Chapter 1:

Introduction to vegetation dynamics and seasonal grazing regimes

1.1 INTRODUCTION

The aim of this thesis is to develop an understanding of the importance of seasonality of grazing for vegetation dynamics. Vegetation is the basal resource in the uplands of Scotland; its structure and composition determines the value of an area for animal production, biodiversity and amenity (Armstrong & Milne, 1995). An understanding of changes in the structure and composition of vegetation, termed 'vegetation dynamics' is therefore an essential tool for the manager and policy maker, whatever the management aims.

Grazing animals influence vegetation dynamics through the processes of selective defoliation (Fenton, 1936), trampling (Nagy *et al.* 2002) and dunging (Bakker *et al.* 1983; Lane, 1992). While other species of herbivore (particularly red deer) have had considerable impact on vegetation in the Scottish uplands, sheep, the primary species of domestic stock since the 1800s (Watson, 1932), have been central to vegetation development (Miles, 1988, Ritchie, 1919). The form of the sheep industry in the UK, with comparatively high numbers of animals present on hill ground throughout the year, has implications for conservation in the uplands (Anderson & Yalden, 1981).

Seasonal sheep grazing regimes, as opposed to year-round grazing, have been advocated for the purposes of biodiversity conservation (Harris & Jones, 1998; Backshall, 2001) and for increased animal production (Hulbert *et al.* 1999; Cunningham, 1979). However, the practice of removing grazing stock during the winter months has been criticised by some conservationists (Helmer, 2002; Milner *et al.* 2002) as an inappropriate form of management. The subject of this thesis is the impact of grazing by domestic sheep (*Ovis aries*) on vegetation dynamics, focussing on the effects of seasonal grazing regimes. The grazing regime of interest involves removing sheep from hill ground between October and April, termed 'off-wintering'. The particular context of the work is the effect of seasonal grazing regimes on upland acid grasslands in the West and Central Highlands of Scotland.

Current standard sheep husbandry in the uplands involves leaving ewes on the hill throughout the year (Waterhouse, 1999), in spite of the fact that low temperatures and sub-maintenance food availability from January to April result in a period of nutritional stress (Cunningham, 1979). In the Hill Sheep and Native Woodland (HSNW) Project (section 2.2), a systems-scale experiment is in progress to assess the impact of sheep off-wintering. The long-term aim of the HSNW Project is to integrate summer or autumn grazing of sheep within a newly established woodland in an upland valley.

Upland acid grasslands cover around 20 % of the total area of the uplands, compared with around 50 % by heather moorland (Milne *et al.* 1998). Although the upland grasslands are a very important resource for agriculture and biodiversity conservation, research effort has usually been directed toward heather moorland. While acid grasslands are viewed by some conservationists as merely degraded heath, they have conservation value in their own right, and have a variety of important vertebrate and invertebrate species associated with them (Holland, 2002; Cosgrove, 2002). This work will focus on the impacts of grazing on acid grassland communities. Since the majority of plant species in upland acid grassland are perennial and seedling establishment occurs only rarely (Bullock *et al.* 1994 a) the effects of grazing on vegetative processes are highlighted.

In this thesis, the impacts of seasonal grazing regimes of the type proposed in the HSNW Project on vegetation are explored. The perspective is generally that of the plant rather than the grazing herbivore. The impacts are studied at three levels of organisation, the plant species, plant community and landscape level. A variety of approaches are employed: experimental work on the response of plant species to simulated seasonal grazing (Ch 3); field monitoring of the impact of seasonal and year-round systems-scale grazing regimes on species abundance (Ch 4); collation of qualitative information on plant-herbivore interactions (Ch 5); qualitative modelling to predict changes in species abundance (Ch 6); and a study of plant herbivore interactions in grazed woodlands (Ch 7).

1.1.1 Background of land-use and vegetation history

At the end of the last ice-age, approximately 11,500 before present (BP), the vegetation of Scotland was tundra, dominated by *Juniperus* spp. and *Empetrum* spp. (Lowe & Walker, 1981). From 11,000 years BP to 8000 years BP colonisation by woodland occurred (Tipping, 2003). Waves of tree species invaded: birch (*Betula* spp.); hazel (*Corylus avellana*); wych elm (*Ulmus glabra*); Scots pine (*Pinus sylvestris*); alder (*Alnus glutinosa*) (Birks, 1989). The density and extent of the woodland cover that developed is difficult to determine precisely, but it is likely that the landscape would have comprised a shifting mosaic of patches of woodland, mire, heathland and grassland (Tipping, 2003; Fenton, 1997).

