SCOTTISH NATURAL HERITAGE

# COMMISSIONED REPORT

Commissioned Report No. 203

# The effects of cattle on the natural heritage of Scotland

(ROAME No. F04AA103)

*For further information on this report please contact:*


Barbara Bremner
Scottish Natural Heritage
Great Glen House
Leachkin Road
INVERNESS
IV3 8NW
Telephone: 01463 725000
*E-mail: barbara.bremner@snh.gov.uk*


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COMMISSIONED REPORT

# Summary

## The effects of cattle on the natural heritage of Scotland

Commissioned Report No. 203 (ROAME No. F04AA103)
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### Background

This review aimed to clarify the benefits and detrimental effects of cattle on a range of unimproved habitats, wildlife species and on the landscape in Scotland. Specifically the review aimed to:

a) collate existing published and unpublished information on the impact of cattle on specific unimproved habitats, wildlife species and the landscape;

b) summarise the information, consider the generality of the findings and draw conclusions about the impacts of cattle, including benefits and adverse effects of cattle and the associated farming systems and;

c) identify areas of uncertainty in current knowledge.

The review concentrated primarily on information from Scotland and other parts of the UK, but where relevant, information from outside the UK was included.

### Main findings

- Cattle are less selective in their grazing behaviour than other domestic herbivores.
- This results in different impacts on unimproved, semi-natural habitats compared to, for example, sheep. Compared to other domestic grazers, cattle result in:
  - a more structurally diverse sward;
  - a reduction in the cover of tussock forming species;
  - creation of more niches for plant regeneration.
- There is a lack of empirical objective information on the impacts of cattle grazing for many unimproved habitats.
- For the habitats for which there is empirical information, in most cases, grazing by cattle is either beneficial or at least neutral, *provided that the grazing is at an appropriate stocking density and seasonal pattern*.
- Cattle should not graze bog vegetation (blanket bog and raised lowland bog).
- There have been no scientific studies of foraging behaviour of different breeds of cattle.
- There is very little information on the effects of cattle grazing on priority species.
- As well as having a direct effect on habitats, cattle can affect the natural heritage by being part of the farming system.
- Potential negative effects of cattle farming systems include trampling and poaching, bank erosion and pollution of water courses from farm yard manure, slurry and silage effluent. These impacts can all be minimised by adhering to good practice guidelines.
- Positive impacts of cattle farming systems include dung, where it supports high populations of invertebrates, fodder production which can result in hay meadows and small-scale cereal production.

*For further information on this project contact:*
**Barbara Bremner, Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness IV3 8NW**
**Tel: 01463 725000**

*For further information on the SNH Research & Technical Support Programme contact:*
Senior Management Unit Advisory Services, Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness IV3 8NW
Tel: 01463 725000 or **ascg@snh.gov.uk**

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# 1 INTRODUCTION

## 1.1 National and international perspectives

The Scottish landscape comprises large areas of unimproved, semi-natural habitats. This is especially the case in the uplands, which are dominated by semi-natural vegetation types which have been affected by human activities to a greater or lesser degree. There are also some important semi-natural habitats in the lowlands. The two human-influenced activities in recent times which have had, and continue to have, most impact on the nature of the vegetation of the uplands, apart from afforestation, are grazing by domestic and wild large herbivores and burning.

The effect of grazing by large domestic and wild herbivores on the natural heritage value of the uplands have been a long-standing issue (Milne *et al.*, 1998). For example, McVean and Lockie (1969) argued that in the Western Highlands, livestock and deer management was reducing soil fertility and vegetation diversity to lower levels by the end of the 19th century. More recently, there has been an accumulation of evidence of a decline in the area of heather moorland in Scotland (Tudor and Mackey, 1995). There has been also a marked decline in the area and status of semi-natural woodland (Mitchell and Kirby, 1990; Roberts *et al.*, 1992). These changes lead to a reduction in the abundance of fauna (Usher and Gardner, 1998) and an increase in the rarity of some species. However, at many sites grazing is a characteristic part of the landscape, and reduction or abandonment of grazing can lead to loss of nature conservation and amenity value (Fry, 1991).

The national and international significance of areas of blanket bog, montane plant communities and ericaceous dwarf shrubs within Scotland support large bryophyte-rich and pteridophyte-rich communities with localised world distributions and unusual breeding bird assemblages. They provide a unique landscape of high conservation significance (Ratcliffe and Thompson, 1998). This is recognized in the range of habitat types included in Annex 1 of the EU Habitats Directive. These include raised and active blanket bogs, species-rich *Nardus* grassland, alpine and sub-alpine heaths, Caledonian pine woodland and sub-Artic willow scrub. All these habitats are subject to grazing as a major influence.

Domestic livestock, including cattle, have a significant impact on many of these unimproved habitats, either directly through grazing and trampling of habitats, or via the impacts of farming systems which include cattle. The impact of grazing by cattle, along with the impacts of farming systems associated with cattle are considered in this review.

## 1.2 Objectives, methods and structure of the review

The objectives of the review are to:

a) collate existing published and unpublished information on the impact of cattle on specific unimproved habitats, wildlife species and the landscapes;

b) summarise the information, consider the generality of the findings and draw conclusions about the impacts of cattle, including benefits and adverse effects of cattle and the associated farming systems; and

c) identify areas of uncertainty in current knowledge.

The project was undertaken by reviewing the scientific literature and undertaking web-based searches for other relevant published and unpublished information. The review concentrated primarily on information from Scotland and other parts of the UK but, where relevant, information from outside the UK was included. Ongoing, but unpublished research is also referred to on occasion, based on the personal knowledge of the review team.

The structure of the review is firstly to describe the numbers and relevant characteristics of cattle (Chapter 2). Chapter 3 reviews the impact of cattle on a range of semi-natural habitats including summarising best practice, while Chapter 4 considers the effects of cattle on priority species. The role of cattle within farming systems on the natural heritage is considered in Chapter 5 while Chapter 6 gives the conclusions. The Bibliography summarises the studies that have evaluated the impacts of cattle on the natural heritage. Finally sources of information are given in the References section.

## 1.3 Land cover

From the Land Cover of Scotland 1988 dataset (MLURI 1993a and b) the cover of some of the main vegetation types relevant to this review in the uplands has been extracted and is shown in Table 1.1a. The cover of nationally significant mosaics of each of the cover types is given in Table 1.1b. More or less equal amounts of heather moorland and peatland dominate the upland area, covering 55.6% of the area on their own or in mosaics with each other, and being present in other mosaics covering another 14.6% of the area. Grasslands and bracken (14.9% of the area) cover over half of what remains and are also the main vegetation-forming mosaics with heather and peatland (11.4% of the area). Most of the remaining area is divided nearly equally between woodlands and scrub (5% of the area), and unclassified mosaics (5.4% of the area). Native woodlands cover only 1% of the land area of Scotland with 91% of this occurring in the Highlands. The distribution of land cover types is given in Figure 1.1. This shows that heather and peatland predominate in the west and north of Scotland while rough grassland is found largely in the south and east of Scotland.

**Table 1.1** Total area of selected land cover types in the uplands of Scotland (from the Land Cover of Scotland, 1988, MLURI 1993a and b)

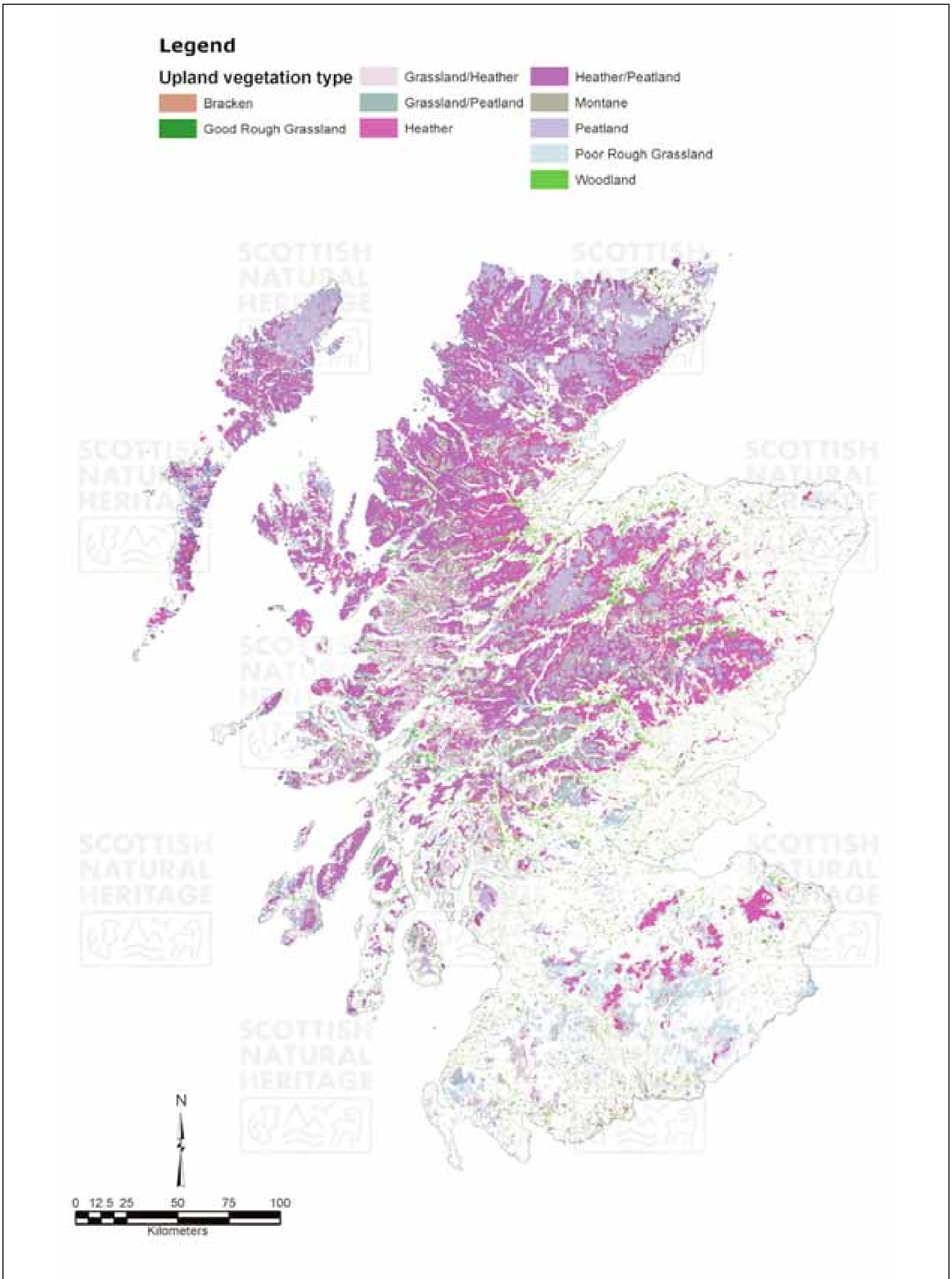
*a) Major cover types*

| Land cover types | Area (km$^2$) | % | Corresponding habitats in Chapter 3 |
|---|---|---|---|
| Good Rough Grassland | 2,472.2 | 5.3 | Neutral, base rich, acidic, coastal grasslands and machair |
| Poor Rough Grassland | 2,011.0 | 4.3 | Acidic grassland, rush pasture |
| Bracken | 117.3 | 0.3 | |
| Heather Moorland | 6,881.5 | 14.8 | Lowland heath, moorland, coastal heath |
| Peatland | 6,600.2 | 14.2 | Lowland raised bog, blanket bog |
| Montane | 1,604.5 | 3.5 | |
| Rocks and Cliffs | 348.1 | 0.7 | |
| Felled Woodlands | 299.8 | 0.6 | |
| Semi-Natural Coniferous | 75.0 | 0.2 | Semi-natural woodland |
| Mixed Woodland | 854.5 | 1.8 | Semi-natural woodland |
| Broad-Leaved Woodland | 1,024.3 | 2.2 | Semi-natural woodland, wood pasture |
| Scrub | 74.4 | 0.2 | Scrub, including montane |
| Marshes | 127.9 | 0.3 | Wetland, fen, saltmarsh |
| Nationally Significant Mosaics (see Table 1.1b) | 24,011.8 | 51.5 | |
| **Total** | **46,502.5** | **100.0** | |

*b) Nationally significant mosaics*

| Cover types in mosaic | | Area (km$^2$) | % |
|---|---|---|---|
| Heather Moorland | Peatland | 12,370.9 | 26.6 |
| Poor Rough Grassland | Heather Moorland | 3,230.0 | 6.9 |
| Good Rough Grassland | Heather Moorland | 1,452.9 | 3.1 |
| Peatland | Montane | 935.5 | 2.0 |
| Good Rough Grassland | Poor Rough Grassland | 848.0 | 1.8 |
| Improved Grassland | Good Rough Grassland | 814.8 | 1.8 |
| Good Rough Grassland | Bracken | 660.9 | 1.4 |
| Poor Rough Grassland | Peatland | 634.0 | 1.4 |
| Heather Moorland | Montane | 539.9 | 1.2 |
| Unclassified | | | 5.4 |
| **Total** | | **24,011.8** | **51.6** |

**Figure 1.1** Main land cover types in upland Scotland



# 2 CATTLE POPULATIONS AND THEIR FORAGING BEHAVIOUR

## 2.1 Distribution and numbers of cattle

Information on the numbers of cattle in recent times is normally based on the June census data collected by SEERAD. Whilst these data provide good estimates of total numbers in Scotland, they provide less useful information on their distribution. The data are aggregated on a parish basis so it is not possible to identify the vegetation of habitat types grazed by these cattle. Also, since 1990, those parishes containing three or less farms have been omitted from the dataset disclosed to protect the confidentiality of the information. Nevertheless most of the information on numbers and distribution that has been published is based on this data set (HFRO, 1970; Harding *et al*., 1994). Although numbers per parish give some indication of grazing impact, livestock densities per parish provide more useful figures since parishes differ in size.

In the last century hill cattle numbers have declined. Darling (1955) noted that sheep: cattle ratios had increased from 15:1–40:1 between 1911 and 1946. Whilst hill cattle numbers increased between the Second World War and 1970 (HFRO, 1970), their numbers have since declined. The number of breeding beef cows in Scotland in 2004 (SEERAD, 2004) was 503,574 while in 1990 there were 541,561. However it is not possible to estimate accurately those that graze specific habitats from currently available statistics even although data are available at the parish level. The distribution of beef cattle, derived from the 1990 and 2004 census, within Scotland is given in Figures 2.1–2.4. The densities of beef cattle (livestock units (LU) per $km^2$ of agricultural land) are shown. This includes beef cows, beef bulls, and other beef cattle and assumes that 1 LU is the equivalent of one adult dairy cow. Figure 2.5 shows the change, by parish, in total beef cattle livestock units. The highest densities of beef cows are in the areas lying between the lowland and hill areas, the traditional 'upland' farms. A broadly similar pattern is evident in the maps of all beef cattle livestock units, except that the densities are also high were there are significant numbers of fattening cattle eg in the North East of Scotland. It is difficult to see a clear spatial pattern in the change in beef cattle livestock units between 1990 and 2004 (Figure 2.5), but parishes where there has been an increase in numbers appear to be mainly in the upland fringe.

The review of the Common Agricultural Policy and the introduction of the Single Farm Payment in 2005 may bring about further changes in the cattle population in Scotland. It has been suggested that breeding cow number in Scotland could fall by about 5% in Scotland as a whole and about 13% in the Highlands and Islands area (Cook and Copus, 2003).

## 2.2 Foraging behaviour and diet selection

The direct impact of cattle on the natural heritage depends primarily upon the numbers of cattle grazing, and the processes of defoliation, trampling and excretal return by individual animals of which defoliation probably has the largest impact. Ultimately the impact of defoliation on the vegetation is at the individual plant level, but the foraging choices that the animal makes within a plant community and its ranging behaviour between plant communities also determines the impact. This means that an understanding of cattle grazing behaviour is required across a number of geographical scales (see Figure 2.2 for a diagrammatic representation of these scales). Different large herbivores have different impacts on vegetation by virtue of their different feeding methods associated with their size and shape of mouth. This information is summarised in Table 2.1 for each species of large herbivore. Cattle are unique among these large herbivores in having a feeding method which involves a tearing action with their tongue. They also have a low ability to be selective in selecting their diet and the minimum sward height grazed is higher than other large herbivores cited except for horses.

