Error	.063	69	.001		
Monocots	.050	1	.050	6.808	.011
Error	.508	69	.007		

Test for effect = Month

Variable	SS	DF	MS	F	P
Tree	3.807	11	.346	38.003	.000
Error	.628	69	.009		
Holly	1.899	11	.173	63.707	.000
Error	.187	69	.003		
Shrub	1.497	11	.136	13.807	.000
Error	.680	69	.010		
Fern	.686	11	.062	19.382	.000
Error	.222	69	.003		
Herb	.382	11	.035	8.174	.000
Error	.293	69	.004		
Moss	.252	11	.023	25.011	.000
Error	.063	69	.001		
Monocots	2.544	11	.231	31.418	.000
Error	.508	69	.007		

Test for effect = Sex * Month

Variable	SS	DF	MS	F	P
Tree	.974	11	.089	9.728	.000
Error	.628	69	.009		
Holly	1.723	11	.157	57.810	.000
Error	.187	69	.003		
Shrub	2.404	11	.219	22.165	.000
Error	.680	69	.010		
Fern	.0.429	11	.039	12.131	.000
Error	.222	69	.003		
Herb	.356	11	.032	7.612	.000
Error	.293	69	.004		
Moss	.109	11	.010	10.831	.000
Error	.063	69	.001		
Monocots	1.199	11	.109	14.802	.000
Error	.508	69	.007		

REFERENCES

Adams, L., O'Regan, W.G. & Dunaway, D.J. (1962) A**nalysis of forage consumption by fecal examination.** J. Wildife Management 26:1, 108-111.

Aitchison, J. (1986) **The Statistical Analysis of Compositional Data.** Publs. Chapman & Hall London & New York. ISBN 0 412 28060 4

Alipayo, D., Valdez, R., Holochek, J. & Cardenas, M. (1992) **Evaluation of microhistological analysis for determining ruminant diet botanical composition.** J. Range Management 45, 148-152.

Anderson, J.E.M. (1976) **Food energy requirements of wild Scottish red deer. In The red deer of South Ross.** eds. W.E.S. Mutch, J.D. Lockies & A.B. Cooper. Edinburgh: Department of Forestry and Natural Resources. University of Edinburgh.

Angers, C. (1974) **A graphical method to evaluate sample sizes for the multinomial distribution.** Technometrics 16:3, 469-47.

Ansells,M. (*pers comm.*) **Blue Peris Mountain Centre, Dinorwic, Gwynedd, N.Wales.**

Anthony, R.G. & Smith, N.S. (1974) **Comparison of rumen and Fecal Analysis to describe Deer diets.** J. Wildlife Management 38:3, 535-540.

Arnold, G.W. & Dudzinski, M.L. (1978) **Ethology of domestic animals.** Publs. Elsevier Scientific Publishing, Oxford. ISBN 0 444 41703 6

Baker, D.L. & Hobbs, T. N. (1987) **Strategies of digestion: digestive efficiency and retention time of forage diets in montane ungulates.** Canadian Journal of Zoology 65, 1978-1984.

Ball, D.F, Mew, G. & MacPhee, W.S.G. (1969) **Soils of Snowdon.** Field Studies 3:1 reprinted by Nature Conservancy Council, Bangor, N.Wales.

Batten, G.J. (1979) New Zealand Journal of Agriculture 139, 31-32.

Beier, P. (1987) **Sex differences in quality of white-tailed deer diets.** Journal of Mammalogy 68:2, 323-329.

Bell, R.H.V. (1970) **The use of the herb layer by grazing ungulates in the Serengeti. In Animal populations in relation to their food resources.** ed, A. Watson. Publs. Blackwell. Oxford.

Belovsky, G.E. (1981) **Food plant selection by a generalist herbivore, the moose.** Ecology 62, 1020-,1030.

Berdecou, C. & Bousses, P. (1985) **Social grouping patterns of a dense population of Chamois in the Western Pyrenees N.P., France. In: The Biology and management of mountain ungulates.** ed. S. Lovari. Publs. Croom Helm. London. pp 166-175.

Bhadresa, R, (1981) **Identification of leaf epidermal fragments in Rabbit faeces.** Rogate Papers 4. Rogate Field Centre, Petersfield. Hants.

Bonham, F.R.H. & Fairley, J.S. (1984) **Observations on a herd of feral Goats *C.domestica* in the Burren.** Irish Naturalists Journal 21:5, 208-212.

Boyd, I.L. (1981) **Population changes and the distribution of a herd of feral goats (*Capra* sp.) on Rhum, Inner Hebrides, (1960-1978).** J. Zool. London 193, 287-304.

Bransby-Williams, G. (1954) **Some characteristics of mountain rainfall illustrated in North-West Wales.** Water & Water Engineering 58, 299-304.

Brindley, E.L., Bullock, D.J. & Maisels, F. (1989) **Effects of rain and fly harassment on the feeding behaviour of free-ranging feral goats.** Applied Animal Behaviour Science 24, 31-41.

Brown, D. (1977) **Status, Distribution and some physical characteristics of feral goats in the Rhinog mountains of Meirionydd.** Nature Conservancy Council Information Sheet no.3, Nature Conservancy Council, Bangor, N.Wales.