Hunter-gatherer societies present in Scotland before 2,500 BP would have had comparatively little impact on vegetation (Smout, 1997; Tipping, 2003). With the introduction of agriculture 6000 years BP management of domestic stock started to affect patterns of vegetation change: woodland declined, and grasslands and heaths increased in cover (Sydes & Miller, 1988). This change roughly coincided with a change in climate, known as the atlantic-boreal shift, which resulted in cooler temperatures and higher rainfall (Barry & Chorley, 1992). By the arrival of the Romans, much of the South of Scotland was deforested (Dickson, 1994), though tracts of forest remained in the highlands. Reductions in woodland cover in the highlands occurred in response to a variety of factors, including climate change (resulting in the development of blanket bog), leaching of soils, felling of trees and the presence of grazing animals (Smout, 1997). A map of the Strathfillan area (which includes the main study site) dating from the late 18th Century (Stobie, 1783) shows that the location and size of woodland patches was very similar to that of patches of native woodland today. This pattern is repeated for many other locations (Stewart, 2003). The cause of deforestation in the Scottish highlands was therefore not, as suggested by some sources (e.g. Ritchie, 1919) necessarily the introduction of commercial sheep farming in the late 18th and early 19th centuries.

Subsistence farming in upland Scotland probably changed relatively little from the iron age until the Highland clearances (Armit & Ralston, 2003). Small sheep were kept for meat and wool, along with cattle and goats for meat and milk, and ponies for work (Watson, 1932). A transhumance system involved stock being grazed on hill pastures for six to eight weeks during summer (Livingstone, 1973) and over-wintered in human dwellings (Watson, 1932).

The Highland clearances of the mid- to late-18th Century, a period of considerable socio-economic change (Smout, 1969), saw the introduction of large-scale commercial sheep farming, based on the Blackface sheep, a larger and hardier breed than that used by subsistence farmers (Watson, 1932). The hardiness of this breed allowed less intensive husbandry, with animals left on the hill throughout the year. While the numbers and types of sheep grazing in upland Scotland have fluctuated somewhat in response to economic and environmental pressures, the overall system of year-round sheep grazing has been maintained since the early 19th century (Holland, 2001).

It is claimed that the quality of the vegetation of the uplands for commercial sheep farming was excellent when the sheep were first introduced, but that a decline in carrying capacity occurred from 1850 onwards (Watson, 1932). The changes in vegetation are said to have involved increases in bracken (Fenton, 1936), heather and 'other original types of vegetation' (*Nardus stricta*?) on patches that had previously supported 'fine sweet grassy herbage' (Watson, 1932). These changes are attributed to the cessation of folding stock at night, which concentrated nutrients in localised areas, to the increase in sheep numbers and the year-round sheep grazing system, and to the decrease in cattle grazing (Watson, 1932). However, other factors would have influenced vegetation change; before the clearances bracken was used extensively for thatching and for animal bedding (Dickson & Dickson, 2000). It should also be noted that perceived changes in vegetation may not be factual; it seems unlikely that heather should increase following a change to more intensive year-round sheep grazing.

Hill flocks are self replenishing, with the majority of ewe lambs retained for breeding. Animals are habituated to a 'heft' or home-range, within which they forage for herbage throughout the year (Cunningham, 1979; Ashworth *et al.* 2000). Following mating in November, ewes bearing a single lamb are left on the hill and survive a 'hungry gap' from January to April. Hill ewes are undernourished during this time, and mobilise their body tissues to allow themselves and their foetuses to survive (Armstrong *et al.* 1979; Williams, 1973). Since the 1970s, ewes bearing twin lambs have generally been brought in-bye (i.e. lower, enclosed pastures) or housed in sheds from February until lambing in May (Ashworth *et al.* 2000). Output from hill sheep systems is generally low, with weaning percentages (number of lambs weaned in relation to number of ewes of breeding age) ranging from 60 to 110 percent (Cunningham, 1979). As with other land-based industries in the uplands, hill farming is heavily dependent on subsidies (Dewar-Durie, 2000) and has been experiencing economic problems for decades (Cunningham 1979; Williams, 1973).

1.1.2 Current land-use objectives

At present there are several objectives for land-use in upland Scotland, some conflicting. They vary from the maintenance of the rural economy and rural employment, through the subsidised production of lamb and wool (Ashworth *et al.* 2000), through habitat maintenance for game birds and deer for sporting interests (Armstrong, 1991; Price *et al.* 2002), timber production (Tudor & Mackey, 1995), and biological conservation of rare species and habitats (Sydes, 1990). All of the major traditional forms of land-use in the uplands are subsidised in some form (Price *et al.* 2002). A further, un-subsidised source of income for rural areas is tourism, an industry that is affected by land-use, and that in turn can influence land-use. Some tourists take a very active interest in the management of the land they wish to visit, for example those who would like to see the Scottish mountains restored to some "pristine" state:

> ".. how do you restore … land to allow natural processes to become dominant again? … by stopping certain human activities which prevent natural processes taking their course, particularly sheep farming" (Kempe, 2002).