**Figure 2.1** Distribution of beef cows in Scotland, 1990. (Number per ha of agricultural land)

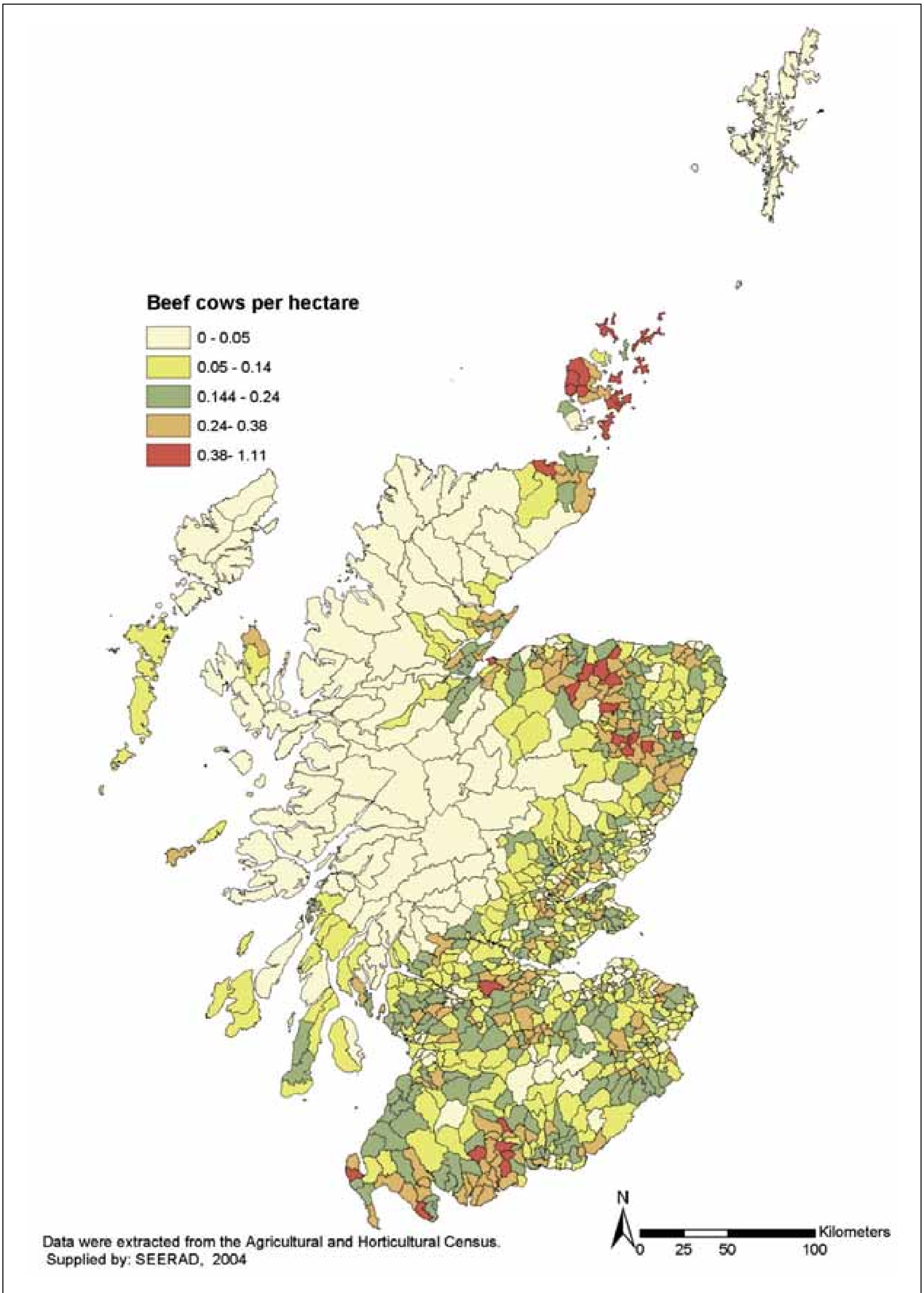


**Figure 2.2** Distribution of beef cows in Scotland, 2004. (Number per ha of agricultural land)

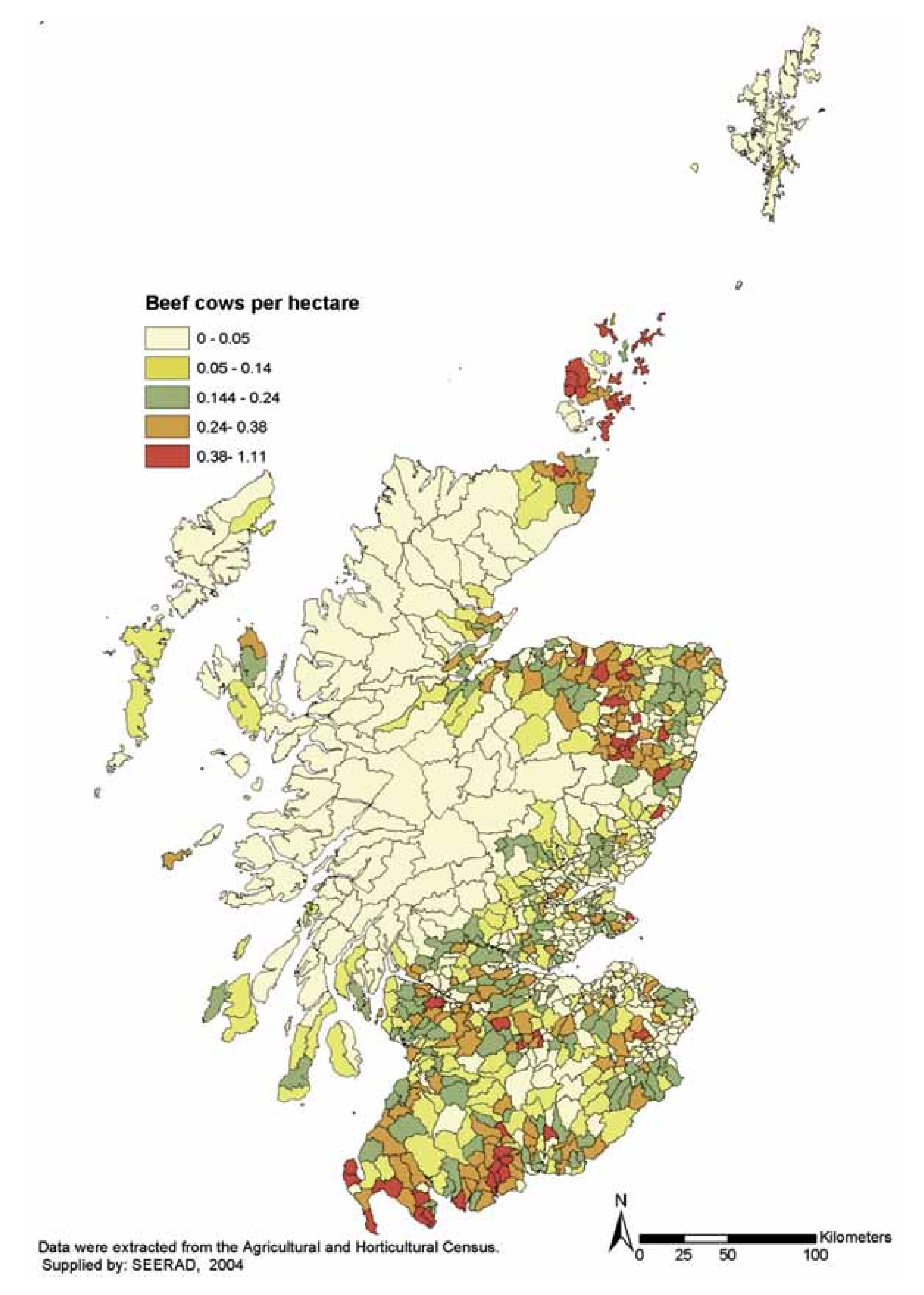


**Figure 2.3** Distribution of all beef cattle in Scotland, 1990. (Number of livestock units per ha of agricultural land)

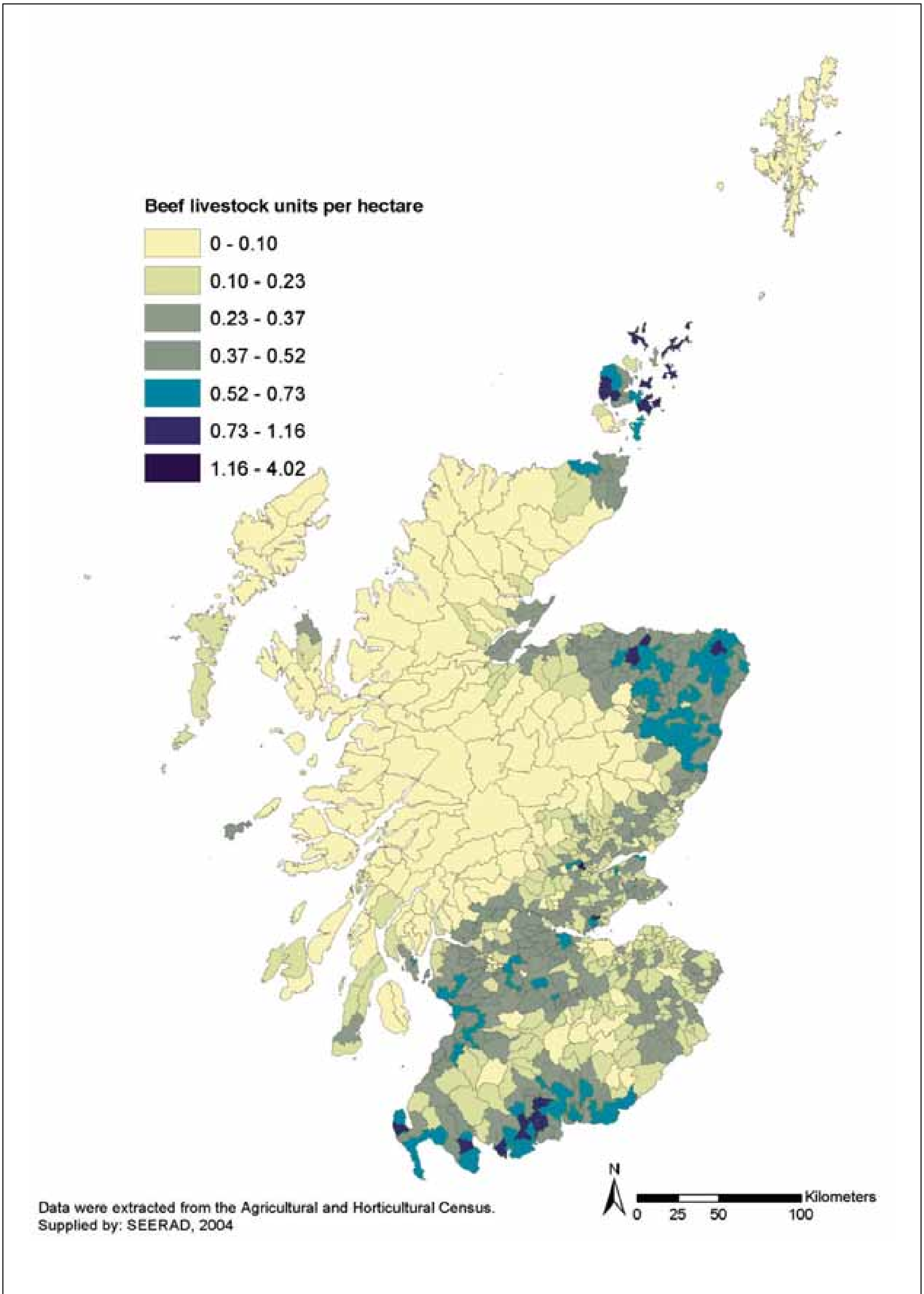


**Figure 2.4** Distribution of all beef cattle in Scotland, 2004. (Number of livestock units per ha of agricultural land)

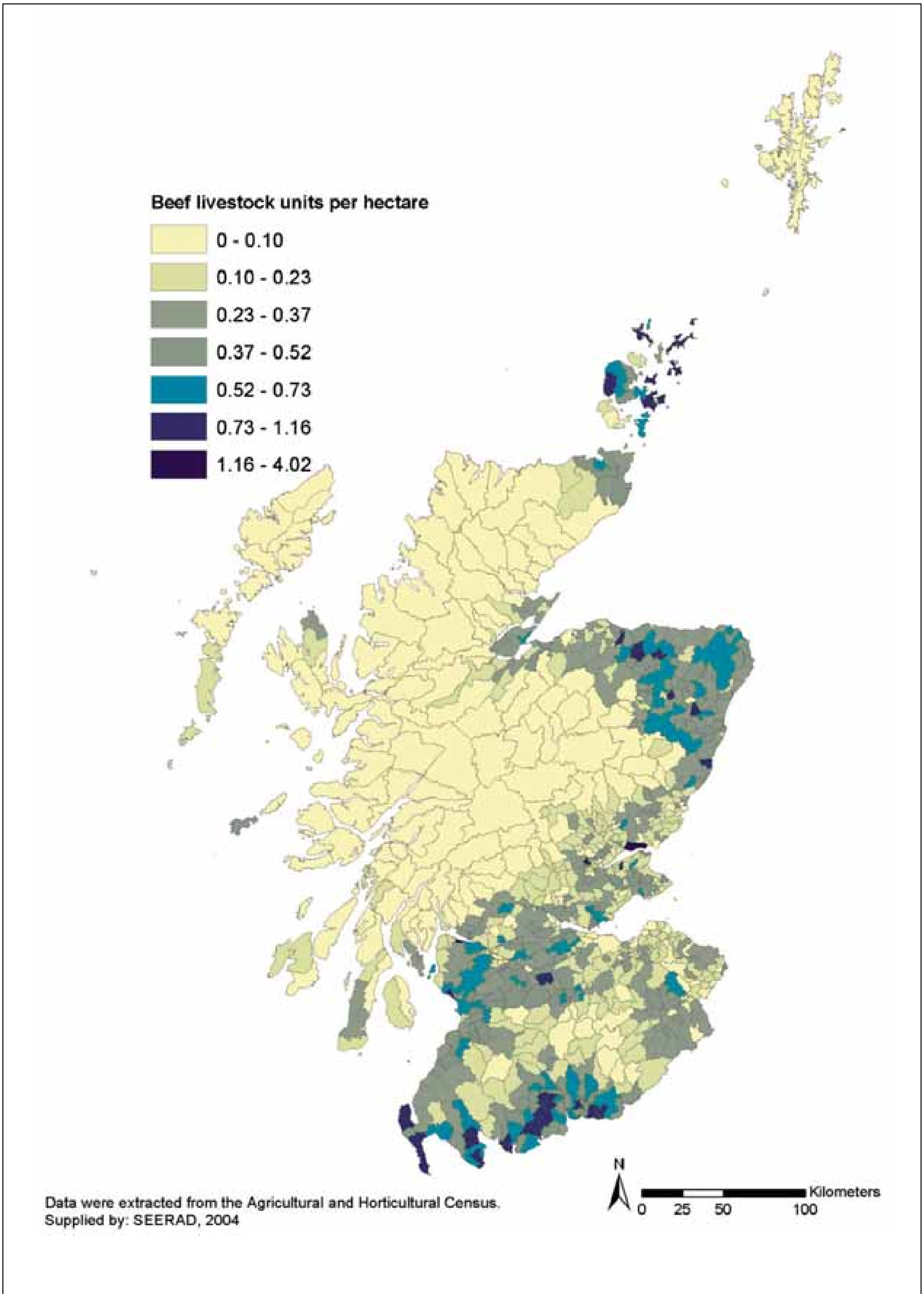


**Figure 2.5** Difference in beef cattle livestock units 1990–2004. (Numbers per ha of agricultural land)

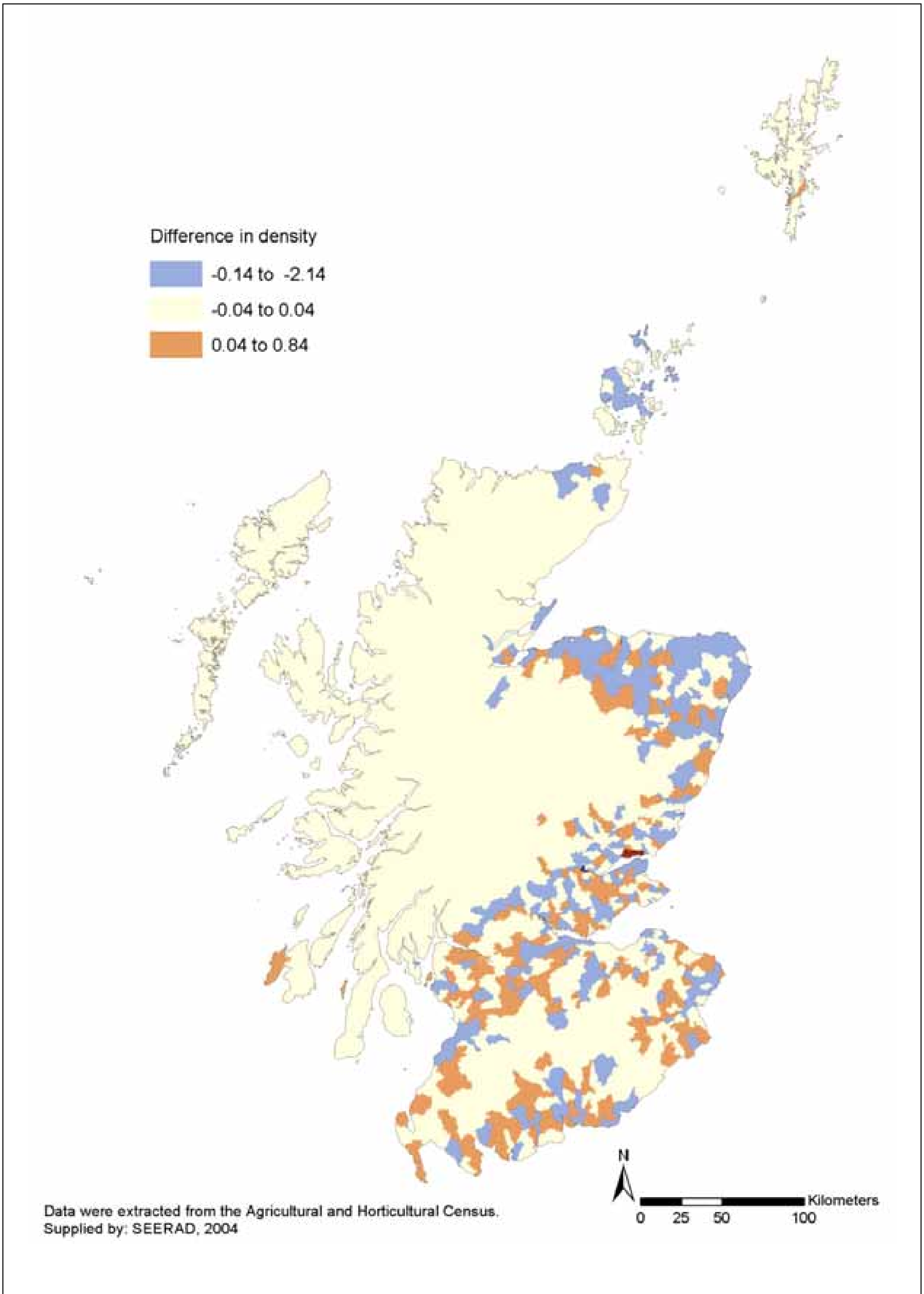


**Table 2.1** Summary of grazing attributes of herbivores (Armstrong and Milne, 1995; Gordon and Iason, 1989; Hewson, 1989; Mitchell and Kirby, 1990; Pehrsen, 1979; del Pozo *et al.*, 1996; Wright and Whyte, 1999)

| | **Feeding method** | **Selectivity** | **Type** | **Minimum sward height grazed** |
|---|---|---|---|---|
| Cattle | Tear with tongue | Low | Grazer | 5cm |
| Horses | Shearing | Low | Grazer | 6cm |
| Sheep | Biting/shearing | High | Grazer | 3cm |
| Red Deer | Biting/shearing | Intermediate | Grazer/browser | 3cm |
| Goats | Biting/shearing | High | Browzer/grazer | 4cm |
| Rabbits | Biting/shearing | Very high | Grazer | 1cm |
| Mountain hares | Biting/shearing | High | Grazer | 3cm |

The size of a large herbivore also has a major impact on the amount of vegetation removed through its intake. Potential intake is determined by the metabolic live weight (live weight raised to the power of 0.75) of the animal, ie larger animals have higher intakes, and its physiological status, for example lactating cows have higher intakes and fatter cattle have lower intakes per unit body size. Potential intake can also be modified by a number of factors such as the availability and quality of the vegetation, microclimate and social behaviour. The most important modifiers of intake are available biomass and the quality (or digestibility) of that biomass. Generally, as available biomass increases, intake by large herbivores increases, but at a decreasing rate, until there come a point when intake ceases to increase even at higher biomass. This relationship holds for cattle grazing perennial ryegrass/clover swards (Wright and Whyte, 1989) and there is no reason to suspect that it will not hold for semi-natural vegetation communities.