Brown, D. (1983) **The Rhinog goats(II): Social and Spatial organisation.** Nature Conservancy Council Report, Nature Conservancy Council, Bangor, N.Wales.

Bullock, D.J. (1982) **Aspects of the ecology of feral goats in the southern uplands.** PhD thesis, University of Durham. Unpublished.

Bullock, D.J. (1985) **Annual diets of hill sheep and feral goats in southern Scotland.** J. Applied Ecology 22, 423-433.

Bullock, D.J. (1991) **Feral Goat *Capra hircus*. In: The Handbook of British Mammals.** eds. G.B. Corbert & S. Harris (1991) Publs. Blackwell. Oxford.

Bullock, D.J. & Grabrovaz, M. (1990) **The impact of goat farming on upland vegetation in Scotland - a preliminary review.** Nature Conservancy Rural Development Report no.1 Nature Conservancy Council (Scotland).

Bullock, D.J. & Kinnear, P.K. (1988) **The use of goats to control scrub in Tensmuir Point National Nature Reserve: A Pilot Study.** Trans. Bot. Soc. Edinb. 45, 131-139.

Bullock, D.J. & Pickering, S.P. (1984) **The validity of horn ring counts to determine the age of Scottish feral goats (*Capra domestica*).** J. Zool. London. 202, 561-564.

Burrell, G.C. (1982) **Winter diets of Mule deer in relation to bitterbrush abundance.** J. Range Management 35:4, 508-510.

Carr, H.R.C. & Lister, G.A. (1948) **The mountains of Snowdonia.** Crosby-Lockwood & Sons Ltd. London.

Castle, E.J. (1956) T**he rate of passage of foodstuffs through the alimentary tract of the goat.** British Journal of Nutrition 10, 15-23.

Cathrall, W. (1828) **The History of North Wales. Vol II.** J. Gleave & Sons, Manchester.

Charles, W.N. McCowan, D. & East, K. (1977) **Selection of upland swards by red deer on Rhum.** J. Applied Ecology 14, 55-64.

Chatterton, & N.J. Powell, J.B. (1974) **Stomatal guard cell integrity and resistance to rumen fluid digestion.** Agronomy Journal 66, 812-814.

Clapham, A.R., Tutin,T.G. & Moore, D.M. (1987) **Flora of the British Isles.** Cambridge University Press. 3rd Edition.

Clark, D.A. Lambert, M.G., Rolston, M.P. & Dymock, N. (1982) **Diet selection by goats and sheep on hill country.** Proceedings of the N.Z. Soc. of Animal Production 42, 155-157.

Clifford, H.T. & Watson, L. (1977) **Identifying Grasses: Data, Methods and illustrations.** University of Queensland Press, Australia. ISBN 0 7022 1312 8

Clutton-Brock, T.H., Guinness, F.E. & Albon, S.D. (1982a) **Red Deer Behaviour And Ecology Of Two Sexes.** Edinburgh University Press. ISBN 0 85224 446 9

Clutton-Brock, T.H. & Harvey, P.H. (1983) **The functional significance of variation in body size among mammals.** In: Symp. of the National Zoological Park, Washington D.C. Smithsonian Institute.

Clutton-Brock, T.H. Iason, G.R., & Guinness (1982b) **Sexual segregation and density-related changes in habitat use in male and female Red deer (*Cervus elaphus*).** J. Zool. London. 211, 275-289.

Clutton-Brock, T.H., Iason, G.R., Albon, S.D. & Guinness, F.E. (1982c) E**ffects of lactation on feeding behaviour and habitat use in wild Red Deer hinds.** J. Zool. London 198, 227-236.

Clutton-Brock, T.H., Iason, G.R. & Guinness, F.E. (1987) **Sexual segregation and density-related changes in habitat use in male and female Red deer (*Cervus elaphus*).** J. Zool. London 211, 275-289.

Coblentz, B.E. (1977) **Some Range relationships of feral goats on Santa Catalina Island, California.** J. Range Management 30:6, 415-419.

Coblentz, B.E. (1978) **The effects of feral goats (*Capra hircus*) on Island Ecosystems.** Biological Conservation 13, 279-286.

Coed Cymru (1985) **Broadleaved Woodlands in Wales: the core report.** Countryside Commission.

Cooper-Driver, G., Finch, S., Swain, T. & Bernays, E. (1977) **Seasonal variation in secondary plant compounds in relation to palatibility of *Pteridium aquilinum*.** Biochem. Syst. Ecol. 5, 177-183.

Countryside Council for Wales (CCW) (1985) **Coed Dinorwig SSSI.** Unpublished report. CCW, Ffordd Penrhos, Bangor, N.Wales.

Crawley, M.J. (1983) **Herbivory. The Dynamics of animal-Plant Interactions.** Blackwell Scientific Publications. Oxford. ISBN 0 632 00808 3

Crete, M., Huot, J. & Gauthier, L. (1990) **Food selection during early lactation by Caribou on the Tundra in Quebec.** La Terre et la Vie 43:1, 60-65.
Crisp, D.J. (ed.) (1964) Grazing in terrestrial and marine environments. Blackwell Scientific Publications. Oxford.

Croker, B.H. (1959) A method of estimating the botanical composition of the diet of sheep. N.Z. J. Agric. Res. 2, 72-85.