The human activity of sheep farming is centred around the process of grazing, which has been ongoing in Scotland by wild herbivores since before the end of the last ice-age (Tipping, 2003). Since sheep grazing can be considered as an analogue of natural grazing, its prevention is not necessary to restore natural processes. Less radical are the conservationists who propose that the appropriate level of herbivore numbers for a given area is that which can survive over winter (Helmer, 2002). While this is ideal for large nature reserves in countries with little snow, it may not be the method that most closely resembles either natural or traditional patterns of grazing, when considered at the scale of a few square kilometres in the uplands and mountains of Scotland. The most appropriate pattern of grazing here could be a summer-seasonal grazing regime, reflecting the migratory patterns of wild herbivores (Albon & Langvatn, 1992), and the traditional pattern of transhumance (Livingstone, 1973).

Views on the relationship between sheep farming and conservation are deeply divided. Some parties are determined to see a reduction in sheep numbers (Crofts *et al.* 1996), while others stress the importance of the presence of grazing for managing grasslands for biodiversity objectives (National Sheep Association, 1991; Oates & Tolhurst, 2000). In reality, sheep farming is a cultural activity supported by UK and European subsidies (Ashworth *et al.* 2000), and management objectives must be set so as to meet the demands of as many of the interested parties as possible. It should also be remembered that people are part of Scotland's environment:

> "The historical and cultural background in this mountain country is very important and local people have a vital role in managing their environment. Scotland has very few areas that can be regarded as pristine wilderness – this is a landscape in which mankind has played a role for hundreds, indeed thousands of years" (Hawkins, 2002).

While open, non-wooded habitats frequently have high biodiversity value, carefully situated native woodlands add structural diversity, increasing landscape amenity and potentially increasing biodiversity. Integrating grazing within such woodlands at a moderate, seasonal level may be a way of maximising biodiversity and conservation goals (Kirby *et al.* 1994) without penalising any animal or timber production values.

In the HSNW Project it is planned to integrate spring-summer-autumn sheep grazing within a birch-pine woodland planted in 1999 (see Ch 2 for further information). It is hoped that this will result in several positive outcomes: shelter for sheep; shade cast by trees could potentially increase the abundance of palatable grass species; lengthening of the growing season, resulting from the increased shelter and producing increased food for sheep at critical times (lambing and mating); grazing would be managed in such a way that it does not compromise the ability of the woodland to regenerate itself.

On the negative side, it should be noted that the HSNW project system is still heavily reliant on grant aiding, albeit forestry combined with farming rather than farming alone, and that there may be practical management issues relating to the gathering of sheep from inside the woodland. The upland habitats on which the woodland was established, acid grassland, and in some areas, mire, will decline in area as the woodland develops.

The HSNW project should further meet the objectives of increased rural employment, improved landscape and conservation, without compromising potential for renewable energy production.

1.1.3 Vegetation responses to herbivory

A major determinant of the trajectory of vegetation succession is the intensity of grazing (Milne *et al.* 1998). In temperate climates with moderate to high rainfall, under very light levels of grazing or in the absence of grazing, woodland or scrub

are likely to develop. At light to moderate grazing dwarf-shrub heath is dominant, and under heavy grazing grassland develops (Milne *et al.* 1998). However, in a global context, the replacement of grasslands by shrublands has been observed under heavy grazing (Milchunas & Lauenroth, 1993). Within plant communities, shifts in species abundance occur because the competitive ability of species is affected by the level of herbivory experienced by species, and by the species response to grazing (Augustine & McNaughton, 1998; Noy-Meir *et al.* 1989; Gordon & Hutchings, 1993; Milner *et al.* 2002). Although the response to grazing is also influenced by climate, soils, geology, and historical grazing (Milchunas & Lauenroth, 1993), these factors are explored less in the thesis than plant responses to grazing and herbivore preferences.

Levels of herbivory are affected by the numbers of animals present relative to the availability of food and animal selection preferences (Baumont *et al.* 2000). If the sward is grazed during part of the year only, significant differences in the species abundance may result (Bullock *et al.* 2001). These issues are of considerable importance, and are explored in depth in this thesis.