### *Foraging behaviour between plant communities*

On most unimproved habitats grazing cattle can make choices between patches of different communities. Cattle, like other species of large herbivore, preferentially graze on communities that offer the highest rate of nutrient intake. They therefore tend to graze communities with higher levels of digestibility. Therefore, by knowing the digestibility of the diet selected from different plant communities, based on research, the plant community patch on which the cattle beast will graze can be predicted. Figure 2.3 shows the pattern of digestibility throughout the year for some of the major plant communities of the uplands assuming that available biomass is not limiting. Gordon (1989) described the choices made by cattle between different plant communities on the Island of Rum throughout the year and they support the outcomes that would be predicted on the basis of the availability of digestible nutrients of the plant communities at different times of the year.

Such an approach does not allow for the sampling of a range of vegetation types that cattle normally make and, hence, may overemphasise the proportion of high digestibility plant communities in the diet. It also does not take into account shelter-seeking behaviour and social behaviour which may cause localised deviations from selection for plant communities based on availability and digestibility. Supplementary feeding will also cause cattle to congregate around feeding sites and lead to grazing of plant communities which would not be predicted to be used so frequently.

**Figure 2.6** The range of scales involved in herbivore grazing

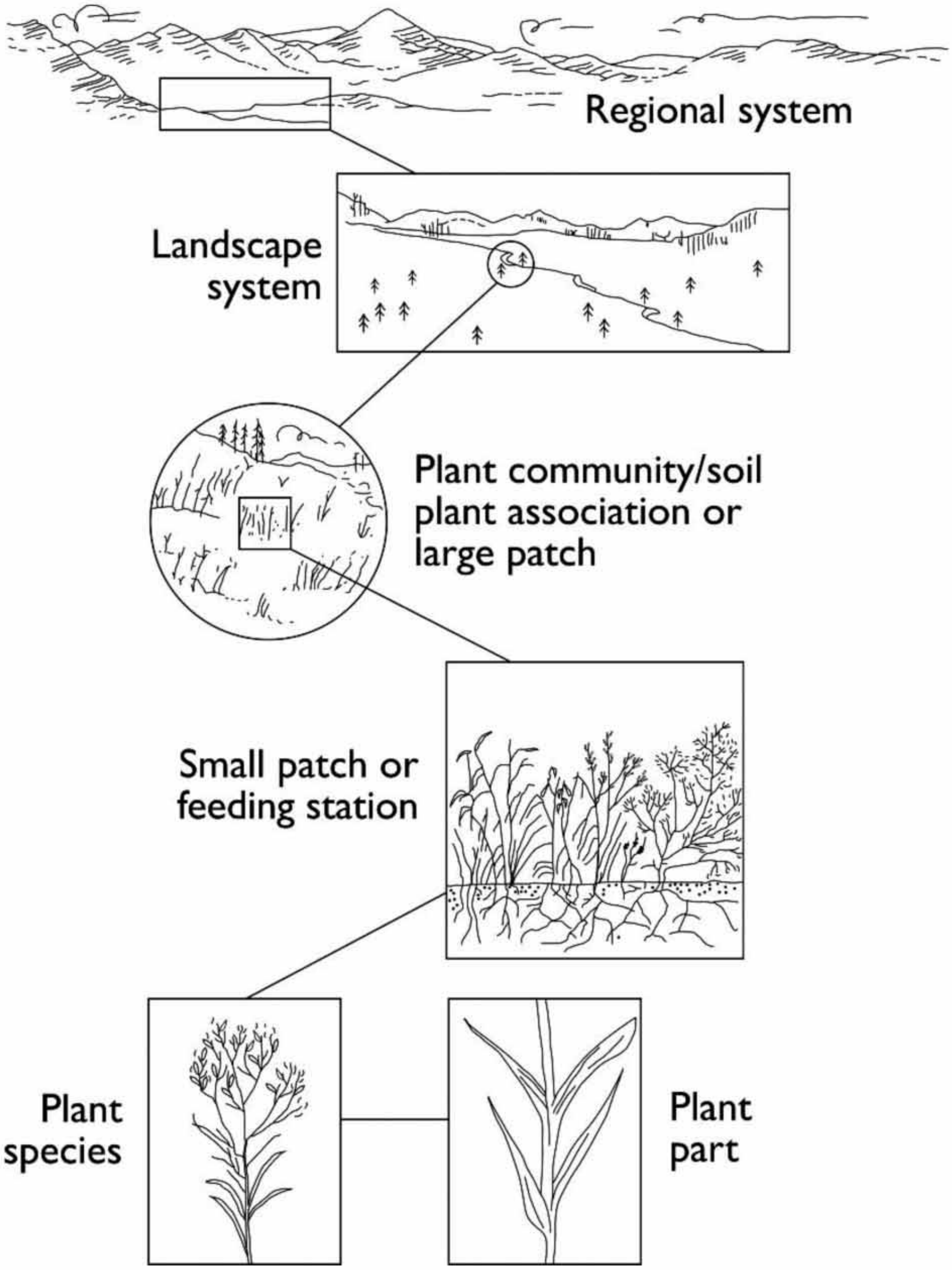
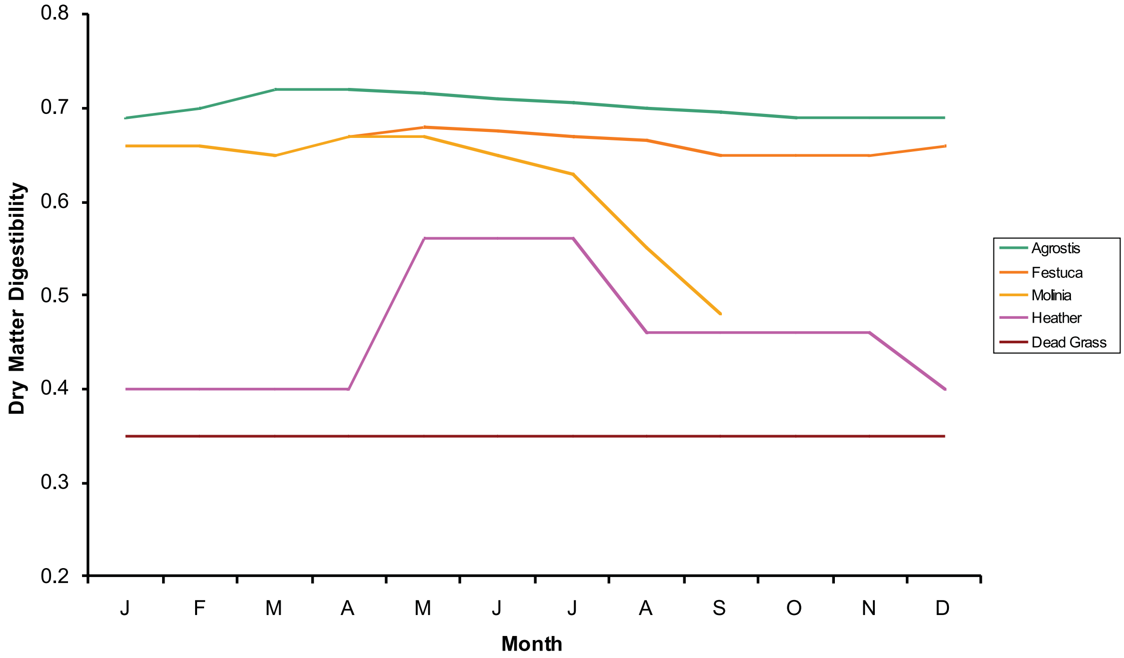


**Figure 2.7** The pattern of digestibility of different vegetation types throughout the year



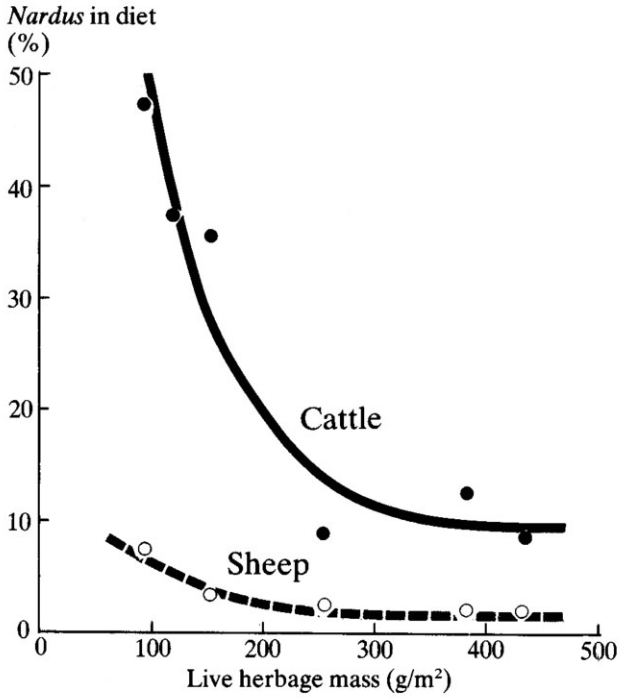

The spatial distribution of plant communities has also been shown to affect selection of plant communities by sheep and red deer (eg Oom *et al*., 2000) but similar work has not been carried out with cattle. Thus although the general spatial pattern of grazing may be predicted it is not yet possible to predict with any certainty that specific spatial pattern of grazing across a landscape. This makes it difficult to predict the precise impact of grazing by cattle at the landscape scale.

### *Diet selection within plant communities*

Within plant communities there will be a range of plant species with different biomasses and ratios of dead to live tissue. This leads to differences in digestibility and available biomass in a similar manner to that of the between-community level. Grazing animals usually select a diet with a higher proportion of live material than that found in the sward as a whole (eg Grant *et al*., 1985). This is partly due to the fact that grazing animals tend to graze from the top of the sward down and there is a higher proportion of dead material at the bottom of the sward and so bites taken from the top of the sward will have a lower proportion of dead material and a higher proportion of live material than in the sward as a whole. Since cattle take deeper bites than sheep, the difference between the sward and diet composition is greater in sheep than in cattle but cattle still have a diet that contains a higher proportion of live plant material than that found in the vegetation community that they graze (Grant *et al*., 1985).

A similar theoretical approach to that used to predict foraging between plant communities can be used to predict what would be selected within a plant community. A good example to illustrate this conclusion is the grazing of a *Nardus* and *Agrostis/Festuca* community by cattle. The *Nardus* has a higher biomass but a much lower digestibility than the *Agrostis/Festuca* component of the community such that the intake of digestible nutrients from the *Agrostis/Festuca* component is much higher than that of *Nardus*. The diet selected by cattle is predominantly *Agrostis/Festuca* but the proportion of *Nardus* in the diet increases as the availability of the biomass of *Agrostis/Festuca* declines (Figure 2.4). Because of the feeding method of cattle associated with the size and shape of its mouth, cattle are much less selective in their feeding behaviour than other large herbivores when selecting a diet with an intimate mix of species within a plant community. Also trampling effects of cattle are greater than other smaller species such as sheep because of their size.

**Figure 2.8** The percentage of *Nardus* in the diet of sheep and cattle at different levels of intertussock biomass (based on Grant *et al.*, 1985).




***Potential breed differences in foraging behaviour***

The question as to whether different breeds of cattle forage in different ways is one that has been asked for many decades. There is much anecdotal evidence to suggest that there may be differences between cattle in foraging behaviour, but to date there is very little scientific evidence that breed differences exist (Wright *et al.*, 2002; Rook *et al.*, 2004). Research is currently underway at the Institute of Grassland and Environmental Research on whether breed influences foraging behaviour in cattle. Nevertheless many conservation agencies prefer to use traditional breeds to promote biodiversity. The Royal Society for the Protection of Birds, for example, uses Highland cattle on some of its nature reserves. At Vane Farm reserve in Fife, a herd of Highland cattle is used to control rushes and maintain species-rich grassland. Highland cattle are also used on Rum, where, as a result, there has been an increase in variety of plants in most plant communities. However, there has been very little research done to compare the grazing behaviour, diet selection, herbage intake and impact on vegetation of rare and traditional breeds with modern or imported breeds.

One of the few studies that has been conducted was with sheep on *Molinia*-dominated vegetation (Newborn, 2000). Over a five-year period (1992–96) grazing by Hebridean sheep compared with Swaledale sheep led to a consistently higher level of utilisation of *Molinia*. It is therefore possible that this apparent preference for purple moor grass by the Hebridean sheep could be exploited to reduce the content of purple moor grass significantly. There was a significant increase in the heather cover under grazing by Hebridean sheep although the author could not draw any conclusions about the reasons for this, except that further study is required to fully understand the mechanisms involved. Dwyer and Lawrence (1997) observed that when Blackface and Suffolk ewes grazed in a field comprising improved pasture and semi-natural vegetation, the Suffolk ewes tended to graze the improved pasture and the Blackface ewes the semi-natural pasture. However this does not conclusively demonstrate genetic differences in grazing behaviour, since the differences could be due to competition between the larger Suffolk sheep and the smaller Blackface ewes for the better resource.

One of the difficulties in studying breed differences in grazing behaviour, is that differences between populations of animals could be learned as well as being genetic in origin. It is well recognized that aspects of feeding behaviour can be learned in animals, especially from their mothers (Thorhallsdottir *et al*., 1990). Therefore any breed comparisons must take this into account.

One of the most comprehensive sources of information on foraging by cattle is *The Breed Profiles Handbook* (Tolhurst and Oates, 2001) published by the Grazing Animals Project (http://www.grazinganimalsproject.org). This provides description of the foraging behaviour of a number of British breeds of cattle. However it is not clear how these descriptions were derived and little if any of the information seems to be based on sound scientific information. There is a major gap in our knowledge about the foraging behaviour of different breeds and to what extent genotype and learned behaviour influences diet selection and foraging. Wright *et al*. (2002) concluded that there was a pressing need for research on the potential differences between breeds in foraging behaviour and on vegetation and other aspects of vegetation.

## 2.3 Summary

1 It is only possible to describe the distribution of density of cattle in Scotland approximately.

2 On the basis of digestibility and available biomass, it is possible to predict which plant communities will be grazed by cattle at different seasons of the year. Since the digestibility of communities based on *Agrostis/Festuca* species is higher than that of other grass species, such as *Nardus* and *Molinia*, and shrubs, such as heather, and trees, they are grazed preferentially except when limited by available biomass. Depending on stocking density, such limitation in biomass is likely to occur in autumn and winter.

3 Preferences within plant communities are determined by the same factors as between-community selection although cattle are less selective feeders than other large herbivores.

4 The impact at any site is a function of the density of cattle and their intake and diet selection. The latter two variables can be predicted with some precision for the most abundant plant species although not taking into account local factors, such as shelter, social behaviour and supplementary feeding.

5 There is little scientific information on which to draw conclusions about differences in foraging behaviour among breeds. This does not mean that such differences do not exist, but rather that until such time as more research has been conducted care must be taken in interpreting claims that such differences can be used to manage particular vegetation communities for specific objectives.

# 3 EFFECTS OF CATTLE ON UNIMPROVED HABITATS

## 3.1 Neutral grasslands

Neutral grasslands (National Vegetation Classes MG1, 5–7, 9–13) are not common in Scotland. Only one study has been conducted on the effects of grazing by cattle (Tallowin *et al.*, 2005). After five years of grazing by cattle at different grazing pressures there was no difference in botanical diversity, but differences in vegetation structure emerged. The cover of *Poaceae* increased under more lenient grazing pressures, but the abundance of *Fabaceae* increased under higher grazing pressures. Abundance of *Heretoptera*, bumble bees and spiders all increased under lower grazing pressures. There have been no comparative studies of grazing by cattle compare to grazing by other species. However a low stocking density (eg 0.5 LU/ha year) is likely to lead to greater structural heterogeneity in the sward than grazing by sheep. The overall level of grazing, in terms of the amount of vegetation grazed, is likely to have a greater impact on the long-term species composition than the type of grazer. English Nature (2001) in The Upland Management handbook suggests the following management for upland neutral grassland (NVC types MG2–10):

- flower-rich pastures and hay meadows; 5 sheep/ha or 0.75 cattle/ha at any time. Meadows must be closed for at least 8 weeks before mowing and the aftermath should be grazed. (Countryside Council for Wales, 1992);
- damp and marshy grassland: 0.5 cattle/ha/year. (Lower stocking rates are recommended between 1 March and 30 June to reduce nest trampling. (Countryside Council for Wales, 1992).

*Summary*

The overall level of grazing is likely to have a greater effect that the species of grazer although cattle grazing may lead to greater structural heterogeneity.

***Best practice***

- On the basis of studies on other vegetation types grazing by cattle at low (0.5 LU/ha/year) stocking densities in summer is likely to lead to greater structural diversity than grazing by sheep and in the long term greater diversity of invertebrates. Lower stocking rates in spring and early summer will reduce nest trampling.

## 3.2 Base-rich grasslands

Base-rich grasslands occur mainly in the uplands in Scotland (NVC classes CG10–14) with only about 260ha in the lowlands (NVC classes CG2, CG7 and CG10). These grassland are more species rich than acid grasslands. No specific studies have been conducted into the impacts of cattle grazing in Scotland. However the overall level of grazing in terms of biomass removed, including grazing by wild herbivores is likely to have a greater effect on these grasslands than the species of grazer. Given the tendency for cattle to select taller, coarser vegetation (see Chapter 2) it is possible that the grazing of cattle in early summer may reduce seed setting and shedding. English Nature (2001) gives the following recommendations for the grazing of upland calcareous grasslands (NVC types CG2, CG3, CG6, CG7, CG9, CG10):

- graze stock at no more than 1 sheep/ha or 0.15 cattle/ha for any continuous period of eight weeks between 1 May and 31 August;

- at any other time graze stock at no more than 2 sheep/ha or 0.3 LU/ha. Grazing rates may be higher when gathering stock on up to five separate days per year (Mercer and Evans, 1997);
- encourage diversity of the habitat by having some areas only grazed in autumn and others ungrazed by stock.

The recommendations regarding stocking by cattle appear to be based on sheep equivalents as no specific research has been conducted on cattle grazing.

On lowland calcareous grasslands Kirkham *et al*. (2003) suggest that an annual stocking rate of about 0.33 LU/ha may be appropriate. On more productive sites, which in their study were often grazed by cattle, stocking rates were up to 0.6 LU/ha/annum. However care must be taken with these figures as firstly all the sites were in England or Ireland and secondly no check was carried out that these stocking densities were actually achieving the appropriate conservation objectives.