Crook, I.G. (1969) **Ecology and Behaviour of Feral goats in North Wales.** MSc thesis. University of Wales, Bangor. Unpublished.

Cuartas, P. & Garcia-Gonzalez, R. (1992) ***Quercus ilex* browse utilization by Caprini in Sierra de Cazorla Segura (Spain).** Vegetatio 99, 317-330.

Curtis, J.T., McIntosh, R.P. (1950) **The Interrelations of certain analytic and synthetic phytosociological characters.** Ecology 31:3 434-455.

Davies, I. (1959) **The use of epidermal characteristics for the identification of grasses in the leafy stage.** J. Br. Grassland Soc. 14, 7-16.

Davis, G.G., Bartel, L.E. & Cook, C.W. (1975) **Control of Gambel Oak sprouts by Goats.** J. Range Management 28:3, 216-218

Dearden, B.L., Hansen, R.M. & Pegau, R.E. (1975) P**lant fragment discernibility in Caribou rumens.** Proc. 1st Int. Reindeer and Caribou Symp. Ed: J.R.Luick, University of Alaska.

Dearden, B.L., Pegau, R.E. & Hansen, R.M. (1975) **Precision of microhistological analysis of ruminant food habits.** J. Wildlife Management 39:2, 402-407.

Demment, M.J. & Van Soest, P.J. (1985) **Nutritional explanation for body size patterns of ruminant and non-ruminant herbivores.** Am. Nat. 125, 641-72.

Devendra, C. (1978) **The digestive efficiency of goats.** World Review of Animal Production 14:1, 9-22.

Domingue, B.M., Dellow, D.W. & Barry, T.N. (1991a) **The efficiency of chewing during eating and ruminating in goats and sheep.** British Journal of Nutrition 65, 355-363.

Domingue, B.M.F., Dellow, D.W., Wilson, P.R., & Barry, T.N. (1991b) **Comparative digestion in deer, goats and sheep.** N.Z Journal of Agricultural Research 34, 45-53.

Dunnet, G.M., Harvie, A.E. & Smit, T.J. (1973) E**stimating the proportions of various leaves in the diet of the Opossum by faecal analysis.** J. Applied Ecology 10, 737-745.

Fitter, R. & Fitter, A. (1989) **Grasses, Sedges, Rushes and Ferns of Britain and Northern Europe.** Collins Sons & Co Ltd. London. ISBN 0 00 21

Fox, J.L., Smith, C.A. (1988) **Winter Mountain Goat diets in Southeast Alaska.** J. Wildlife Management 52:2, 362-365.

Fracker, S.B. & Brischle, J.A (1944) **Measuring Local Distribution Of Ribes.** Ecology 25:3, 283-303.

Free, J.C., Hansen, R.M. & Sims, P.L (1970) **Estimating Dryweights of foodplants in feces of herbivores.** J. Range Management 23:4, 300-302.

Free, J.C., Sims, P.L. & Hansen, R.M. (1971) **Methods of estimating dry weight composition in diets of steers.** Journal of Animal Science 32, 1003-1008.

Galt, H.D., Ogden, P.R., Ehrenreich, J.H., Theurer, B. & Martin, S.C. (1968) **Estimating Botanical Samples from fistulated Steers by a microscope point method.** Journal of Range Management 21, 397-401.

Geist, V. (1971) **Mountain sheep: a study in behaviour and evolution.** University of Chicago Press, Chicago.

Geist, V. (1974) **On the relationship of social evolution and ecology in ungulates.** Amer. Zool. 14, 205-220.

Geist, V. & Petocz, R.G. (1977) **Bighorn sheep in winter: do rams maximise reproductive fitness by spatial and habitat segregation from ewes?** Canadian Journal of Zoology 55, 1802-1810.

Genin, D. & Badan-Dangon, A. (1991) **Goat herbivory and plant phenology in a Mediterranean shrubland of northern Baja California.** J. of Arid Environments 21, 113-121.

Gill, R.B., Carpenter, L.H., Bartmann, R.M., Baker, D.L. & Schoonveld, G.G. (1983) **Fecal Analysis to estimate Mule deer Diets.** J. Wildlife Management 47:4, 902-915.

Gordon, I.J. (1987) **Feeding Strategies of Ungulates.** PhD thesis. Cambridge. Unpublished.

Gordon, I.J. (1989) **Vegetation community selection by Ungulates on the Isle of Rhum. II Vegetation Community Selection. III determinants of Vegetation Community Selection.** J. Applied Ecology 26, 53-79.

Gordon, I.J., Iason, G.R. (1989) **Foraging strategy of ruminants: its significance to vegetation utilization and management.** Annual Report: Macauley Land Use Research Institute. (1988-1989)

Gordon, I.J., Illius, A.W. (1989) **Resource partitioning by ungulates on the Isle of Rhum.** Oecologia 79, 383-389.

Grant, S.A., Bolton, G.R. & Russel, A.J.F. (1984) T**he utilization of sown and indigenous plant species by sheep and goats grazing hill pastures.** Grass and Forage Science 39, 361-370.

Grant, S.A. & Campbell, D.R. (1978) **Seasonal variation in in vitro digestibility and structural carbohydrate content of some commonly grazed plants of blanket bog.** J. Brit. Grassland Soc. 33, 167-173.