This thesis is directed towards two tasks. The first is practical and applied, and to some extent context specific: to determine the impact of the system changes implicit within the HSNW Project on plant species and communities (Chapter 4) and the landscape (Chapter 7). The second is more academic and of broader application, and involves an exploration of the factors that determine changes in plant species abundance in seasonally grazed systems.

Plant species abundance in grazed systems is thought to be related to the interaction between plant responses to grazing and herbivore selection preferences (Augustine & McNaughton, 1998, Noy-Meir *et al* 1989; Gordon & Hutchings, 1993). The interactions between these variables are explored in Chapter 6.

The extant morphological and physiological characteristics of plants determine their ability to survive in a given set of environmental conditions (Steffen, 1996;

Lavorel *et al.* 1997). Workers exploring the interaction between plant traits and plant response to grazing have focussed on grouping species on the basis of traits thought to determine responses to grazing (McIntyre & Lavorel, 2001; Lavorel *et al.* 1999; Sternberg *et al.* 2000). While this is a useful approach to aid comparison of the behaviour of a range of communities, a finer scale approach, where the characteristics of individual species are studied, is adopted in Chapter 3.

Grazed ecosystems are complex, with a large number of factors interacting to determine animal production levels and changes in plant species composition (Table 1.1) (Gordon & Hutchings, 1993). Those factors under study in the thesis, as well as those beyond the scope of the thesis, are indicated in Table 1.1. Models of grazed systems have been developed, aimed at understanding how the systems work, at making predictions of the effect of various management regimes, and at highlighting gaps in scientific knowledge (Herrero *et al.* 1998). The majority of these models are empirical and therefore limited in the number of cases for which predictions can be made. However, qualitative models based on functional types of vegetation have been used to predict changes in vegetation abundance in response to different disturbance regimes (Pausas, 1999; Noble & Slatyer, 1980), though not to grazing. In Chapter 5, two sources of information, expert opinion and plant trait information from the literature, on plant herbivore interactions are collated and compiled. In Chapter 6, a comparison of the predictions of change in species abundance is made using the two sources of information from Chapter 5 and the information from Chapter 3.

Chapter 7, the final research chapter of the thesis, broadens the context of the work to include grazed woodlands. The long-term aim of the HSNW project is to integrate seasonal sheep grazing within a recently established native woodland. It is considered desirable that the woodland continues to regenerate itself so that grazing can be continued year after year. Many conservationists and foresters believe that regeneration of woodlands is not possible if sheep are present (Pigott, 1983; Chatters & Sanderson, 1994). In Chapter 7, examples of woodlands

regenerating in the presence of grazing animals are presented, and the levels of browsing damage to small trees documented.

Table 1.1. Factors determining the effects of grazing on vegetation. Those of interest in this thesis are indicated. Factors 1-6 and 8-11 from Ausden & Treweek (1995). Factor 7 from Holland (2001). Key to symbols: ● = major topic for thesis; ○ = minor topic for thesis; blank = factor beyond scope of this thesis.

Factor	Examples	Under study in thesis?
1. Types and areas of vegetation	Acid grassland, heather moorland	○
2. Condition of the vegetation	Proportion of different age classes of heather	○
3. Timing of grazing	Year-round, seasonal, occasional	●
4. Intensity of grazing	Numbers of animals, length of grazing period	○
5. Type of grazing animal	Species, breed, age, sex	○
6. Associated practices	Supplementary feeding, presence and nature of shepherding practices	
7. History of grazing management	Previously ungrazed, stocked with different species, stocked with same species	○
8. Other management practices	Burning, cutting, bracken management	
9. Existence and location of fences and other boundaries	In-bye land separated from hill, unfenced marches.	
10. Geographical location of the area		
11. Underlying geology, soil type and soil wetness of the area	Dalriadan mica-schist, soil pH	
12. Climate, topography, altitude and aspect		

1.2 AIM AND OBJECTIVES

Aim: develop an understanding of the importance of seasonality of grazing for vegetation dynamics.

Objectives:

1. Provide information on the effects of seasonal herbivory on upland plant species with a range of life-forms and phenologies (Ch 3).
2. Investigate the effect of sheep grazing regimes on upland plant communities (Ch 4).
3. Identify and collate sources of qualitative information for predicting plant-herbivore interactions (Ch 5).
4. Explore the potential of qualitative models for predicting change in vegetation (Ch 6).
5. Increase understanding of the impact of sheep browsing on natural regeneration of birch, and of the value of mature woodlands to sheep (Ch 7).
6. Assess the contribution to the overall aim made by the various methods used for objectives 1-5 (Ch 8).
7. Identify the potential for manipulation of seasonality of grazing systems to achieve specific conservation/animal production objectives (Ch 8).