***Summary***

No specific information is available on the effects of cattle grazing. The overall level of grazing is likely to have a greater effect that the species of grazer. On the basis of known differences in foraging behaviour between species (Chapter 2), it is possible that grazing by cattle in early summer may reduce seed setting.

***Best practice***

- No specific information on cattle grazing.
- Limit grazing by cattle to 0.15 LU equivalents for any continuous period of eight weeks between May and August.
- At other times limit grazing to 0.3 LU/ha, although on very productive lowland sites higher stocking rates may be possible.

## 3.3 Acidic grasslands

Acid grasslands are one of the most extensive semi-natural habitats in Britain (NVC classes U2, 4–6). Acid grassland dominated by *Agrostis* and *Festuca* species is the most digestible, and is preferred by grazing livestock during summer growth whilst there is a high proportion of green leaf available (Armstrong, 1996; Mowforth and Sydes, 1987). Summer grazing reduces the accumulation of dead material from these species in autumn. There is little direct experimental comparison of the grazing of *Agrostis–Festuca* grassland with cattle compared with other species. However, to achieve acceptable levels of performance cattle need higher sward heights that sheep (Mayne *et al*., 2000) and cannot graze to such short sward height as sheep (see Table 2.3). Therefore cattle-grazed *Agrostis–Festuca* swards are likely to be taller. Taller swards, especially those grazed by cattle, have greater heterogeneity in height (Gibb and Ridout, 1986; 1988; Wright and Whyte, 1989) and therefore have more structural heterogeneity, which in turn is likely to lead to more diverse population of invertebrates (Dennis *et al*., 1998).

*Nardus stricta* is the least palatable of the acid grassland species with a high silica content (Armstrong, 1996). Cattle are more effective than sheep at controlling *Nardus stricta* (mat-grass) of *Nardus stricta–Galium saxatile* grassland (U5), because they are less selective and consume a higher proportion of this species as they forage (Grant *et al*., 1985; 1987; Welch, 1986; see also Chapter 2 Figure 2.4). In contrast, intensive grazing by sheep will increase the proportion of *Nardus* in the vegetation because other grasses are favoured and grazed more intensively. Cows with calves grazed on *Nardus*-dominated grassland from June–August for six years, consumed a larger proportion of *Nardus* than was present in the sward as a whole (Common *et al.*, 1998). The outcome of two grazing treatments (lactating cows grazed to maintain either a 4.5 or 6.5cm average sward height between tussocks) was a marked reduction in the cover and average tussock size of *Nardus*. However, the cows of the shorter sward treatment lost condition during the period of summer grazing, while cows grazing the taller sward gained weight and also reduced the extent of *Nardus* in the grassland, albeit at a slower rate. Thus it appears that high rates of utilisation of *Nardus* are not compatible with high levels of nutrition and animal performance (Common *et al.*, 1998) due to the lower nutritional value of *Nardus* compared with the other species in the sward (Armstrong *et al.*, 1986). In particular, after the main period of growth the digestibility declines rapidly from the end of July and this has a negative impact on cattle live-weight gain (Common *et al.*, 1998). Thus, if lactating cows and calves are to graze *Nardus*-dominated vegetation, acceptable levels of performance can probably only be achieved from late May until the end of July, depending on location. Outwith these periods dry stock may have to be used.

Mixed grazing of cattle with sheep on *Nardus*-dominated vegetation can result in higher levels of sheep performance compared to sheep-only grazing. In one study (Howard and Wright, 1994) lambs gained 30g per day more when cattle were grazing with the sheep than when only sheep were present.

*Molinia caerulea* (purple moor grass) typical of *Molinia caerulea–Potentilla erecta* mire (M25) is the dominant grass species in 10% of the uplands of Britain (Bunce and Barr, 1988). Burning regimes and light grazing tend to increase the proportion of *Molinia* in the vegetation (Common *et al.*, 1997; Wildig, 2000). Cattle can be effective at controlling the spread of purple moor grass, especially if grazed early in the season when this grass is at its most preferred and susceptible to grazing effects. Experimental grazing of cattle on *Molinia*-dominated vegetation reduced its area of cover and increased floristic diversity, compared with ungrazed treatments (Grant *et al.*, 1996b). Two stocking densities were used to achieve either 33% or 66% utilization of *Molinia*. In the former case, the area of cover of *Molinia* stabilized at 60–65% after 3–5 years, whereas the cover was reduced by 86% after six years at the higher stocking density.

Wavy hair-grass, *Deschampsia flexuosa*, of *Deschampsia flexuosa* grassland (U2) is less preferred by livestock than *Agrostis* and *Festuca* species and is mostly grazed during May–July. However, in grassland dominated by this species it may also be eaten in winter because it is evergreen (Mowforth and Sydes, 1989). In contrast, cattle grazing failed to improve the species richness of montane Deschampsia cespitosa grasslands in the Czech Republic, even in comparison with ungrazed areas, and it was concluded that cattle were of little value for the restoration of species rich grasslands in this circumstance (Matějková *et al.*, 2003).

Indicative stocking densities for different types of acid grassland (NVC types U1–6) are given in the Upland Management Handbook (English Nature, 2001):

- unimproved upland grassland with more than 50% *Agrostis–Festuca* grassland: 5 sheep/ha or 0.75 cattle/ha or 0.5–0.75 LUs/ha all year, or equivalent during the summer only (Countryside Council for Wales, 1992);
- unimproved upland grassland with less than 50% *Agrostis–Festuca* grassland (ie *Molinia*- or *Nardus*-dominated): 2.5 sheep/ha or 0.5 cattle/ha all year or 3.7 LUs/ha or equivalent during the summer only. (Countryside Council for Wales, 1992);
- stocking should not normally exceed 0.25–0.6 LU/ha on upland rough grazing pastures.

However, it must be stressed that these indicative stocking densities are only a guide. The appropriate stocking density will be determined by, amongst other things, the management objectives, the site (location, soil type, altitude, aspect) and weather.

Virtually all sub-montane grasslands require some mechanism to prevent succession to shrubs and woodland if they are to remain as grassland. Where the grassland is of value for wildlife halting this succession is obviously desirable although the presence of some trees and scrub can increase biodiversity. At low stocking densities, grazing will tend to produce a mosaic of tall and short vegetation, especially on larger areas. High stocking rates are more likely to create a uniformly short turf with few flowers (Ausden and Treweek, 1995). Winter grazing can prevent the build-up of dead vegetation and arrest succession, but still allow plants to flower and set seed. Many areas of species-poor grassland have been derived from heavy grazing of dwarf-shrub communities. Conservation objectives for some upland areas may, therefore, focus on the restoration of an upland heath resource rather than the maintenance of a species-poor grassland community.

***Summary***

Grazing by sheep alone can lead to *Nardus* and *Molinia* becoming dominant. Cattle will graze both these plant species to a greater extent than sheep and this may reduce their dominance and result in greater botanical diversity. Mixed grazing by cattle and sheep has been shown to be effective in reducing the dominance of *Nardus* and results in increased sheep performance.

***Best practice***

- Acid grassland with more than 50% *Agrostis–Festuca* can be grazed with 5 sheep/ha or 0.75 cattle/ha all year, or equivalent during the summer only.
- Grazing by cattle can be used to reduce the dominance of tussock-forming grasses such as *Nardus stricta* and *Molinia caerulea*. Acid grassland with less than 50% *Agrostis–Festuca* (ie *Molinia*- or *Nardus*-dominated) can be grazed with 2.5 sheep/ha or 0.5 cattle/ha all year or 3.7 LUs/ha or equivalent during the summer only.
- Mixed grazing with cattle and sheep can result in increased sheep performance. To be effective the stocking density of the cattle should be about 0.5–1.0 cattle/ha, depending on the cover of *Nardus* and *Molinia*, during June and July.
- Productive cattle eg lactating beef cows and their calves may have to be removed by early August from *Nardus* and *Molinia* grassland if animal performance is not to suffer. Dry stock may be used outwith the growing season of these plant species.

## 3.4 Periodically flooded grasslands

There is no specific information on the effects of grazing by cattle on periodically flooded grasslands. An experimental study on *Cynosurus cristatus–Centaurea nigra* (MG5) and *Cynosurus cristatus–Caltha palustris* (MG8) grasslands on the Somerset Levels (Mountford *et al.*, 1993; Kirkham *et al.*, 1996) on the effects of fertilization used cattle to graze aftermaths after cutting for hay, but there is no information on the effects of the grazing by cattle *per se*.

## 3.5 Coastal grasslands including cliff-tops

The vegetation of maritime cliffs is dependent on the access of grazing animals. Grazing of *Festuca rubra–Armeria maritima* (MC8) maritime grassland shifts the composition to the *Plantago coronopus* sub-community at the expense of the others (Rodwell, 2000). Grazing is also responsible for the characteristic short sward of the *Festuca rubra–Plantago* spp. (MC10) maritime grassland, and the predominance of this community at the expense of *Festuca rubra–Holcus lanatus* (MC9) maritime grassland in areas where the vegetation is grazed.

Replacement of sheep by cattle would reduce the impacts of grazing on most cliff communities, as the proportion of the vegetation accessible to grazing would fall.

One bird particularly associated with coastal grassland is the chough. They require grassland management that produces medium-high grass sward height during June–September and short, open swards between January and May. The reduced grazing in the summer produces good conditions for Tipulid egg laying, whilst short swards in the winter allow effective searching by the choughs (Bignal *et al.*, 1996). Locally this could conflict with requirements to keep the vegetation in optimal condition.

***Summary***

There is no specific information on cattle grazing, although it could be implied that some areas will not be accessible to cattle.

***Best practice***

- Replacement of sheep by cattle may lead to greater diversity by reducing grazing in more inaccessible areas. Where chough are present, grazing should be manipulated to produce medium-high grass sward heights during June–September and short, open swards between January and May.

## 3.6 Machair

Machair is traditionally managed in one of two ways; rotational cropping or permanent pasture. In general, the flatter, accessible areas are managed by arable cropping with a crop of traditional varieties of oats, barley and rye being taken for two years with the aid of seaweed fertiliser and then the area is left fallow for two years to allow fertility and soil organic matter to build up again. These areas are usually winter grazed. However, in recent years a greater number of townships have fenced the machair, either into individual holdings or larger areas, which allows the possibility of grazing the fallow areas in summer. Areas where ploughing is not possible have tended to be used as permanent pasture (Love, 2003). In both situations the vegetation is typically described as *Festuca rubra–Galium verum* fixed dune grassland (MC8). Grazing is accepted as maintaining the diversity of machair vegetation through its removal of taller growing species, provision of regeneration niches through trampling and the opening of the vegetation to allow the growth of mosses. Late summer or winter grazing breaks up rank vegetation and allows the flowering/seed set of many plants (D. Beaumont, *pers. comm.*). This is particularly important for corncrake which require ungrazed cover vegetation from February–October, adjacent to areas of grassland without grazing from March/April–August. Grazing levels are set within the township and generally reflect long-term sustainable levels.

However, the impact of summer grazing on the diversity of the characteristic fallow flora is unknown, as is the effect of continuing replacement of cattle by sheep as the main grazing animal. This is in part due to the ageing crofter population switching to an easier care system, as well as younger crofters doing the same in response to a need to earn more off-croft income as a result of depressed agricultural incomes. However, cattle are the foundation of the 'traditional' cultivation system of the machair since the cereals are grown only for cattle feed. Without continuing cultivation a range of bird species would probably suffer (corncrake, corn bunting, twite, ringed plover – J. Wilson, *pers. comm.*).

For other dune grasslands, reduced grazing can lead to the replacement of open *Ammophila arenaria–Festuca rubra* semi-fixed dune (SD7) by the ranker *Ammophila arenaria–Arrhenatherum elatius* grassland (SD9) (Rodwell, 2000), and grazing has been put forward as the best means of management to prevent the dominance of a few tall grasses in dune vegetation (Kooijmann and van der Meulen, 1996). Absence of grazing in calcareous dune communities results in tall vegetation with a spider fauna made up of only common species. Heavily cattle-grazed areas contained a number of rarer species, but diversity and the presence of rare species was promoted by heterogeneity in the vegetation and the presence of transitional areas between short and tall vegetation (Bonte *et al.*, 2000). This suggests that moderate grazing, that produces this heterogeneity, is likely to be optimal at providing the correct habitat structure for spiders in these habitats.

***Summary***

Traditionally, machair areas have been grazed by cattle. The exact impact of replacement of cattle by sheep is not known, but it can be implied that grazing by sheep rather than cattle may result in less structural heterogeneity in the swards.

***Best practice***

- Winter grazing with cattle at moderate (<0.5 LU/ha) stocking densities on cropped areas will enhance soil fertility.
- Moderate (<0.5 LU/ha) grazing of pasture areas in summer is likely to lead to the greatest heterogeneity in habitat.

## 3.7 Rush pasture

This section deals with rush pasture, purple moor grass and rush pasture and *Juncus–Festuca* grassland.

In South-West Scotland, *Molinia–Juncus* occurs in a natural state and is an important habitat in its own right (centered on NVC class M23 *Juncus effusus/acutiflorus–Galium palustre* rush pasture). The UK Biodiversity Action Plan states that no area estimates are available for Scotland, but the total extent is thought likely to be in the region of 2,000ha (www.ukbap.org.uk). However this may be an underestimate as MacIntosh (unpublished) reports that the total area of NVC types M10, M22, M23, M25 and M26 is in the region of 8000ha.

It is estimated that the Stewartry ESA covers one of the main concentrations of purple moor grass and rush pasture in the country (purple moor grass and rush pastures Habitat Action Plan; UK Biodiversity Action Plan, http://www.ukbap.org.uk). Key plant species associated with purple moor grass and rush pastures include:

wavy St. Johns-wort *Hypericum undulatum*, whorled caraway *Carum verticillatum*, meadow thistle *Cirsium dissectum*, marsh hawk's beard *Crepis paludosa*, greater butterfly orchid *Platanthera chlorantha* and lesser butterfly orchid *Platanthera bifolia*. These purple moor grass and rush pastures are a priority for nature conservation because they are highly susceptible to agricultural modification and reclamation, afforestation, scrub encroachment under light or no grazing, or loss of floristic species through overgrazing and too frequent burning. Little specific information is available on the role of cattle grazing in the historic degradation or conservation management of this habitat. The Upland Management Handbook provides information on the role of cattle in conservation management (English Nature, 2001). It is recommended on NVC types M17, M22, M23, M24 and M26 to use light spring/summer grazing by cattle (although 'light grazing' is not defined), increasing the stocking density in late summer/autumn to allow the flowering of species-rich communities. In *Molinia*-dominated areas, a relatively high grazing intensity (the equivalent of one cow/ha) may be necessary to reduce the dominance of *Molinia*, preferably with cattle, during the period of maximum growth and palatability of *Molinia*, ie, mid-May to mid-July. Kirkham *et al*. (2003) found that on lowland sites with purple moor grass and rush pastures, mainly in the SW of England, actual stocking densities were about 0.4 LU/ha annually.

The *Juncus squarrosus–Festuca ovina* grassland (U6) is strongly encouraged by particular kinds of burning and grazing treatments on blanket bog. Once established, *Juncus squarrosus* can be persistent and invasive, but it can decline due to competition from *Sphagnum* or taller vegetation if grazing is reduced or removed. Cattle readily graze rushes *Juncus* spp., especially later in the summer when grass species die back (Grant *et al*., 1985) and at moderately high stocking levels can significantly reduce their extent in a field. They will graze sharp-flowered rush *Juncus acutiflorus* in preference to soft rush *J. effusus* and compact rush *J. conglomeratus* and this can lead to the replacement of the former by soft rush in some circumstances.

***Summary***

Without cattle, the *Molinia* in *Molinia–Juncus* pastures may become very dominant, as sheep tend not to graze *Molinia* (Grant *et al*., 1985). Cattle will also graze *Juncus* spp., especially in late summer.

***Best practice***

- Cattle may graze rush pasture lightly (0.25 LU/ha) in spring and early summer prior to the flowering of a number of species. Thereafter stocking density may be increased in late summer/autumn.
- Rush dominance in *Juncus–Festuca* grassland may be reduced by grazing with cattle in late summer/autumn.

## 3.8 Lowland heath

Rodwell (1991) describes six lowland heath communities but these are mainly distributed across England and into North Wales. In Scotland, sub-montane heaths are more widespread. They are distributed on free-drained, acidic soils of hill slopes and include the *Calluna vulgaris–Arctostaphylos uva-ursi* heath (H16) in the Grampian hills and *Calluna vulgaris–Vaccinium myrtillus–Sphagnum capillifolium* heath (H21) of the far north of Scotland (Rodwell, 1991).

Light summer grazing was associated with successful wildlife populations on lowland heaths, but is only one tool in heathland management (Bacon, 1998). Cattle suppress birch scrub and reduce the competitive dominance of grass species and encourage a greater diversity and structure of vegetation. Trampling serves to incorporate litter and create pockets of bare ground that facilitates seed germination and recruitment. Bracken invasion can be countered through the trampling disturbance of cattle compared with smaller herbivores. However, as for moorlands, the stocking densities must be carefully monitored because there is a substantial risk of dieback to heather and later colonization by opportunistic grass species. Grazing is an essential part of the management of lowland heaths but has become less common in recent decades and this has led to scrub or bracken encroachment. Grazing with cattle is a cost-effective means of managing lowland heaths and for the maintenance of a balance between scrub (desirable for wildlife in small patches within heathland) and *Calluna* in its various developmental phases, and for the suppression of bracken (Sutherland and Hill, 1995).

*Summary*

Grazing by cattle may be more effective at maintaining diversity of plant species. Trampling by cattle may create niches for seed germination and help to control the spread off bracken.

***Best practice***

- Grazing by cattle in summer at a light (eg 0.5 LU/ha) stocking rate will suppress undesirable species and achieve a balance of scrub and dwarf shrub species.

## 3.9 Moorland

Moorlands are composed of a mosaic of plant communities, such as heath, grass and mire, dependent on climate, altitude and geographic location. Moorland can be dominated by dwarf shrub, mainly H10, H12, H13, H14, H19, H20 and H21, all NVC classes that include *Calluna vulgaris*, and/or indigenous grasses (where dominant representing U1, U4, U5 and U6 acid grasslands described elsewhere) (Rodwell, 1991; 1992). Grasslands have most frequently replaced heather as a result of degradation related to recent increased stocking densities of livestock, combined with overly frequent burning (UK Biodiversity Action Plan; English Nature, 2001; Hester, 1996). Such grass, rush and sedge communities are of a lower nature conservation value than the dwarf shrub communities they replace (Welch and Scott, 1995).