Grant, S.A., Lamb, W.I.C., Kerr, C.D. & Bolton, G.R. (1976) **The Utilization of Blanket Bog Vegetation by Grazing sheep.** J. Applied Ecology 13, 857-869.

Green, M.J.B. (1987) **Diet Composition and quality in Himalayan Musk deer based on faecal analysis.** J. Wildlife Management 51:4, 880-892.

Grimes, R.C., Watkin, B.R. & May P.F. (1965) **The botanical and chemical analysis of herbage samples obtained from sheep fitted with oesophageal fistulae.** Journal of the British Grassland Society 20, 168-173.

Grubb, P. & Jewell, P.A. (1966) **Social grouping and home range in feral Soay sheep.** Symp. Zool. Soc. Lond. 18, 179-210.

Gwynedd County Council (1980) **Padarn Country Park Management Plan.** Gwynedd County Council. Caernarfon, N.Wales

Gwynne, M.D. & Bell, R.H.V. (1968) **Selection of vegetation components by grazing ungulates in the Serengeti National Park.** Nature, London. 220, 390-393.

Hansen, R.M. & Dearden, B.L. (1975) **Winter Foods of Mule Deer in Piceance Basin Colorado.** J. Range Management 28:4, 298-300.

Hansen, R.M., Reid, L.D. (1975) **Diet overlap of Deer, Elk and Cattle in Southern Colorado.** J. Range Management 28:1, 43-47.

Harker, K.W., Torrell, D.T. & Van Dyne, G.M. (1964) **Botanical examination of forage from esopahageal fistulas in cattle.** J. Anim. Sci. 23, 465-469.

Harrington, G.N. (1978) T**he Implications of Goat, Sheep and Cattle Diet to the management of an Australian Semi-Arid Woodland.** Proc. of the 1st Int. Rangeland Congress 1978 pp 447-450.

Harrington, G.N. (1986) **Herbivore diet in a semi-arid *Eucalyptus populnea* woodland.** 2. Feral goats. Aust. J. Exp. Agric 26, 423-429.

Havstad, K.M., Donart, G.B. (1978) **The microhistological technique: Testing two central assumptions in South Central New Mexico.** J. Range Management 31:6, 469-470.

Hearney, A.W, Jennings, J.J. (1983) **Annual foods of the Red Deer and the Roe Deer in the East of England.** J. Zool. 201:4, 565-570.

Hellawell, T.C. (*pers comm.*) Countryside Council for Wales, Ffordd Penrhos, Bangor, Gwynedd.

Hellawell, T.C. (1991) **Aspects of the Ecology and Management of the Feral Goat (*Capra hircus* L.) Populations of the Rhinogau and Maentwrog areas, North Wales.** PhD thesis, University College of Wales. Cardiff. Unpublished.

HMSO (1952) **Climatological Atlas of the British Isles.** HMSO London.

Holechek, J.L. (1982) **Sample preparation techniques for microhistological analysis.** J. Range Management 35:2, 267-268.

Holechek, J.L. & Gross, B,D. (1982a) **Training needed for quantifying simulated diets from fragmented range plants.** J. Range Management 35:5, 644-647.

Holechek, J.L. & Gross, B.D. (1982b) **Evaluation of different calculation procedures for microhistological analysis.** J. Range Management 35:1, 721-723.

Holechek, J.L., Gross, B.D., Dabo, S.M., & Stevenson, T. (1982b) **Effects of sample preparation, growth stage and observer on microhistological analysis of herbivore diets.** J. Wildlife Management. 46:2, 502-505.

Holechek, J.L., Vavra, M. & Pieper, R.D. (1982a) **Botanical composition determination of range herbivore diets: A Review.** J. Range Management 35:2, 309-315.

Hosey, G.R. (1981) **Annual foods of the Roe Deer in the South of England.** J. Zool. 194, 276-278.

Howells, M.F., Reedman, A.J. & Leveridge, B.E. (1985) **Geology of the country around Bangor.** HMSO. British Geological Survey.

Hubbard, C.E. (1984) **Grasses. A Guide to their Structure, Identification, Uses and Distribution in the British Isles.** Pelican Books. ISBN 0 14 022279

Hubbard, R.E. & Hansen, R.M. (1976) **Diets of Wild horses, Cattle and Mule Deer in The Piceance Basin, Colorado.** J. Range Management 29:5, 389-392.

Hume, I.D. (1989) **Optimal digestive strategies in mammalian herbivores.** Physiol. Zool. 62, 1145-1163.

Hunter, R.F. (**1962)** Hill Sheep and their pasture: A study of sheep-grazing in S.E. Scotland. Journal of Ecology 50, 651-680.

IDRISI (1992) IDRISI: **A grid based geographic analysis system.** (Computer software) Production: Clark University. Source code : J. Ronald Eastman, (1987)-(1992) version 4.0.

Illius, A.W. & Gordon, I.J. (1987) T**he Allometry of food intake in grazing ruminants.** J. Anim. Ecol. 56, 989-999.

Illius, A.W. & Gordon, I.J. (1990) **Variation in foraging behaviour in Red Deer and the consequences for population demography.** Journal of Animal Ecology 59, 89-101.