Heather and other dwarf shrubs are less preferred by grazing livestock than grasses but are eaten by livestock when there is nothing else available to consume (English Nature, 2001). Heather decline does not happen instantly because it has energy reserves in the roots to replace the current year's shoots that are eaten. Studies in the Peak District, England have shown that 36% of the heather cover in 1913 is now dominated by grasses (Anderson and Yalden, 1981). A similar change was observed in Cumbria, where aerial photographs have indicated that 70% of heather-dominated vegetation of 1946 has been replaced by vegetation dominated by grasses (Nature Conservancy Council, 1987). Dependent on local edaphic and climatic conditions, heather may have been replaced by *Festuca ovina–Agrostis capillaris–Galium saxatile* grassland (U4) (Welch, 1974) on drier soils or by *Nardus stricta–Galium saxatile* (U5) on the more species rich and dry sites and *Molinia caerulea–Potentilla erecta* mire (M25) and *Juncus squarrosus–Festuca ovina* grassland (U6) on the wetter soils (Rodwell, 1991; 1992).

Cattle can be part of the problem of habitat degradation in the uplands, but at moderate to low stocking densities, cattle have been shown to be effective in restoring upland habitats. Cattle have a greater ability than sheep to digest poor quality forage (Armstrong, 1996) and as a result they are more likely to forage amongst mat-grass or purple moor-grass in summer. Cattle have been successfully used to reverse the expansion of purple moor grass and to restore *Calluna vulgaris* on Marsden Moor, Derbyshire (http://www.whitebredshorthorn.com/bluegrey/marsdenmoor.html). Cattle are also effective at trampling tall, coarse vegetation such as bracken and scrub and are effective at opening up uniform, dense vegetation for habitat restoration (English Nature, 2001). The Upland Management Handbook provides a comprehensive review of general effects of changes to grazing management for different situations and conservation objectives. There is little specific mention of the role of cattle in grazing management on moorlands but cattle are cited mainly as a tool for remediation where moorland has been degraded to *Molinia*- and *Nardus*-dominated grassland. The plants and animals typically associated with heather moorland are generally of greater nature conservation value than those associated with the acid grassland or bracken, *Pteridium aquilinum–Galium saxatile* (U20) communities which replaces them (Evans and Felton, 1987).

Heather growth is characterized by architectural changes that have been classified into pioneer, building, mature and degenerate phases, each larger and with a larger proportion of wood content than the previous phase (MacDonald, 1996). Each phase lasts about 5–10 years but heather grows most rapidly in the building phase and reaches its maximum cover and density during this phase. Low intensity grazing can slow down the rate at which heather ages, keeping more plants in the building, rather than degenerate phase, of growth (Gimingham, 1995; Mowforth and Sydes, 1989). In this way grazing can decrease the frequency with which burning or cutting is used to manage heather moorland. Too much grazing can lead to the loss of heather cover (Hester, 1996) because it will generally decline if grazing animals utilise more than 40% of the season's growth (Grant *et al.*, 1982). A secondary effect of excessive grazing is the loss of representation of each growth phase. Heather is most vulnerable to cattle grazing in the autumn (when energy reserves are low after flowering and seed set) and spring (after the first flush of growth), and winter grazing should be avoided altogether (Mowforth and Sydes, 1989). Grazing effects on heather tend to be lower in summer when cattle graze other more nutritious and abundant herbage. *Calluna vulgaris* is killed by trampling, urine enrichment and smothering by dung pats (Dennis, 1999). Supplementary feeding of cattle should be avoided throughout the year on any heather moorland because this would attract livestock to dry heath, wet heath and blanket bog in the moorland mosaic, all intolerant of treading damage.

Poaching from treading of hooves can lead to the formation of bare ground, tracks, ruts and more general erosion. Likewise, water troughs should be located in areas of low conservation interest, such as in acid grassland parts of moorland. Nutrient enrichment can result from dung and supplementary feed incorporation into the soil, with consequences for local vegetation. Cattle dung is an important resource for beetles and flies which, in turn, provide food for birds.

If grazing pressure is kept relatively low, heather and other plants mature and this can result in a patchy structure to the vegetation (Gimingham, 1972). As patches of heather reach this degenerate stage, bracken or calcifugous grasses can replace heather in the open patches (Rodwell, 1992). However heather can also regenerate vegetatively by the growth of adventitious roots on stems to produce stable stands of heather (MacDonald *et al.*, 1995). Where restoration of *Calluna* is the management objective for a site, the current botanical composition can strongly influence the response of the vegetation to changes in stocking densities of livestock, although most studies have focused upon sheep. A cessation of grazing on moorlands where heather was already present in the vegetation led to an increase in its cover at a rate of up to 0–5% per year (English Nature, 2001). Without heather, tall grass, scrub and woodland vegetation communities developed on such moorland sites (Hester, 1996; Ward *et al.*, 1995), dependent on factors such as initial floristic composition, proximity to seed source, extent of soil disturbance and niche availability (Milne *et al.*, 1998). Grazing on other shrubs, eg, *Vaccinium myrtillus*, occurs mainly in September and October but it is more tolerant of grazing than heather. Moderate levels of grazing may lead to a change in dominance from heather to bilberry (Welch *et al.*, 1994).

The numbers of sheep and wild herbivores such as red deer must be taken into account when planning stocking densities of cattle for grazing heather moorland. An assessment of grazing pressure on moorland may be necessary using the 'Grazing Index' (English Nature, 2001; MacDonald *et al.*, 1998). The Grazing Index is calculated as the proportion of shoots with evidence of grazing. Great care must be taken in its interpretation as the relationship between the Grazing Index and level of offtake is not linear. At high levels of offtake the Grazing Index is insensitive. Also it does not allow comparison between grazing caused by different herbivores, so that a tip removed by a red grouse equates to the same level of damage as a shoot bitten back into the previous year's growth by a cow. The timing of grazing management can be modified to promote the recovery of degraded heaths and mires; cattle or other livestock can be removed from the management unit at the end of September and their return delayed until June. Stocking densities should not culminate in excessive poaching or other indicators of overgrazing such as an increase in the area of bare ground (MacDonald, 1993). Annual stocking rates on dry heath (NVC types: H4, H8, H9, H10, H12, H15, H16, H17, H18, H21) should never exceed 0.075–0.225 LU $ha^{-1}$ (Edwards and Marsden, 1991). Increased altitude and soil wetness would further reduce the potential annual stocking density that could be sustained. Heather recovery is possible if grazing is reduced to c. 0.8–0.9 sheep/ha/yr on degraded dry heath (Pakeman *et al.*, 2003) and to c. 0.7 sheep/ha/yr on degraded wet heath (Hulme *et al.*, 2002).

***Summary***

Cattle are not necessary for the effective management of heather moorland and excessive grazing by cattle will damage heather plants. On areas where the moorland has been degrade by ingression of *Nardus* or *Molinia*, grazing by cattle may help to reduce the dominance of these species.

***Best practice***

- Avoid supplementary feeding of cattle on heather moorland.
- Remove cattle from heather moorland in winter.
- Light grazing (0.075–0.225 LU/ha/year) of heather by cattle can be tolerated, but stocking densities must be set to avoid high levels of utilisation. Actual stocking densities of cattle must take account of the presence of other species of herbivores such as sheep or deer.

## 3.10 Lowland raised bog

Lowland raised bogs are peatland ecosystems which develop in lowland areas such as the head of estuaries, along river flood-plains and in topographic depressions. Anaerobic conditions prevail from the waterlogged state and this slows down the decomposition of plant material and leads to the accumulation of peat that elevates the bog surface. A dome of peat of up to 12m thickness can accumulate that separates the bog surface from the water table, so that it forms an 'ombrotrophic' (or 'rain-fed') bog. The surface is typically waterlogged, acidic and deficient in plant nutrients and gives rise to a depauperate but distinctive, specialised plant assemblage. The spongy surface is characterized by the *Sphagnum* mosses that lead to the development of peat and a surface mosaic of pools, hummocks and lawns which support different species assemblages. *Sphagnum* also retains water through dry periods and keeps the bog surface wet.

The plant assemblages include the bog pool communities M1–M3 and M18 E*rica tetralix–Sphagnum papillosum* raised and blanket mire. As elsewhere across the UK and north-west Europe, the area of lowland raised bog has declined considerably since the early nineteenth century. The area of lowland raised bog in Scotland retaining a largely undisturbed surface is estimated to have diminished from an original 28,000–2,500ha (UK Biodiversity Action Plan). The historic causes of loss and degradation have been agricultural intensification, afforestation and commercial peat extraction. Threats to remaining areas of lowland raised bog are more likely to be drainage and general lowering of groundwater tables. Such disturbances, including peat cutting can result in the development of *Scirpus cespitosus–Erica tetralix* (M15) wet heath, *Calluna vulgaris–Eriophorum vaginatum* blanket mire (M19), *Eriophorum vaginatum* blanket and raised mire (M20) and *Molinia caerulea–Potentilla erecta* mire (M25).

Grazing is rarely the primary cause of degradation of lowland raised bogs and there is little mention in the literature of the role of cattle in managing this habitat. Cattle grazing may be an additional factor after drainage and lowering of the water table have dried out the site and allowed access to grazers. On the drier fringe of the habitat, natural succession may lead to scrub and tree growth (*Betula pubescens–Molinia caerulea* woodland, M4) and grazing cattle may have a role in suppressing growth of these species to maintain the higher valued bog plants.

***Summary***

There is little specific mention of grazing by cattle in the literature.

***Best practice***

Avoid grazing by cattle, except on the drier fringes to suppress scrub.

### 3.11 Blanket bog

Blanket bog or wet mire is waterlogged, composed of deep peat soils and has a low annual productivity in vegetation growth (Coulson *et al.*, 1992). Wet heath is the most productive, as a transition between blanket bog and *Calluna*-dominated dry moorland. Blanket bog vegetation has lower digestibility and mineral content than similar vegetation on mineral soils. The peat of blanket mires is constantly leached by rain, is low in available nutrients, and is generally too deep to allow root penetration to the underlying mineral soil (English Nature, 2001). The biotope is characterized by a ground layer of sphagna and a low canopy of ericoid shrubs (*Calluna vulgaris* and *Erica tetralix*) and graminoids (*Eriophorum vaginatum, Scirpus cespitosus* and *Molinia caerulea*) in various proportions representing NVC classes M15–M20 (Rodwell, 1991). The wetter the site the lower the productivity of the blanket mire plants and the greater the sensitivity to grazing. Long-term grazing of sheep and burning of mire communities has lead to the replacement of the sphagna and ericoid shrubs by grasses and cotton-grass *Eriophorum* spp.-dominated communities in many areas (Ratcliffe, 1959; Rawes and Williams, 1973; Tansley, 1939; Miles, 1988; Felton and Marsden, 1990; Rodwell, 1991; Thompson and Miles, 1995).

There is a dilemma concerning a role for cattle grazing in these biotopes. Cattle are not suitable for wet bog because of the substantial damage caused by poaching by these heavy grazing animals (Spedding, 1971). The dilemma arises from the high proportion of *Molinia* in these biotopes, a grass species that is not consumed by sheep. Thus, cattle may have a role in summer in reducing the extent of *Molinia* because they will readily consume this species where available, in preference to the typical blanket bog species of *Calluna*, *Erica* sp. and *Empetrum* sp. (Grant *et al.*, 1987). Cattle also consume more dead components of vegetation than sheep and reduce litter and open up the soil for new growth. In the absence of enough grass, cattle have a detrimental effect on *Calluna* by biting more of the shoot length than sheep. In conclusion, Grant *et al*. (1987) recommended that cattle should not graze where *Calluna* is dominant on blanket bog but that they may be a useful means of reducing undesirable grass species on wet moorland and blanket bog composed of a mixed vegetation cover. The Upland Management Handbook (English Nature, 2001) provides a comprehensive review of grazing interactions with blanket peat, blanket bog and wet heath, although most information relates to grazing by sheep only. Some recommendations are given that are pertinent to cattle grazing:

- undisturbed wet heaths and blanket mires require little management and should be left completely alone as far as possible;
- if bare peat is exposed, it is very difficult to stabilise and any stocking will make matters worse;
- there should be no grazing in the autumn or winter, with at most very light grazing in the summer, as the ideal grazing regime for wildlife on most wet heaths and blanket mires;
- all cattle should be removed in winter, but it is preferable to remove all livestock in winter.

***Summary***

Generally blanket bog should not be grazed by cattle. The exception is where the bog has been degraded by ingression of *Molinia*.

***Best practice***

- Do not graze *Calluna*-dominated blanket bog by cattle.
- Light grazing (eg two cattle/ha for short periods of a few weeks in early summer) of blanket bog of mixed vegetation in summer by cattle may reduce dominance of *Molinia*.
- Remove cattle in autumn and winter.

## 3.12 Semi-natural woodland

Few quantitative studies have been undertaken on cattle grazing in woodlands. Recently, the Forestry Commission has reviewed cattle grazing in British woodlands based on surveys of current grazing practices (Mayle, 1999; Armstrong *et al.*, 2003; Armstrong and Bullock, 2003). The field layer of woodlands is composed of typical grassland, heath or moorland vegetation and the foraging patterns and effects of cattle are very similar to those observed for these vegetation types in open habitats (refer to corresponding sections). Grazing by cattle in woodlands can lead to reductions in bracken and *Agrostis* sp. and lead to colonization by wavy hair grass (*Descampsia flexuosa*) and creeping-soft grass (*Holcus lanatus*) (Rodwell, 1991). Poaching by cattle also encourages the colonization of creeping-soft grass but has also been observed to mechanically remove moss mats from boulders and thus reduce abundance of these plants (Mountford *et al.*, 2000). The major difference in the woodland context is the availability of bark or browse on low branches of mature trees, or of regenerating trees and shrubs as a supplement of forage to that normally available in the field layer. Continuous or winter access of cattle to woodlands can cause significant reductions in the density of saplings (eg, Wistman's Wood on Dartmoor; Mountford *et al.*, 2000). In this study cattle grazing led to a reduced density of oak saplings and the absence of rowan and holly (palatable species). There have been numerous anecdotal accounts of damage to woodland flora caused by high stocking densities of cattle in Scottish woodlands (Dennis, 1999).

Armstrong *et al*. (2003) surveyed UK woodlands grazed by cattle and found several differences in the purpose of cattle grazing in woodlands in Scotland compared with England and Wales. In Scotland, most sites were in private ownership and were grazed with commercial breeds for cattle production, often being used for winter shelter. This was a substantial contrast with the situation in England and Wales, where many woods were managed by conservation agencies or conservation NGOs, using traditional breeds and with low stocking densities in summer only to realize nature conservation objectives. Little information was provided on seasonal effects of cattle grazing but a study on Rum was cited (Armstrong *et al.*, 2003) in which deciduous trees were browsed more in summer than winter while in winter seedlings of Scot's pine were preferentially taken (Scoggins, 1999). The main objective of the study was to reduce the cover of *Molinia caerulea*, open up the vegetation and to allow natural regeneration of trees. There was no particular stocking density used to achieve tree regeneration within UK woodlands, although stocking densities higher than 0.1 cattle/ha/year reduced even poor levels of regeneration (Armstrong *et al.*, 2003). By their trampling, cattle are thought to create regeneration niches for trees (Dennis, 1999). Hence, an increased number of trees germinating may offset the mortality of young trees caused by cattle browsing. High browsing intensity is indicated by evidence of browsing damage to hawthorn and holly. By contrast, evidence of only light browsing on oak, goat willow or birch saplings would suggest overall light browsing intensity (Armstrong *et al.*, 2003). In conclusion, this survey showed that conservation managers were content that cattle grazing achieved their conservation objective for the woodlands, and these were summarized as follows:

1 to benefit biodiversity generally by:
   - reducing tree/scrub regeneration;
   - reducing the existing shrub layer;
   - maintaining open habitats;
   - reducing dominant plant species.

2 to benefit individual species or groups;

3 to encourage tree regeneration.

Cattle can also maintain the structural and botanical diversity of riparian vegetation within coniferous plantations by reducing the competitive dominance of *Juncus* rush, calcareous flush vegetation and *Agrostis–Festuca* grasses that would otherwise prevail without grazing (Humphrey and Patterson, 2000). It was concluded that habitat quality could be maintained as long as the riparian areas were of sufficient length to avoid localized trampling effects on vegetation. The nine years of experimental grazing failed to increase the frequency of rare herbs in these habitats.

### *Summary*

Limited studies suggest that grazing by cattle can create more niches for the regeneration of saplings. However significant damage can occur if grazing pressure is too high, especially in winter.

### *Best practice*

- Avoid grazing by cattle in woodlands in winter as significant damage to saplings can occur.
- Light grazing in summer at (<0.1 cattle/ha) can increase biodiversity by maintaining open habitats, creating re-generation niches alongside water courses running through forestry.

## 3.13 Wood pasture

Wood pasture represents the extreme of woodland grazing where widely spaced, pollarded or individually fenced trees remain in an otherwise open pasture context. Such pastures are characterized by the complete absence of the botanical species composition and structural patchiness that would be associated with semi-natural woodland (Kirby, 1992). The field layer will therefore most often represent mesotrophic grassland and cattle grazing effects on this habitat are reviewed under neutral grasslands. The most valued part of this type of pasture is the old age of the trees. Such 'veteran' trees have important standing deadwood components and are extremely important habitats because this age class of trees is often absent from managed woodlands. Such trees support saproxylic insects, saprophytic fungi and epiphytic lichens and bryophytes. The main concern for these trees is potential ring-barking from livestock having close access to them, and the lack of replacement and slow disappearance of these trees from wood pastures.

### *Summary*

No specific information on cattle grazing.

### *Best practice*

- Old trees may need to be protected from ring barking and rubbing.

## 3.14 Wetland

Management issues related to wetlands are broadly similar to fen, in that continued traditional mowing is the most appropriate management to maintain species richness in most situations, but cattle grazing can be a substitute (Gander *et al.*, 2003). However, cattle grazing results in redistribution of nutrients and hence eutrophication of resting areas and cattle avoid species such as *Cladium mariscus* such that it might spread at the expense of other species.

### *Summary*

Mowing is the preferred management, but grazing by cattle can substitute.

### *Best practice*

- Grazing by cattle can substitute for mowing. However no research has quantified the appropriate levels for different objectives.

## 3.15 Fen

Management of some form (burning, grazing or mowing) is necessary to prevent succession of this habitat to scrub and woodland (Vinther and Hald, 2000). This has been noted for a range of fen communities such as *Pinguiculo–Caricetum dioicae* (M10) and *Carici–Saxifragetum aizoides* (M11) mire (Rodwell, 1991). It is also important for maintaining the characteristic vegetation of fen meadow communities such as *Juncus subnodulosus–Cirsium palustre* (M22) fen meadow, *Juncus effusus/acutiflorus–Galium palustre* rush pasture (M23) and *Cirsio–Molinietum caeruleae* fen meadow (M24). Grazing has also been noted to prevent the succession of swamp communities to woodland, such as *Glyceria fluitans* (S22) water margin vegetation, *Carex rostrata–Potentilla palustris* tall herb fen and *Phalaris arundinacea* tall herb fen (S28) (Rodwell, 1994).

It has been suggested in recent years that extensive grazing is the best method of managing fen vegetation (Tolhurst, 1997). However, one of the main conclusions of this report was that further research was necessary to match breed and management strategy to site conditions. The report also suggested that cattle and ponies would often be preferable to sheep as they can provide structural diversity, poach areas, browse on scrub and avoid flowering heads of species such as orchids.

A comparison of light cattle grazing (average of 0.4 livestock units/ha) with ungrazed fen (Ausden *et al.*, 2005) showed that grazing reduced the dominance of *Phragmites australis*, increased stem densities of *Glyceria maxima*, and increased the plant-species richness of grazed areas. The shift from *Phragmites* to *Glyceria* is similar to that in other studies of fen grazing and in studies of the effects of summer grazing (summarized in Ausden *et al.*, 2005). However, in this study, grazing was detrimental to the rare snail *Vertigo moulinsiana*. The conclusions of this study were that light grazing with an appropriate cattle breed was a useful method of increasing plant species richness and habitat heterogeneity. However if grazing pressure was too high ungrazed areas suitable for *V. moulinsiana* would not be left. Also, cattle lose condition in the winter on this vegetation, so grazing of this habitat needs integration with other sources of winter fodder.

A study in southern Germany contrasted cattle grazing with mowing (Stammel *et al.*, 2003). They concluded that mowing was the most appropriate method to maintain a high species richness, but that grazing could be recommended as an alternative if the other option was abandonment.

Grazing and mowing have also been used to restore scrub-dominated, former fen vegetation. This re-instatement of management increased species richness and reduced the dominance of woody species. Grazing resulted in a greater dominance of rush or sedge species, whilst mowing increased the dominance of grasses (Vinther and Hald, 2000).

There is no study that contrasts the effects of cattle with other livestock types. Traditional mowing of fen vegetation is the preferred method of maintaining high species richness, but light grazing with cattle is an acceptable alternative.

### *Summary*

Mowing is currently the preferred management for fen, but grazing by cattle can substitute. It has been suggested that cattle (or ponies) are preferable to sheep as they can provide structural diversity, poach areas, browse on scrub and avoid flowering heads of species such as orchids.

### *Best practice*

- Mowing is the preferred management regime for fen vegetation.
- Light grazing by cattle in summer (<0.4 cattle/ha) may be used as an alternative to mowing.

## 3.16 Coastal heath

This vegetation is found on a wide variety of moderately base-poor soils on the less exposed parts of maritime cliffs (*Calluna vulgaris–Scilla verna* heath (H7), Rodwell, 1991). The dwarf-shrub canopy is often open, allowing grassy swards with many herbs to form between bushes. Grazing regulates the density and height of the dwarf shrub component, but also prevents succession to scrub. Where heavily grazed the rosette hemicryptophytes *Plantago lanceolata* and *P. maritima* can dominate. It is claimed that cattle grazing gives a less close cropping to this vegetation and hence a greater heterogeneity to the sward (Rodwell, 1991). There is no experimental work on coastal heaths. Best practice should follow that of lowland heath.

### *Summary*

Grazing by cattle may be more effective at maintaining diversity of plant species, but grazing is necessary to prevent scrub encroachment.

### *Best practice*

- Grazing levels should be set to prevent suppression of dwarf shrubs but to maintain a high proportion of forbs in the sward. However, no research has quantified the appropriate grazing regimes for coastal heath, and grazing regimes would have to take into account the relative proportions of dwarf-shrub and herbaceous vegetation and any specific requirements of species present.

## 3.17 Saltmarsh

Saltmarsh in Scotland covers the following NVC classes: SM 1–2, 6, 8, 10, 13–20, 23, 28. The UKBAP (http://www.ukbap.org.uk/UKPlans.aspx?ID=33) states that 'grazing has a marked effect on the structure and composition of saltmarsh vegetation by reducing the height of the vegetation and the diversity of plant and invertebrate species'. However, this appears at odds with other conclusions that moderate grazing increased plant diversity as it prevents the dominance of rank grasses, and only at high grazing intensities does it reduce diversity. This has been shown for a range of situations on saltmarshes both where grazing has been removed or where it has been reinstated following removal (eg Bakker *et al*., 1997; Olff *et al*., 1997; Bouchard *et al*., 2003). For instance on *Puccinellietum maritimae* (SM13) salt marsh, grazing maintains the dominance of the perennial grasses *Puccinelia maritime* and *Festuca rubra*, and at heavier grazing levels species such as *Halimione portulacoides* and *Limonium* spp. are reduced in abundance (Boorman, 1967).

The effects of grazing are to:

- retard the process of sedimentation;
- reduce the species richness of lower marsh at high stocking rates;
- increase the abundance of lower marsh species in the upper marsh, and their invertebrate assemblages;
- increase habitat heterogeneity;
- decrease litter and detritivore populations;
- decrease immigration of higher marsh animals into lower marsh;
- decrease species-richness of plant feeding insects.

Conversely, abandonment reverses the above effects and leads to a:

- decrease in plant species-richness;
- decrease in the diversity of vegetation types;
- loss of characteristic halophytic vegetation;
- reduction in species-richness of invertebrates (Andresen *et al.*, 1990).

The UKBAP goes on to say that 'intensive grazing creates a sward attractive to wintering and passage wildfowl and waders, whilst less intense grazing produces a tussocky structure which favours breeding waders'. Habitat heterogeneity has been shown to be important in increasing the diversity of wading birds present (Milsom *et al.*, 1997) and increased heterogeneity is a feature of cattle grazing rather than sheep grazing (see Chapter 2). Moderate grazing by cattle has also been put forward as a means of maintaining saltmarsh at a young successional stage which makes it suitable for a wider range of halophytic species and for breeding redshank and grazing waterfowl (Esselink *et al.*, 2000). Increased grazing has been shown to be detrimental to breeding redshank (Norris *et al.*, 1998).

There is little information comparing grazing by different herbivores or on the timing of stocking. Cattle grazing may be preferable to sheep grazing due to the increase in heterogeneity it brings. Cattle grazing may allow more shrubby species to dominate, whilst sheep grazing may shift the dominance more to grassy vegetation (Rodwell, 2000). It has been suggested (Andresen *et al.*, 1990) that a stocking rate of c. 0.5 cattle/ha is most suitable for nature conservation purposes. However, heavy cattle trampling can lead to poaching.

***Summary***

No specific information on cattle grazing, but it has been suggested that cattle may lead to a more diverse flora.

***Best practice***

- Grazing by cattle (ca. 0.5 cattle/ha) may result in more heterogeneity that grazing by sheep.

## 3.18 Scrub including montane scrub

In general, the presence of scrub is reduced through grazing (Hester, 1996). However, there is no published information on the relative effects of cattle compared to other grazers. It is possible that grazing cattle may help create regeneration niches for seedling establishment through trampling. However, they are also likely to browse off any seedlings that emerge above the vegetation.

Browsing of montane scrub (*Juniperus communis* ssp. *Communis–Oxalis acetosella* woodland, W19 and *Salix lapponum–Luzula sylvatica* scrub, W20), particularly by sheep in the last 200 years and red deer over recent decades, has been widely assumed to have caused a reduction in area covered by montane scrub to the small areas in existence today (Mardon, 2000; Scottish Natural Heritage, 2003). However, complete removal of grazing may have a long-term impact on populations of montane scrub species (*Salix* spp., *Juniperus communis*) as a result of competition from taller growing vegetation or by the absence of disturbance to provide new regeneration niches. Replacement of sheep or deer by cattle could be beneficial, as cattle are less agile and hence less likely to browse scrub on steeper ground. They may also increase the possibility of regeneration from seed by increasing the amount of disturbance and bare ground. However, there is no specific information regarding the effect of cattle grazing on montane scrub, either in isolation or in comparison with other species of grazer.

*Summary*

No specific information on cattle grazing.

*Best practice*

- No specific information on grazing by cattle.

## 3.19 Summary of impacts of grazing by cattle on habitats

Table 3.1 provides a summary of whether grazing by cattle is likely to be beneficial, neutral or detrimental compared to grazing with other species. It should be emphasized that the information in the table is inevitably a simplification and that the effects will depend on the specific management objectives that are set for any particular site. It is further assumed that the grazing by cattle is carried out according to best practice as identified in the section of the text dealing with each habitat ie that the grazing is carried out at an appropriate stocking density and with the correct seasonal pattern. If these conditions are not met then grazing by cattle could be very detrimental to many habitats.

**Table 3.1** Summary of effects of cattle on habitats

| Habitat | Beneficial | Neutral | Detrimental | Comments |
|---|---|---|---|---|
| Neutral grasslands | | | | No specific information |
| Base-rich grasslands | | | | No specific information |
| Acidic grasslands | ✔ | | | |
| Periodically flooded grasslands | | | | No specific information |
| Coastal grasslands including cliff-tops | | | | No specific information |
| Machair | ✔ | | | |
| Rush pasture | ✔ | ✔ | | |
| Lowland heath | ✔ | | | |
| Moorland | ✔ | ✔ | | |
| Lowland raised bog | | | ✔ | No specific information |
| Blanket bog | ✔ | ✔ | ✔ | |
| Semi-natural woodland | ✔ | | | |
| Wood pasture | | | | No specific information |
| Wetland | | ✔ | | |
| Fen | ✔ | ✔ | | |
| Coastal heath | | | | No specific information |
| Saltmarsh | | | | No specific information |
| Scrub, including montane scrub | | | | No specific information |

For many habitats there is no specific information about the effects of grazing by cattle. For most habitats for which there is empirical evidence, compared to grazing with other species the effects are likely to be neutral or beneficial provided best practice is followed. Only on blanket bog when *Calluna* is dominant and on raised lowland bog is cattle grazing always likely to be detrimental.

# 4 EFFECTS OF CATTLE ON PRIORITY SPECIES

## 4.1 List of priority species

A list of priority animal and plant species that might be impacted by grazing associated with different habitats is shown in Table 4.1.

**Table 4.1** List of priority animal and plant species that may be affected by grazing for each habitat (Status: P, UK Priority species; C, UK species of conservation concern; L, Locally important species). Information from National Biodiversity Action Plans and cross checked for Scottish distributions using Local Biodiversity Action Plans, where available (http://www.ukbap.org.uk)

| Habitat | Fauna | Status |
|---|---|---|
| Neutral grasslands | Pearl bordered fritillary *Boloria euphrosyne* | P |
| Base-rich grasslands | Mason bee *Osmia inermis* | P |
| | Mason bee *Osmia parietina* | P |
| | Ruby-tailed wasp *Chrysura hirsuta* | P |
| | Snail *Vertigo geyeri* | P |
| | Snail *Vertigo genesii* | P |
| | an Alchemilla *Alchemilla minima* | P |
| Acidic grasslands (lowland) | Pearl-bordered fritillary *Boloria euphrosyne* | P |
| (Upland and Montane) | Pearl-bordered fritillary *Boloria euphrosyne* | P |
| | Dotterel *Charadrius morinellus* | L |
| | Snow bunting *Plectrophenax nivalis* | L |
| | Purple sandpiper *Calidris maritime* | L |
| | Ptarmigan *Lagopus mutus* | L |
| | Golden eagle *Aquila chrysaetos* | L |
| | Mountain hare *Lepus timidus* | L |
| | Northern dart *Xestia alpicola alpina* | C |
| | Scotch burnet moth *Zygaena exulans subochracea* | C |
| | Mountain ringlet *Erebia epiphron* | L |
| | Thatch moss *Leptodontium gemmascens* | P |
| Periodically flooded grasslands | Lapwing *Vanellus vanellus* | L |
| | Redshank *Tringa nebularia* | L |
| | Curlew *Numenius arquata* | L |
| | Pink-footed goose *Anser brachyrhynchos* | L |
| Coastal grasslands including cliff-tops | Snow bunting *Plectrophenax nivalis* | L |
| | Small blue butterfly *Cupido minimus* | L |
| | Scottish scurvy-grass *Cochleria scotica* | P |
| | an Eyebright *Euphrasia rotundifolia* | P |
| | Dune gentian *Gentianella uliginosa* | P |
| | Juniper *Juniperis communis* | P |
| | Petalwort *Petalophyllum ralfsii* | P |
| | Matted bryum *Bryum calophyllum* | P |
| | Sea bryum *Bryum warneum* | P |

**Table 4.1** *(continued)*

| **Habitat** | **Fauna** | **Status** |
|---|---|---|
| Machair | Skylark *Alauda arvensis* | P |
| | Corncrake *Crex crex* | P |
| | Corn bunting *Miliaria calandra* | C |
| | Beetle *Protapion ryei* | P |
| | Great yellow bumble bee *Bombus distinguendus* | C |
| | Northern colletes *Colletes floralis* | P |
| | Belted beauty moth *Lycia zonaria* | P |
| Rush pasture | Marsh fritillary butterfly *Eurodryas aurinia* | P |
| | Brown hairstreak *Thecla betulae* | L |
| | Narrow-bordered bee hawkmoth *Hermaris tityus* | C |
| | Curlew *Numenius arquata* | L |
| | Snipe *Gallinago gallinago* | L |
| | Barn owl *Tyto alba* | L |
| | Scottish small-reed *Calamagrostis scotica* | P |
| Lowland heath<br>(inc. Scottish upland heathland) | Twite *Carduelis flavirostris* | L |
| | Golden plover *Pluvialis apricaria* | L |
| | Golden eagle *Aquila chrysaetos* | L |
| | Hen harrier *Circus cyaenus* | L |
| | Merlin *Falco columbarius* | L |
| | Mountain hare *Lepus timidus* | L |
| | Scottish burnet moth *Zygaena exulans* | P |
| | Small pearl-bordered fritillary *Boloria selene* | L |
| | Large heath *Coenonympha tullia* | C |
| | Netted mountain moth *Semiothisa carbonaria* | L |
| | Broad-bordered white underwing *Anarta melanopa* | L |
| | Small dark yellow underwing *Anarta cordigera* | P |
| | Black grouse *Tetrao tetrix* | P |
| | Cranefly *Tipula (Savtshenkia) serrulifera* | P |
| | Moth *Semiothisa carbonaria* | P |
| | Moth *Xestia alpicola alpine* | P |
| | Moth *Xylena exsoleta* | P |
| | an Eyebright *Euphrasia campbelliae* | P |
| Moorland<br>(Heather moor) | Golden plover *Pluvialis apricaria* | L |
| | Dunlin *Calidris alpine* | L |
| | Snipe *Gallinago gallinago* | L |
| | Large heath *Coenonympha tullia* | L |
| | Juniper *Juniperis communis* | P |
| | Northern prongwort *Herbertus borealis* | P |
| | Thatch moss *Leptodontium gemmascens* | P |

**Table 4.1** *(continued)*

| Habitat | Fauna | Status |
|---|---|---|
| Lowland raised bog | Marsh fritillary *Eurodryas aurinia* | P |
| | Small pearl-bordered fritillary *Boloria selene* | L |
| | Large heath *Coenonympha tullia* | L |
| | Reed bunting *Emberiza schoeniclus* | P |
| | Baltic bog-moss *Sphagnum balticum* | P |
| | Skye bog-moss *Sphagnum skyense* | P |
| Blanket bog | Golden plover *Pluvialis apricaria* | L |
| | Dunlin *Calidris alpine* | L |
| | Snipe *Gallinago gallinago* | L |
| | Large heath *Coenonympha tullia* | L |
| | Baltic bog-moss *Sphagnum balticum* | P |
| Semi-natural woodland | Roe deer *Capreolus capreolus* | L |
| (Birch woodland) | Badger *Meles meles* | L |
| | Cousin German moth *Paradiarsia sobrina* | C |
| (Pine woodland) | Kentish glory *Endromis versicolera* | L |
| | Song thrush *Turdus philomelos* | P |
| | Capercaillie *Tetrao urogallus* | P |
| | Scottish crossbill *Loxia scotica* | P |
| | Crested tit *Parus cristatus* | L |
| | Red squirrel *Sciurus vulgaris* | P |
| | Pine marten *Martes martes* | L |
| | Narrow-headed wood ant *Formica exsecta* | P |
| | Wood ant *Formica aquilonia* | C |
| | Wood ant *Formica lugubris* | C |
| | Cousin German moth *Paradiarsia sobrina* | C |
| | Hoverfly *Metasyrphus lapponicus* | C |
| | Hoverfly *Blera fallax* | C |
| | Juniper *Juniperis communis* | P |
| | Twinflower *Linnaea borealis* | P |
| (Upland oak wood) | Robber fly *Laphria flava* | L |
| | Spider *Dipoena torva* | L |
| | Spotted flycatcher *Muscicapa striata* | C |
| | Song thrush *Turdus philomelos* | P |
| | Redstart *Phoenicurus ochruros* | L |
| | Wood warbler *Phylloscopus sibilatrix* | L |
| | Daubenton's bat *Myotis daubentonii* | L |
| | Slug *Limax tenellus* | L |
| | Small cow-wheat *Melampyrum sylvaticum* | P |

**Table 4.1** *(continued)*

| Habitat | Fauna | Status |
|---|---|---|
| Wood pasture | Unspecified saproxylic insects | |
| Wetland | Irish lady's-tresses *Spiranthes romanzoffiana* | P |
| Fen | Yellow marsh saxifrage *Saxifraga hirculus* | |
| | Greater water parsnip *Sium latifolium* | |
| | Slender green feather-moss *Hamatocaulis vernicosus* | P |
| Coastal heath | an Eyebright *Euphrasia rotundifolia* | P |
| Saltmarsh | Unspecified rare invertebrates | |
| | Waders, gulls and terns – summer | |
| | Ducks and geese – winter | |
| | Ground beetle *Amara strenua* | P |
| | Ground beetle *Anisodactylus poeciloides* | P |
| | Natterjack toad *Bufo calamita* | P |
| | Narrow-mouth whorl snail *Vertigo angustior* | P |
| | an Eyebright *Euphrasia heslop-harisonii* | P |
| Scrub, including montane scrub | Song thrush *Turdus philomelos* | P |
| | Linnet *Carduelis cannabina* | C |
| | Yellowhammer *Emberiza citrinella* | L |
| | Dunnock *Prunella modularis* | L |
| | Whinchat *Saxicola rubetra* | L |
| | Stonechat *Saxicola torquata* | L |
| | Whitethroat *Sylvia communis* | L |
| | Broom-tip moth *Chesias rufata* | L |
| | Wooly willow *Salix lanata* | P |

No specific information on direct effects of cattle on priority species could be found. It is only possible to infer potential effects through general investigations of cattle grazing and habitat quality, measured as changes to habitat structure or floristic composition dealt with below.