Jackson, J. (1977) **The annual diet of the Fallow deer (*Dama dama*) in the New Forest, Hampshire, as determined by rumen content analysis.** Journal of Zoology, London 181, 465-473.

Jacobs, J. (1974) **Quantitative Measurement of Food Selection.** Oecologia 14, 413-417.

Jarrige, R.0. (1965) **The composition of sheep faeces and its relation to forage digestibility.** Proceedings of the 9th Internat. Grassland Cong. pp 809-814.

Johnson S., (1816) **Diary of a journey into North Wales in the year 1774.** ed: R. Duffa. London.

Johnson, M.K. & Pearson, H.A. (1981) **Esophageal, Fecal and Exclosure estimates of Cattle diets on a Longleaf pine-Bluestem Range.** J. Range Management 34:3, 232-234.

Johnson, M.K. & Wofford, H. (1983) **Digestion and Fragmentation: Influence on herbivore diet analysis.** J. Wildlife Management 47:3, 877-879.

Kerridge, F.J. & Bullock, D.J. (1991) **Diet and dietary quality of Red Deer and Fallow Deer in late Summer.** J. Zool. Lond 224, 333-337.

Kirby, E.L. (*pers comm.*) Dyffryn Mymbyr Farm, NantGwryd, Capel Curig. N. Wales.

Leslie, D.M. , Starkey, E.E. & Vavra, M. (1984) **Elk and deer diets in old-growth forests in western Washington.** Journal of Wildlife Management 48:3, 762-775.

Leslie, D.M., Vavra, M., Starkey, E.E. & Slater, R. (1983) **Correcting for differential digestibility in microhistological analyses involving common forages of the Pacific Northwest.** Journal of Range Management 36: 6, 730-732.

Lippert, M., Grant, S.A., & Russel, A.J.F. (1984) **Grazing studies on sown and indigenous hill pastures.** HFRO Biennial Report (1982)-(1983) pp 100-101.

Lippert, M., Russel, A.J.F. & Grant, S.A. (1987) **The use of Goats in hill pasture management. In: Agriculture and Conservation in the Hills and Uplands.** ITE Symp. No.23, eds: Bell, M. & Bunce R.G.H. (1987). ITE.

MacDonald, A. (1987) **Feral Goats in Scotland: Habitat Selection, Diet and Ranging Behaviour.** NCC Internal Report of the Hill Vegetation Management Project. 1st Dec. 1987.

Maisels, F.G. (1988) **The feeding ecology of the Cyprus Mouflon (O*vis orientalis*, Gmelin 1774) in the Paphos forest, Cyprus.** DPhil thesis. University of Edinburgh. Unpublished.

Malechek, J.C. & Leinweber, C.L. (1972) **Forage selectivity by goats on lightly and heavily grazed ranges.** J. Range Management 25, 105-111.

Malechek, J.C. & Provenza, F.D. (1983) **Feeding Behaviour and Nutrition of Goats on rangelend.** World Animal Review 47, 38-48.

Mann, J.C.E. (1983) **The Social Organisation and Ecology of Japanese Sika Deer (*Cervus nippon*) in Southern England.** Phd thesis. University of Southampton. (Quoted in Putman 1984). Unpublished.

Martin, D.J.(1955) **Features On Plant Cuticle. An Aid to the Analysis of the** Natural Diet of Grazing Animals, with Especial Reference to Scottish Hill Sheep. Trans. Bot. Soc. Edin. 36:4, 278-288.

Matrai, K., Koltay, A. & Vizi, G. (1986) **Key based on leaf epidermal anatomy for food habit studies of herbivores.** Acta Botanica Hungarica 32, 255-271.

McCammon-Feldman, B., Van Soest, P.J., Horvath, P. & McDowell, R.E. (1981) **Feeding Strategy of the Goat.** Cornell International Agriculture Mimeog. 88, 1-37.

McCullough, D.R, (1985) **Variables influencing food habits of white-tailed deer on the George Reserve.** Journal of Mammalogy 66:4, 682-692.

McCullough, D.R., Hirth, D.H. & Newhouse, S.J. (1989) **Resource partitioning between the sexes in White-tailed Deer.** J. Wildlife Management 53:2, 277-283.

McDougall, P. (1975) **The feral goats of Kielderhead Moor.** Journal of Zoology, London 176, 215-246.

McInnis, M.L., Vavra, M. & Krueger, W.C. (1983) **A Comparison of four methods used to determine the diets of large herbivores.** J. Range Management 36:3, 302-306.

Miller, G.D. & Gaud, W.S. (1989) **Composition and Variability of Desert Bighorn Sheep Diets.** J. Wildlife Management 53:3, 597-606.

Milner, C., Goodier, R. & Crook, I.G. (1968) **Feral goats in Wales.** Nature in Wales 11:1, 3-11.

Mitchell, F.J.G. & Kirby, K.J. (1990) T**he Impact of large Herbivores on the Conservation of Semi-natural Woods in the British Uplands.** Forestry 63, 333-353.

Mitchell, R.J., Fordham, R.A. & John, A. (1987) **The annual diet of feral goats in lowland rimu-rata Kamahi forests on eastern Mt Taranaki.** N.Z. J. Zool. 14, 179-192.