## 4.2 Overview of effects of grazing and trampling on priority habitats

### *Birds*

Knowledge of the effects of grazing on moorland bird populations is extremely poor and very little is understood about how different grazing levels affect different bird species (Fuller and Gough, 1999). There are various mechanisms by which grazing animals may influence breeding birds, including effects on vegetation structure, trampling of nests and young (particularly waders) and dunging, which provides invertebrate food (English Nature, 2001). Upland habitats provide significant breeding or foraging habitat for a unique mix of ca. 40 bird species, of which 40% are currently declining. Of these, seven occur in internationally important numbers, and eight are listed in Annex 1 of the EC Birds Directive 70/409/EEC (Thompson and Miles, 1995). Existing knowledge concerning the ecology and habitat requirements of many of these is limited to a small number of broad-scale correlative studies (eg Brown and Stillman, 1993), and a few PhD studies covering single site, single species autoecological studies (eg Whittingham, 1996; Pearce-Higgins, 1999). Changes in the scale and intensity of management practices in the uplands are implicated in the deterioration of habitat quality for breeding populations of wading birds and passerines of international conservation significance (EC Birds Directive) and for game birds of economic importance (Fuller and Gough, 1999).

Investigations suggest that declines in bird populations are not simply the result of a direct interaction between birds and cattle. The RSPB has produced evidence of the impacts of grazing on upland bird species through changes in vegetation composition and structure from studies in the Southern Uplands of Scotland and the Pennines of northern England. The research involved a correlation of the abundance of a suite of breeding birds with detailed assessments of moorland vegetation and grazing intensity (Pearce-Higgins and Grant, 2002). This study did not assess the mechanism of effects, and the role of arthropod food supply remains a possible reason for reduced breeding success. The interaction between grazing animals and nesting habitat or arthropod food for meadow pipits has been investigated in a three year project coordinated by the Macaulay Institute. Unpublished data show that a reduction in grazing intensity to one third of a commercial sheep grazing intensity doubled the arthropod biomass available to foraging birds.

In lowland farmland, the abundance of invertebrates is a critical factor accounting for the declines of farmland bird populations (Fuller *et al.*, 1995; Wilson *et al.*, 1999; Chamberlain *et al.*, 2000). However, the relationships between farmland birds, their prey items and farm management practices are complex. Insectivorous birds require arthropod food resources of adequate abundance in close proximity to their nesting or roosting sites and the soil and vegetation structure needs to be such to allow access to these food items (Berg, 1993; Beintema *et al.*, 1991; Green *et al.*, 1990).

Leatherjackets, larvae of craneflies (Diptera: Tipulidae), represent the largest invertebrate biomass in the uplands and significantly contribute to the diet of the rare upland *Dotterel*, *Eudromias morinellus* (Charadridae) (Galbraith *et al.*, 1993) and the economically important red grouse, *Lagopus lagopus* (Park *et al.*, 2001). McCracken *et al.* (1995) indicated that the abundance of leatherjacket populations eaten by birds is influenced by previous farm management practices in addition to the location and characteristics of a site. In addition, both current and past farm management are important in determining the availability of soil-dwelling arthropods to birds at any one time of year (Berg, 1993; Beintema *et al.*, 1991; Green *et al.*, 1990). Furthermore, heterogeneity in habitat structure must be considered at a spatial scale appropriate for the size and mobility of the birds (Morris, 1987; Wiens, 1989; Ziv, 2000) and their life-history characteristics (Naugle *et al.*, 1999). A lighter summer grazing regime on flatter, unenclosed ground can provide a short sward of benefit for breeding waders such as golden plover, although different waders have different requirements (Ausden and Treweek, 1995). Bignal *et al.* (1996) found that chough (*Pyrrhocorax pyrrhocorax*) foraged for leatherjackets during the breeding season on grasslands of short sward generated by intensive grazing by sheep, cattle and/or overwintering barnacle geese. This allowed access to the prey but larger densities of leatherjackets were associated with grasslands where there had been a taller sward in autumn related to a low stocking density of cattle. Such taller vegetation was preferred by adult craneflies for egg laying. It is essential to increase our understanding of the interactions between structure of vegetation and arthropod abundance before appropriate grazing management strategies can be developed for conservation (eg McCracken *et al.*, 1995; McCracken and Bignal, 1998; Perkins *et al.*, 2000). Caterpillars of moths (Lepidoptera), sawflies (Hymenoptera: Symphyta) and spiders contribute to the diet of black and red grouse (Baines, 1991; Baines, 1996). These caterpillars, in addition to the soil-dwelling leatherjacket larvae (Diptera: Tipulidae) described above, are also essential in the diet of upland ground-nesting birds, including waders of international conservation importance (Brown and Bainbridge, 1995). Black grouse broods use upland grass or heather habitats with taller vegetation that have more arthropods, particularly caterpillars but also including flies, plant bugs and parasitic wasps (Baines, 1996). However, in this case the timing of the hatch of black grouse coincided with the peak availability of moth caterpillars preferred by chicks. Adult black grouse also feed on cotton-grass *Eriophorum* flowers which is very nutritious but is also consumed by livestock at moderate to high stocking densities. The availability of arthropods as food to birds will be a product of the species composition, abundance and biomass of arthropods, their guild, location in the soil or vegetation and their seasonality.

**Table 4.2** Summary of key studies of impacts of grazing by cattle on birds

| Study | Facilitation | Detrimental | Reference |
|---|---|---|---|
| Grazing and moorland vegetation response compared with upland wading birds | | Cattle of mixed grazing systems removed favourable botanical and structural composition | Pearce-Higgins and Grant, 2002 |
| Grazing and Upland Bird experiment – upland acid grassland | Higher density of meadow pipits with larger eggs on vegetation grazed by cattle mixed with sheep at one third commercial stocking rate | | Dennis *et al.*, 2005 |
| Cattle grazing of chough grassland in Western Isles | Provision of insect prey of chough in dung enhanced by cattle grazing | Grassland damaged by the continuation of out of season grazing | Bignal *et al.*, 1996 |
| Cattle grazing for chough | Cattle can maintain feeding lawns for chough where they can access cranefly larvae in soil | Grazing vegetation too short in autumn can inhibit egg laying by adult craneflies | McCracken *et al.*, 1995; McCracken & Bignal, 1998 |
| Trampling and ground nesting birds | | Eggs and nests can be damaged by higher stocking densities of cattle | Beintema and Müsken, 1987 |

Cattle can influence birds by trampling nests. Beintema and Müsken (1987) found in the Netherlands that the probability of a nest surviving trampling was a simple function of stocking density and the number of days of grazing, a similar finding to that of Green (1986) in the Ouse Washes. Of four types of grazing (dairy cattle grazing during the day only, dairy cattle grazing day and night, young cattle grazing day and night and sheep grazing day and night), young cattle were the worst tramplers. However the authors point out that it was not clear to what extent re-nesting compensated for damage by trampling and the extent or re-nesting will depend on the stage of the breeding season. O'Brien (2001) found that on improved grassland, horses caused more trampling damage to lapwing nests at a given stocking density, with sheep causing least damage and cattle being intermediate. On unimproved pasture the damage was considerably lower because of the lower stocking density although when stocking density was taken into account the probability of a nest being trampled was similar.

There are many woodland birds that are conservation priorities but many of these will only be affected by the long term effects of grazing on woodland plant species and structural composition.

### *Mammals*

In general, cattle grazing will affect other mammals indirectly through changes to the quality and quantity of habitat. Red deer may benefit directly from the reduction in competition for forage with domestic herbivores should there be a reduction in stocking densities. Changes in grazing, that may include the use of cattle to achieve better habitat condition, should improve habitat quality for mountain hares and short-tailed voles. One key species that is of considerable interest to land managers in upland areas is the field vole *Microtus agrestis*. An increased abundance of voles was observed when livestock grazing was removed from grasslands in Montana (Smit *et al.*, 2001). This response could have both positive and negative implications for biodiversity in the Scottish context as:

a) field voles are a major source of food for other species;

b) they are a major cause of damage to newly planted or established trees; and

c) they are potential vectors for diseases (Lyme's Disease, Louping ill, Anoplasma) that infect wildlife and man, although there has been little research on the importance of this in the Scottish environment.

Cattle contribute as one species of a broader range of wild and domestic herbivores that affect the structure and composition of upland woodlands. The effects are long term in contributing to the structural and floristic species composition of woodlands and the precise impacts of cattle on the list of mammal species associated with woods are tenuous. Native deer (roe *Capreolus capreolus* and red *Cervus elaphus*) could be displaced from woods where there is intensive grazing by domestic livestock, including cattle (Kirby *et al.*, 1994, Hester *et al.*, 1998, Mitchell and Kirby, 1990). Upland woods are important habitat for the red squirrel *Sciurcus vulgaris*. Very large pinewoods (in excess of 2000ha) and composed mainly of coniferous species provide the best refuges for red squirrels. A diverse age structure is ideal with 50–60% of the trees being of cone bearing age. Young trees of 15–30 years provide good cover, and continuous belts of trees linking seed-bearing areas are desirable. All these aspects could be managed using grazers, possibly cattle, although most likely it is a case of excluding wild herbivores (English Nature, 2001). Upland and upland fringe broadleaf woods with a good range of understorey shrubs can hold populations of dormice *Muscardinus avellanarius*. Young plantations are valuable habitats for small mammals, when there is a thick covering of ground vegetation. Later, similar conditions may be provided along wide grassy rides (English Nature, 2001). Otters *Lutra lutra* may use riverside woodland strips and lines of trees as cover for holts and hunting territory (http://www.wwf.org.uk/core/wildlife/fs_0000000027.asp). Large upland conifer plantations are important for pine marten *Martes martes* but cattle have little or no role in conserving this species.

### *Invertebrates*

Insects and arachnids (arthropods) typically contribute more than half the species to the biodiversity in any particular habitat (Anon, 1995). The overall diversity of insects and arachnids in the uplands is a product of the adaptation of individual species to particular upland biotopes (habitats) and their specific guild. In general, arthropod assemblages of heather and grassland biotopes in the uplands are distinct compared with those of other habitats such as riversides, woodlands, marsh and grassland, eg ground beetle (Luff *et al.*, 1989), butterfly, moth and spider species (Ratcliffe, 1977). The species composition of these arthropod assemblages is also very different within upland plant communities (Coulson and Butterfield, 1985), namely lowland mires, northern heaths, blanket bogs, steep-gradient peaty soils and upland limestone grasslands. The greatest difference in insect assemblages is between heather and grassland, mainly because of the association of phytophages with specific plants (Coulson and Butterfield, 1985); those of blanket bog and peatland support the most distinct species.

Cattle are generally better than sheep at maintaining a structurally patchy sward of benefit to arthropods. This is partly due to the dunging behaviour of cattle. Cattle dung randomly across a sward and then avoid dunged areas whilst grazing, and this develops into a series of tall sward islands that are favourable for arthropods (Dennis *et al.*, 1998; Dennis, 2003). Dung beetles are rare or absent from ungrazed grassland, since the dung of small mammals is unsuitable for most dung feeders (Morris, 1990). A complete absence of animal dung will lead to the loss of specialised arthropod species of the detritivore guild, such as the nationally scarce dung beetle *Aphodius fasciatus*, which is associated with sheep and cattle dung in moorland and montane areas (English Nature, 2001). Many other dung feeders are opportunists that colonize rapidly over short distances, but if grazing is reintroduced after being absent from a large area the rate of breakdown of dung and hence nutrient cycling will be suppressed over the period of recolonisation. Many insect guilds are herbivorous (phytophagous) and depend on the presence of particular vegetation types or plant species. Due to their small size, compared with the size of individual plants, and diverse modes of feeding, they often select specific parts of a plant, such that they are sensitive to plant architecture in addition to the presence of a suitable host species (Strong *et al.*, 1984). The abundance of their populations tends to increase with the standing biomass of their food plants. Predators are more dependent on the physical features of their habitats. For example, web-spinning spiders depend on taller, more rigid plants for web anchorage that may be present at low densities (Gibson *et al.*, 1992b).

Small, insect herbivores, namely leafhoppers (Homoptera: Auchenorrhyncha) and other plant bugs (Heteroptera) select for particular species or groups of plants (Whittaker and Tribe, 1998; Waloff, 1980). Particular species will therefore associate with upland communities where these host plants are abundant (Dennis, 2003) and direct competition between large herbivores and these insects will occur when grazing selects those host plants and reduces their abundance within a particular upland community (Gibson *et al.*, 1992). Grazing herbivores have an indirect effect on many arthropods by modifying the structural characteristics of upland habitats (Dennis *et al.*, 1998). The structural appearance of vegetation can be dramatically altered by the grazing regime, more so than plant species composition (Dennis, 2003; Hulme *et al.*, 1999; Grant *et al.*, 1996a and b). The development of distinct tussocks or hummocks has consequences for the distribution of small arthropods, both leafhoppers and spiders (Dennis *et al.*, 1998). These structural components of grasslands contributed to arthropod species diversity. More individuals and species of leafhoppers were sampled in the taller, more complex components of grasslands, either tussock or hummocks (Dennis, 2003). Further, the impact of increased grazing intensity on these insects was, somewhat, buffered by these structures. The structural complexity of tussock-forming grasses encourages more planthoppers and web-building spiders in upland grasslands (Cherrett, 1964; Dennis *et al.*, 1998; 2001). For wolf spiders (Araneae: Lycosidae), species which pursue prey and do not build webs, the reverse is true and ca. 92% of individuals of this family mainly use the shorter grass between tussocks (Bayram and Luff, 1993). The relationships between grazers, vegetation and arthropods for upland, indigenous grasslands were consistent with the situation in lowland grasslands. The diversity of many arthropod taxa of lowland grasslands was favoured primarily by an increase in average vegetation height (Morris, 1990; Gibson *et al.*, 1992a; 1992b; Kruess and Tscharntke, 2002).

If we consider predators requiring architectural diversity for the anchorage of webs, eg, the money spider, *Silometopus elegans*, its general abundance increases where there is a lower grazing intensity but declines where grazing is absent for over two years (Dennis, 2003). By contrast, the common money spider, *Lepthyphantes mengii*, demonstrates a similar trend except that the highest catches were in the ungrazed *Nardus stricta* (Dennis, 2003). The difference is caused by the different locations of web building by these spiders. *Lepthyphantes mengii* constructs webs high in the leaves of tussocks or hummocks and this microhabitat is increased where grazing ceases for longer periods (Dennis, 2003). Taller swards were the most influential factor, typically being patchier, ie, having greater variability in sward height (Dennis *et al.*, 1998).

Dennis (2003) found an interaction between grazing intensity and environmental conditions for leafhopper and plant bug species indicated by the consistent declining numbers with increased stocking density. There were fewer potential species on the less productive vegetation at high altitude, on wet, cold slopes, eg *Festuca–Agrostis*. In addition, there was greater sensitivity of the plant bug species to grazing intensity on the sites of lower productivity. Ground and rove beetles (Coleoptera: Carabidae, Staphylinidae), predatory species that roam around on the ground over tens of metres, were sampled at 120 points where pitfall traps were placed within the grazing experiment on *Nardus stricta* (U5a community). A geostatistical procedure was used to determine the size and location of clusters of high and low numbers of beetle species representative of the main trends of all the species (Dennis *et al.*, 2002). Four distinct patterns were identified that accounted for the main trends expressed by all species and the ecological interpretation identified the relative influences of landform and grazing management (Dennis, 2003). A large south-facing cluster that extended over several contrasting grazing treatments characterized *Calathus melanocephalus* (Col.: Carabidae;), and indeed this species is typical of productive lowland pastures. There was also a large cluster across contrasting treatments for *Philonthus decorus* (Col.: Stapylinidae) and this showed the selection of more northern conditions typified by soil of greater wetness and organic matter content. The remaining two species both suggested responses to the patterns of grazing. *Olophrum piceum* (Col.: Staphylinidae) had clusters only within the ungrazed plots and this probably relates to the increased litter and associated fungi that would develop in the absence of grazing. The clusters of high numbers of the large species, *Carabus problematicus* (Col.: Carabidae) associated with plots grazed by sheep rather than sheep plus cattle suggests that there are effects of cattle, possibly through soil compaction or direct treading disturbance, that are detrimental to this species. *Carabus* spp. depend on soil crevices as daytime refugia to avoid desiccation and predation, and the availability of these features may be reduced under cattle grazing.

Herbivores affect soil by compacting it where they tread and altering its nutrient status where they produce dung and urine. This directly affects soil insects and arachnids and indirectly affects foliar insects and arachnids by changing plant species composition through changes in soil status, as opposed to forage selection during grazing. Trampling is seen as generally harmful to the arthropod fauna (Usher and Gardner, 1988), although dung deposition provides a niche for additional species (Coulson, 1988). Sanderson *et al.*, (1995) provide further evidence of the importance that abiotic factors have in affecting the spatial patterns of arthropod populations in upland landscapes at larger spatial scales. Soil moisture or site wetness is recognized as a major determining factor in the distribution of many ground beetle species (Rushton *et al.*, 1991).

The diversity of ground beetles, plant hoppers (Homoptera: Auchenorhyncha) and spiders (Araneae) in grassland, heathland and montane ecosystems is related to botanical diversity and the structural variability of vegetation (Coulson and Whittaker, 1978; Cherrill and Rushton, 1993, Downie *et al.*, 1995; Sanderson *et al.*, 1995; Dennis *et al.*, 1998). For grasslands in general, there is a positive correlation between the number of botanical species and the species richness of bees (Hymenoptera: Apidoidea), butterflies (Lepidoptera), phytophagous beetles (Coleoptera: Chrysomelidae) and true bugs (Hemiptera) (Tscharntke and Greiler, 1995). Differences between insect and arachnid species in the effects of grazing are highlighted by work undertaken in Wytham Woods, Oxfordshire (Brown *et al.*, 1990, Gibson *et al.*, 1992a and b). For spider assemblages, changes in plant architecture were found to be most important, while other species (eg leaf miners) were affected more by variations in floristic species composition. As a consequence, leaf miners had a rapid turnover whereas spider species accumulated over time. Age of grassland was also important; there are common species of spiders, leaf miners and leaf hoppers (Cicadellidae) that are restricted to grasslands >60 years old (Gibson, 1986).