Moen, A.A. (1973) **Wildlife Ecology.** W.H Freeman & Co. ISBN 0 7167 0826

Munton, P.N. (1975) **A Description of the social life of the Feral Goat. C*apra hircus hircus.*** DPhil. University of Bristol. Unpublished.

Nastis, A.S., & Malechek, J.C. (1981) **Digestion and utilization of nutrients in Oak Browse by Goats.** J. Anim. Sci. 53:2, 283-289.

NCC (Nature Conservancy Council) (1980) **Ratcliffe/Birks Vegetation Classification.** Ratcliffe, D.A., & Birks, H.J.B. NCC Internal Report, Bangor, N. Wales.

NCC (Nature Conservancy Council) (1988) **Upland Vegetation Survey. No. 23 Eryri, the Mountains of Snowdonia.** NCC Report & Map, Wales Field Unit. NCC Bangor, N.Wales.

NCC (Nature Conservancy Council) (1989) **Phase One habitat survey, Llanberis area.** NCC Internal Report. NCC Ffordd Penrhos, Bangor.

NCC (Nature Conservancy Council) (1990) **Handbook for Phase 1 habitat survey.** Publs.: Nature Conservancy Council ISBN0 86139 636 7

Norbury, G.L., & Sanson, G.D. (1992) **Problems with measuring diet selection of terrestrial mammalian herbivores.** Australian J. of Ecol. 17, 1-7.

Norris, J.J. (1943) **Botanical analyses of stomach contents as a method of determining forage consumption of range sheep.** Ecology 24:2, 244-251.

Nugent, G. (1983) **Deer diet estimation by rumen or faecal analysis: An evaluation of available techniques.** New Zealand Forest Research Institute Bulletin 24 1-17.

O'Brien, P.H. (1984) **Feral Goat home range: Influence of social class and environmental variables.** App. Anim. Beh. Sci 12, 373-385.

O'Brien, P.H. (1988) **Feral goat social organisation: A review and comparative analysis.** App. Anim. Beh. Sci. 21, 209-221.

Oosting, H.J. (1956) **The study of plant communities.** W.H.Freeman & Co. San Francisco. pp 77-78.

Owen, M. (1975) **An assessment of fecal analysis technique in waterfowl feeding studies.** Journal of Wildlife Management 39:2, 271-279.

Pallant, D. (1969) **The Food of the Grey Field Slug (*Agriolimax reticulatus*. Muller) in Woodland.** J. Animal Ecology 38,, 391-397.

Papachristou, T.G., & Nastis, A.S. (1993) **Diets of goats grazing oak shrublands of varying cover in northern Greece.** Journal of Range Management 46:3, 220-226.

Parkes, J.P. (1984) **Feral Goats on Raoul Island. II Diet and notes on the flora.** N.Z. J. of Ecology 7, 95-101.

Parkes, J.P. (1990) **Feral Goat Control in New Zealand.** Biological Conservation 54, 335-348.

Pfister, J.A. & Malechek, J.C. (1986) **Dietary selection by Goats and sheep in a Deciduous woodland of Northeastern Brazil.** J. Range Management 39:1, 24-28.

Provenza, F.D. & Malechek, J.C. (1984) **Diet selection by domestic Goats in relation to blackbrush twig chemistry.** J. Applied Ecology 21, 831-841.

Purvis, O.W., Coppins, B.J., Hawksworth, D.L., James, P.W. & Moore, D.M. (1992) **The Lichen Flora of Great Britain and Ireland.** Natural History Museum. London. ISBN 0 565 01163 4

Putman, R.J. (*pers comm*.) Department of Biology, University of Southampton.

Putman, R.J. (1984) **Facts from Faeces.** Mammal Rev. 14:2, 79-97.

Putman R.J. (1991) **Feeding by large herbivores in forests: methods for estimating supply and consumption of forage. In: Methods for the study of large mammals in forest ecosystems.** eds: G.W.T. Groot Bruinderink, & S.E. van Wieren. Publs. Riksinstitut voor Natuurbeheer, The Netherlands. pp 52-63.

Putman, R.J., Culpin, S. & Thirgood, S.J. (1993) D**ietary differences between male and female fallow deer in sympatry and in allopatry.** Journal of Zoology London 229, 267-275.

Putman, R.J., Edwards, P.J., Mann, J.C.E., How, R.C. & Hill, S.D. (1989) **Vegetational and Faunal changes in an area of heavily grazed woodland following relief of grazing.** Biological Conservation. 47, 13-32.

Putman, R.J., Pratt, R.M., Ekins, J.R. & Edwards, P.J. (1987) **Food and feeding behaviour of Cattle and Ponies in the New Forest, Hampshire.** J. Applied Ecology 24, 369-380.

Radcliffe, J.E. (1986) **Gorse: A resource for Goats?** N.Z. J. Experimental Agriculture 14, 399-410.

Radford, A.E., Dickison, W.C., Massey, J.R. & Bell C.R. (1974) **Vascular Plant Systematics.** Publs. Harper & Row. New York. pp 182-201.

Ratcliffe, D.A. (ed.) (1977) **A nature conservation revue.** Vol 2. Publs.: Cambridge University Press.

Riegert, P.W., & Singh, N. (1982) **A Key to identify epidermal fragments of Saskatchewan Rangeland plants.** Can. J. Bot. 60, 2461-2468.

Riney, T. & Caughley, G. (1959) **A study of home range in a feral Goat herd. N.Z.** J. Science 2, 157-170.

Ritchie, M.E. (1990) O**ptimal foraging and fitness in Columbian ground squirrels.** Oecologia 82, 56-67.

Robbins, C.T., Hanley, T.A., Hagerman, A.E., Hjeljord, O., Baker, D.L., Schwartz, C.C. & Mautz, W.W. (1987a) **Role of Tannins in defending plants against ruminants: reduction in protein availability.** Ecology 68:1, 98-107.

Robbins, C.T., Mole, S., Hagerman, A.E. & Hanley, T.A. (1987b) R**ole of Tannins in defending plants against ruminants: reduction in dry matter digestion.** Ecology 68:6, 1606-1615.

Roberts, H. (*pers comm.*) Reserve Warden, Countryside Council for Wales, Ffordd Penrhos, Bangor, Gwynedd, N. Wales.

Roberts, R.A. (1959) **Ecology of Human occupation and land use in Snowdonia.** J. Ecology 47, 317-323.

Rogerson, S.J., Stevens, E.J. & Hughes, J.G. (1976) **An improved preparation technique for identification of plant cuticle in animal faeces.** N.Z. J. Botany 14, 117-119.

Rudeforth, C.C., Hartnup, R., Lea, J.W., Thompson, T.R.E., & Wright, P.S. (1984) **Soils and their use in Wales.** Soil Survey of Eng. and Wales. Bulletin No. 11. Publs. Harpenden ISBN 0 7084 0295 X

Rudge, M.R. (1970) M**other and Kid behaviour in feral Goats.** Z. Tierpsychol. 27, 687-692.

Rudge, M. (1989) **Position statement of the Caprinae Specialist group.** IUCN DSIR Ecology Division.

Samuel, M.J. & Howard, G.S. (1983) **Disappearing forbs in microhistological analysis of diets.** J. Range Management 36:1, 132-133.

Scotcher, J.S.B. (1979) **A review of faecal analysis techniques for determining the diet of wild grazing herbivores.** Proc. Grassland Soc. South Africa 14, 131-136.

Shank, C.C. (1982) **Age-Sex differences in the diets of wintering Rocky Mountain Sheep.** Ecology 63:3, 627-633.

Shank, C.C. (1985) **Inter- and Intra- sexual segregation of Chamois by altitude and habitat during summer.** Z. Saugetierkunde 50, 117-125.

Sidahmed, A.E., Denham, S.C., Morris, J.G., Koong, L.J. & Radosevich, S.R. (1981) **Precision of microhistological estimates of Goats diets from fecal analysis and cell wall passage through the gastrointestinal tract.** Proc. Western Sector Am. Soc. of Anim. Sci. 32, 201-204.

Slater, J. & Jones, R.J. (1971) **Estimation of the diets selected by grazing animals from microscopic analysis of the faeces - A warning.** J. Australian Inst. Agric. Sci 37, 238-240.

Smith, A.D., & Shandruk, L.J. (1979) **Comparison of fecal rumen and utilization methods for ascertaining Pronghorn diets.** J. Range Management 32:4, 275-279.

Smith, A.J.E., (1978) **The Moss Flora of Britain and Ireland.** Cambridge University Press. ISBN 0 521 21648 6

Smith, A.J.E. (1990) **The Liverworts of Britain and Ireland.** Cambridge University Press. ISBN 0 421 23834 X

Smith, J.E. (1989) **Aspects of the Foraging Ecology and Management of feral goats (*Capra hircus*) at Coed Allt Wen and Dinorwic Quarries, N. Wales: A Pilot Study.** MSc Thesis University of Wales, Bangor. Unpublished.

Smith, J.E. & Bullock, D.J. (1993) **A note on the summer feeding behaviour and habitat use of free-ranging goats (*Capra*) in the Cheddar Gorge SSSI.** Journal of Zoology. London 231, 683-688.

Snedecor, G.W. & Cochran, W.G. (1967) **Statistical Methods.** Publs. Iowa State University Press. 6th ed.

Southwood, T.R.E. (1978) E**cological Methods.** Publs. Chapman & Hall. London. ISBN 0 412 30710

Sowell, B.F., Koerth, B.H. & Bryant, F.C. (1985) **Seasonal nutrient estimates of Mule Deer diets in the Texas Panhandle.** J. Range Management 38:2, 163-167.

Sparks, D.R. & Malechek, J.C. (1968) **Estimating percentage dry weight in diets using a microscopic technique.** J. Range Management 21:4, 264-265.

Squires, V.R., (1982) **Dietary overlap between Sheep, Cattle and Goats when grazing in common.** J. Range Management 35:1, 116-119.

Staines, B.W., Crisp, J.M. & Parish, T. (1982) **Differences in the quality of food eaten by red deer (*Cervus elaphus*) stags and hinds in winter.** Journal of Applied Ecology 19, 65-77.

Stephens, D.W. & Krebs, J.R. (1986) **Foraging Theory.** Publs. Princeton University Press. Princeton, N.J.

Stevens, E.J., (1977) **A comparison of three methods of sheep diet determination and the field application of faecal cuticle analysis.** Thesis for Master of agricultural science. University of Canterbury, New Zealand.

Stewart, D.R.M. (1967) **Analysis of plant epidermis in faeces. A technique for studying the food preferences of grazing herbivores.** J. Applied Ecology 4, 83-111.

Storr, G.M. (1961) **Microscopic analysis of faeces, a technique for ascertaining the diet of herbivorous animals.** J. of Applied Ecology 4:1, 157-165.

Stroup, W.W. & Stubbendieck, J. (1983) **Multivariate statistical methods to determine changes in Botanical Composition.** J. Range Management 36:2, 208-212.

Sykes, W.R. (1969) **The effect of goats on vegetation of the Kermadec islands.** Proceeding of the N.Z. Ecological Society 16, 13-16.

SYSTAT (1986) **SYSTAT Inc.: The system for statistics.** (Computer software). SYSTAT 2902 Central St., Evanston, I.L. 60201.

Takatsuki, S. (1978) **Precision of fecal Analysis: A feeding experiment with penned Sika Deer.** J. Mamm. Soc. Japan 7, 167-180.

Taylor, C.A. & Kothmann, M.M. (1990) **Diet Composition of Angora Goats in a short-duration grazing system.** J. Range Management 43:2, 123-126.

Thirgood, S.J. (1990) **Variation in social systems of fallow deer.** PhD thesis. University of Southampton. Unpublished.

Thomas, B. & Fairbairn, C.B. (1956) **The White Bent (*Nardus stricta*): Its composition, digestibility and probable nutritive value.** J. Brit. Grassland Soc. 11, 230-234.

Tilghman, N.G. (1989) **Impacts of White-tailed Deer on forest regeneration in N.W. Pennsylvania.** J. Wildlife Management 53:3, 524-532.

Todd, J.W. & Hansen, R.M. (1973) **Plant fragments in the faeces of Bighorns as indicators of food habits.** J. Wildlife Management 37:3, 363-366.

Trinder, N. (1975) **The feeding value of moorland plants.** Annual Report, ADAS. Science Service. pp 176-187.

Van Dyne, G.M., Brockington, N.R., Szocs, Z., Duek, J. & Ribic, C.A. (1980) **Large herbivore subsystem. In: Grasslands, Systems Analysis and Man.** Eds. Breymeyer, A.I. & Van Dyne, G.M. (1980) Cambridge University Press. ISBN 0 521 21872 1

Van Dyne, G.M. & Heady, H.F. (1965) B**otanical composition of sheep and cattle diets on a mature annual range.** Hilgardia 36:13, 465-492.

Van Soest, P.J. (1982) **Nutritional Ecology of the Ruminant.** Ed. P.J. Van Soest. O & B Books, Corvallis, Oregon.

Vavra, M. & Holochek, J.L. (1980) **Factors influencing microhistological analysis of herbivore diets.** J. Range Management 33:5, 371-374.

Vavra, M., Rice, R.W. & Hansen, R.M. (1978) **A comparison of esophageal fistula and fecal material to determine Steer diets.** J. Range Management 31:1, 11-13.

Villena, F. & Pfister, J.A. (1990) **Sand Shinnery oak as a forage for Angora and Spanish Goats.** J. Range Management 43:2, 116-122.

Voth, E.H. & Black, H.C. (1973) **A histologic technique for determining feeding habits of small herbivores.** J. Wildlife Management 37:2, 223-231.

Watson, A. & Staines, B.W. (1978) **Differences in the quality of wintering areas used by male and female Red Deer in Aberdeenshire.** J. Zool. Lond. 186, 544-550.

Watts, T. & Conley, W. (1984) **Reproductive potential and theoretical rates of increase for feral goat populations.** J. Wildlife Management 48:3, 814-822.

Westoby, M. (1974) A**n analysis of diet selection by large generalist herbivores.** American Naturalist 108, 290-304.

Westoby, M. (1978) W**hat are the biological bases of varied diets?** American Naturalist 112, 627-631.

Westoby, M., Rost, G.R. & Weis, J.A. (1976) **Problems associated with estimating herbivore diets by microscopically identifying plant fragments from stomachs.** J. Mammalogy 57:1, 167-172.

Williams, O.B. (1969) **An improved technique for identification of plant fragments in herbivore feces.** J. Range Management 22, 51-52.

Wilson, A.D, Leigh, J.H., Hindley, N.L. & Mulham, W.E. (1975) C**omparison of the diets of Goat & sheep on a C*asuarina cristata-heterodendrum oleifolium* woodland community in western New South Wales.** Austr. J. Exp. Agric. Anim. Husb. 15, 45-53.

Wofford, H., Holechek, J.L., Galyean, M.L., Wallace, J.D. & Cardenas, M. (1985) **Evaluation of fecal indices to predict cattle diet quality.** J. Range Management. 38, 450-454.

Yocom, C.F. (1967) **Ecology of feral goats in Haleakala, Mauii Hawaii.** Amer. Midl. Natur. 77, 418-451.

Zar, H.J. (1984) **Biostatistical Analysis.** Publs. Prentice-Hall International, Inc. U.S.A. ISBN 0 13 077595 9

Zyznar, E. & Urness, P.J. (1969) **Qualitative identification of forage remnants in Deer feces.** J. Wildlife Management 33:3, 506-510.