Although general arthropod diversity is diminished by intensive management, many species respond within a few years to favourable changes in vegetation structure and botanical species composition that result from modified management (Duffey *et al.*, 1974; Brown *et al.*, 1990; Gibson *et al.*, 1992a; Curry, 1994; Dennis *et al.*, 1998). Similarly, Coleoptera (beetles) of lowland grasslands are affected by the intensity of pasture management and species of ground beetles (Carabidae) have been identified that are resilient to or excluded by such management (Eyre *et al.*, 1989; Luff and Rushton, 1989)

**Table 4.3** Summary of key studies of impacts of grazing by cattle on invertebrates

| Study | Facilitation | Detrimental | Reference |
|---|---|---|---|
| Cattle grazing on upland acid grasslands | Maintain structurally patchy sward better than sheep – benefit to arthropods in general | Combined with sheep can remove structural heterogeneity | Dennis *et al.*, 1998 |
| Grassland spiders | Height variability provides greater opportunity for web construction for spiders and hunting lawns for wolf spiders | More widespread trampling interferes with web building spiders | Dennis *et al.*, 2001; Bayram and Luff, 1993; Cherrett, 1964 |
| Ground beetles | Can increase structural diversity and increase species richness | Combined with sheep, excludes larger species, possibly because soil crevices are trampled out | Blake *et al.*, 1994; Dennis *et al.*, 1997; Eyre *et al.*, 1989 |
| Dung beetles | Most larger species depend on cattle rather than sheep dung | | Morris, 1990; English Nature, 2001 |
| Rove beetles | Dung associated predators benefit from cattle dung | Different species composition in lawn and tussock areas, hence a mosaic is required, avoiding continuous cattle grazing. Many species of composting litter absent under cattle grazing due to trampling and consumption of higher proportion of dead vegetation | Dennis *et al.*, 1997 |
| Plant bugs, including leafhoppers | Can diversify vegetation and number of host plants at low stocking densities | More grazing with cattle as part of mixture reduces species number and abundance through direct competition | Dennis *et al.*, 1998; Dennis, 2003; Gibson *et al.*, 1992b |
| General arthropod diversity | Rotational grazing with low to moderate stocking densities of cattle mixed with other livestock provides mosaic that may support the potential arthropod diversity that cannot be supported by any particular grazing regime | | Morris, 1971; 1990; 1991; Thomas ,1990; Dennis *et al.*, 1997; 1998; Dennis, 2003 |

*Fish*

There is little literature on the direct effects of cattle on fish. The effects of livestock management in general on water quality in water courses, and management actions to reduce negative impacts are dealt with in *The 4 Point Plan*. This is a joint publication between a number of agencies: the Scottish Executive, Scottish Environment Protection Agency, Scottish Agricultural College, The National Farmers' Union of Scotland, Scottish Natural Heritage, The World Wildlife Fund, the Farming and Wildlife Action Group and the BOC Foundation. The plan covers all aspects of pollution from farms (see: http://www.sepa.org.uk/pdf/publications/4pointplan.pdf.

One study on Dartmoor described how allowing cattle access to a watercourse resulted in compaction of the gravel in the river bed which meant that salmon could not dig out the hollows they need to lay their eggs. The solution lies in fence off vulnerable river banks to deny access for cattle (see: http://www.actionforwildlife.org.uk/ProjectDisplay.asp?ID=11).

# 5 EFFECTS OF CATTLE FARMING SYSTEMS ON THE NATURAL HERITAGE

Previous chapters have concentrated on the effects of cattle on particular habitats or species, but it must be recognised that cattle are part of the wider farming system. Thus if cattle are deemed to be able to deliver environmental benefits there is a need to consider:

a) the barriers to the introduction (or reintroduction of cattle into farming systems); and

b) the environmental impacts of farming systems (as opposed to the direct effects of cattle on habitats or species).

## 5.1 Introducing cattle into farming systems

Cattle were at one time a significant feature on most Scottish farms, but recent decades have seen a major shift within the agricultural industry towards greater specialisation, with farmers concentrating on fewer enterprises with more intensive management of those enterprises. Where farms no longer have cattle there are a number of obstacles to their reintroduction, particularly on hill and upland farms. The barriers to the introduction (or reintroduction) of cattle onto farms fall into three categories: capital requirements, infrastructure requirements and labour requirements

*Capital requirements*

The capital requirements for the purchase of cattle are high, especially if a breeding herd is to be established: the capital value of a cow with a calf at foot can be in excess of £1000 and up to £1200. Farmers wishing to start a breeding herd therefore require access to considerable quantities of capital, either from their own resources or by borrowing. Growing cattle, purchased for grazing may require a lower capital investment, over a shorter period (perhaps for only six months between purchase and sale), but nonetheless the capital investment is still considerable. Alternative mechanisms by which cattle could be introduced include summer grazing by cattle owned by another farmer. This may be particularly suitable for grazing replacement heifers. Thus greater co-operation between upland and lowland farmers, whereby the stock can be wintered on lowland farms, where winter feeding can be more easily provided and then returned to the hills for the summer grazing period may be one mechanism by which greater numbers of cattle could be kept on hill farms.

*Infrastructure needed for cattle*

Any cattle enterprise requires access to infrastructure of different types. This includes handling facilities, machinery for preparation and feeding of fodder and possibly housing.

Where a very low intensity system is proposed, with cattle remaining outdoors all year round, housing may not be required. However, on many farms it will be desirable for the cattle to be housed in winter, either to ensure an appropriate standard of animal welfare, and/or to prevent the cattle from causing environmental damage due to grazing and trampling of habitats. Housing for cattle is expensive, as are proper waste disposal facilities, which are mandatory. Many farms still have old cattle buildings but these are often unsuitable for present requirements. Often these traditional buildings require the cattle to be individually fed and mucked out by hand which is very labour intensive. Also, for Organic Standards, the use of traditional tie stalls is forbidden and slatted floors are forbidden in lying and feeding areas in cattle housing on the grounds of animal welfare (Lampkin, 1998).

In addition to appropriate housing, there must be provision for waste disposal, either straw-based farmyard manure or slurry, and provision may need to be made for storage of winter fodder, either hay or silage.

Appropriate handling facilities are essential to ensure that stock receive proper veterinary and welfare care, in addition to ensuring the safety of those who work with cattle. Such facilities, including handling pens, raceways and a crush, are more expensive than those required by sheep.

***Labour required for cattle***

Labour requirements for a cattle enterprise can be high, particularly during winter when feeding is necessary. On most farms financial pressures have led to a considerable reduction in labour availability compared with 10 or 20 years ago and an increase in mechanisation. This trend is likely to continue with CAP reform and the introduction of the Single Farm Payment. The management and handing of cattle often requires more than one person (unlike sheep) and on many farms, particularly in upland areas, this level of labour may not be available. Cattle enterprises also require much larger quantities of winter fodder to be made compared to sheep. A spring-calving beef cow for example will require about 6 tonnes of silage over winter. However, silage and haymaking operations can be undertaken by contractors, particularly silage making which is highly mechanised.

## 5.2 Provision of winter fodder

The ability to provide winter feed for cattle can often be one of the key determinants of the numbers of cattle kept on a farm, especially on hill farms because of the limited land suitable for the conservation of fodder. Silage-based systems require the use of expensive machinery, and it may need to be transported to the animals. Making hay can be labour intensive and, particularly in the west of Scotland, risky due to bad weather.

In the past the 'Sheiling' system was practised in many hill areas where cattle and sheep spent the summer away from the farm on more distant pastures. This meant that the land near the farm could be used for limited arable cropping and for haymaking and the livestock would then be returned to the in-bye land for over-wintering. Such a system allowed the grazing of the hill pastures to control species such as purple moor grass. It also allowed a measure of self sufficiency in terms of winter feeding with less reliance on bought-in hay and concentrates. However, these systems have been abandoned in favour of more intensive methods of production. Instead of the species-rich hay meadows, silage is made from well fertilised swards composed of fast growing and late heading ryegrass monocultures.

Where there is suitable available land for the production of winter fodder hay or silage can be made. On farms with smaller numbers of cattle, and where there is a limited supply of labour, haymaking may be the preferred option but on larger farms silage will be more suitable, particularly as it more easily lends itself to the employment of contractors and is much less weather dependant. Silage can be made in a pit or clamp, or conserved in large bales, wrapped with plastic film. The former option is only really viable if the farm already has a suitable silage pit, with proper provision for effluent storage. On many upland and hill farms and on many small farms and crofts, big bale silage is the preferred option, being easier to make and easier to feed in the winter, to either housed or outwintered stock. Big bale silage, while convenient, is not necessarily a low cost option for two reasons. Firstly, the actual conservation process is considerably slower than for pit silage, with much slower workrates. Secondly, the plastic wrap is more expensive, and is likely to become more so in the future, being closely related to the price of oil. Plastic wrap for big bales has a considerable pollution potential, although schemes for recycling are now in place in some areas. There is also a considerable potential for effluent seepage from stacks of silage bales and for this reason they should not be stored less than 10m from watercourses.

### *Concentrates and bedding*

At certain times of the year cattle may require greater levels of nutrition than can be provided by bulky roughage feeds like hay and silage. Depending on the feed quality of the roughage component of the diet, concentrate feeding may be required at key times of the animals' production cycle if reasonable levels of economic production are to be sustained and the welfare of the animals is not to be compromised eg in late winter and early spring, in the run up to calving when the nutritional demands of the growing foetus may be greater than can be provided for by a cow being fed only a roughage diet. This is particularly the case if the diet is mainly based on hay which tends to be of poorer nutritional quality than silage. The cow will require a supplementary feed, which is usually based on cereals like oats or barley. For many farms the easiest option is to purchase the concentrate feed, although some farms may grow at least some of their own requirements. The introduction of arable cropping onto a farm can have a positive effect on the natural heritage by creating new ecological niches and sources of food for wildlife. On many farms, the straw component of the cereal crop is almost as important as the grain, being essential for bedding. Home produced straw can substantially reduce the requirement for bought in straw.

## 5.3 Positive effects on the natural heritage of farming systems involving cattle

### *Dung and invertebrates*

Cattle dung attracts large numbers of invertebrates, which are an important part of the food chain, particularly for birds (see Chapter 4). However it should be noted that some anthelmintic products, especially the invermectins, can pass through the animal and reduce the numbers of insects in the dung (Strong and Wall, 1994).

### *Fodder production*

One of the important influences of cattle on a farm is that the production of hay and/or silage results in much taller grass swards being present in early summer than is the case with grazed herbage. Historically, most winter fodder was conserved as hay, cut from meadows usually containing a diverse range of grass and broadleaved species (Hughes and Huntly, 1988; Myklestad and Saetersdal, 2004; Kirkham and Tallowin, 1995). More recently, fodder conservation, even on upland farms, has been made from sown grassland containing only a very few species such us perennial ryegrass, perhaps with some white clover. These fields are usually treated with artificial fertilisers and are highly productive but compared to traditional hay meadows are species-poor. The method of conservation has also changed, with haymaking being replaced by silage making on most farms.

From the farmer's point of view, silage has a number of advantages over hay. Silage making needs a much shorter period of good weather to secure the crop compared with hay. Particularly in the wetter areas of the country, it can be very difficult to get a three or four day period of good weather, which is the minimum for making good hay.

Silage making also tends to take place earlier in the season than haymaking. Silage making allows farmers to conserve the grass at a younger and more nutritious stage of its growth cycle. Making hay from young, leafy grass is difficult since the moisture content of the leafier material is higher and the cut grass takes longer to dry. Much of the leaf can be lost during turning and spreading, so for making hay, cutting is usually delayed till the crop is more mature. The result is fodder which is easier to make but is of poorer nutritional quality than silage.

The switch to silage making however has fewer positive effects on the natural heritage than haymaking, mainly due to the material being harvested about 4 weeks earlier than hay. This four-week difference has the potential to impact directly on ground nesting birds such as the corncrake (Stowe *et al*., 1993; Green and Stowe, 1993). Seed eating birds can also be affected by the switch from hay to silage. The earlier cutting of silage means that the crop is harvested before the seeds are shed. Buckingham *et al*. (2002) found that seed eating species tended to avoid silage fields in the summer time. They also found that seedeaters tend to be attracted to hay field aftermaths.

Hay meadows are important habitats due to the rich diversity of plants found within them. However Kirby (1992) found that they are not particularly good habitats for invertebrates. The swards tend to be too tall for invertebrate species which live near to ground level and prefer short swards. As the crop reaches maturity it tends to be harvested just as it becomes a useful habitat for those species which prefer taller swards. He concluded, however, that hay meadows are still a very desirable feature in the landscape for the other biodiversity features which characterise them.

### *Cereal production and other arable cropping*

Cultivation of crops can create ecological diversity within a farm (Allen, 1999) by creating a greater diversity of land cover. Spreading of dung, either onto grassland or prior to ploughing can increase the number of invertebrates available for insect eating birds. After sowing, the bare ground and the growing crop provides nesting sites for species like lapwings, skylarks and oystercatchers. Wild flowers can develop within the cereal crop and if allowed to set seed will, together with grain shed from the harvesting operation, provide food for seed-eating birds. The stubble left over the winter also provides shelter, not just for seed eaters, but also for insect eaters. The ploughing of older grassland and the cultivation of a cereal crop is not necessarily a negative process. Good and Giller (1991) found in South West Ireland that Staphylinid assemblages recovered very quickly from ploughing once a new crop or grass canopy was established.

## 5.4 Negative effects on the natural heritage of farming systems involving cattle

### *Trampling and poaching of the ground*

Cattle can have detrimental effects on the soil and vegetation under certain conditions. This is particularly the case if they are kept outdoors in winter or when the ground is saturated and the stocking rate is too high. In extreme case there can also be a problem with run off into watercourses. Generally these adverse effects are restricted to feeding areas, and if these are sited correctly and the stocking rate is appropriate these problems can be minimised. There is often a temptation to keep cattle outdoors as long as possible in the autumn/early winter to reduce the winter feed requirement as well as to restrict the amount of dung and slurry which will build up and will require subsequent handling and disposal. However, extending the grazing period can lead to nutrients leaching into watercourses. Modelling work by McGechan (2002) looked at phosphorous leaching during extended grazing and concluded that extending the autumn grazing period significantly increased the risk of phosphorous leaching into watercourses. This supported previous experimental work and the resultant advice is that cattle should be housed before soil macropores fill up with water. When this occurs will be dependent on a number of factors, including soil type and rainfall and may vary from year to year.

### *Disposal of dung and slurry*

Keeping cattle indoors leads to the production of either farmyard manure or slurry, depending on the type of housing arrangements. This material has a high concentration of nutrients for grass and crop growth. It is also a serious potential source of pollution, particularly to water courses and ground water. Attention must be paid to careful storage and disposal, particularly with slurry to avoid contamination of watercourses. Smith *et al*. (2002) recommend that account needs to be taken of the nutrient status of the manure, the soil type and weather conditions at and around the time of spreading. Slurry applications to land should be avoided during the months of September, October and November. There are further restrictions on application of organic manures within Nitrogen Sensitive Areas.

### *Run off from yards*

A significant source of pollution can be run-off from farm steadings, roads and tracks and uncovered manure heaps (Hatch *et al.*, 2004; Aitken *et al.*, 2004). Care needs to be taken to collect and properly dispose of dirty water from steadings and handling yards and dung heaps should be carefully sited to avoid proximity to watercourses and drains. Vinten *et al*. (2004) tried to determine the effects of fencing watercourses to exclude livestock. The results were made difficult to interpret because of uncontrolled runoff from steadings.

### *Damage to watercourses*

Cattle may use streams and rivers as their source of drinking water, even if water troughs are readily available. This can cause damage to banks and stream beds. In addition the streams will become polluted by urine and faeces. Information on this aspect of pollution control is available in *The 4 Point Plan* (http://www.sepa.org.uk/pdf/publications/4pointplan.pdf). The adverse effects of cattle on a watercourse are also described at http://www.actionforwildlife.org.uk/ProjectDisplay.asp?ID=11. This describes the problem of compaction of the gravel in a river bed on Dartmoor which meant that salmon could not dig out the hollows they need to lay their eggs. The solution for many of these problems is to fence off vulnerable river banks to deny access for cattle.

### *Silage effluent*

Silage making involves storing grass at much higher moisture contents than hay, the material being preserved by fermentation rather than drying. As mentioned above, the feeding value of silage is usually much higher than hay and the operation is at considerably less at risk from bad weather. If silage is made from grass with a high moisture content, effluent will exude from the silage. Generally, if silage has a dry matter content of less than 26–28% effluent will be an issue (Frame, 1992). Effluent from silage is a very serious pollutant, often quoted to have as much as 200 times the polluting power of domestic sewage. Although an obvious solution is to ensure that the dry matter content of the grass is high enough before the crop is stored, by wilting the grass before ensiling, this may not always be possible, especially during periods of wet weather. Thus, silage stores have to have provision for collection of any effluent which may result. Similarly, stacks of big bales of wrapped silage have to be stored well away from watercourses and species-rich grassland.

*Silage wrap*

It has become common practice on many farms to make silage in big bales wrapped with plastic film. Once the silage has been fed, the used plastic wrap is a potential pollutant. Old plastic wrap can be a hazard to wildlife and is aesthetically unattractive as it can often end up strewn over fences and hedges and flapping around trees. A survey of waste plastic on farmland in the Swale Valley in Northern England found a considerable amount of waste plastic strewn around the countryside (http://www.riverswale.org.uk/project07.html). Waste plastic should be collected and stored for proper disposal. The best method is to send it for recycling and a number of schemes are run throughout the country.

*General pollution issues*

Information on how farmers can best tackle issues of waste management and pollution control can be found in the 'The 4 Point Plan' and Prevention of Environmental Pollution from Agricultural Activity (PEPFAA )code of good practice. Widdeson *et al.* (2004) found that there are large gaps in the knowledge of farmers with respect to the relevant legislation about pollution. This suggests that while there may be potential benefits for the natural heritage from the keeping of cattle on farms, raising the awareness and increasing environmental education amongst farmers may be necessary to ensure that any potential benefits are not outweighed by negative environmental impacts. One recent initiative, described by Langan (2004), approaches these issues in a coordinated way at the level of the catchment in the Tarland Catchment Initiative in Aberdeenshire.

## 5.5 Examples of systems where cattle are used to benefit the natural heritage

Cattle are already being widely used in order to manage the natural heritage, but often only as grazers to achieve specific goals. Often they are only used for short periods of time to remove invasive plant species at certain times of the year. However there are examples of how cattle can be used as part of a whole farm system.

A good example is the management of the Pennine Dales ESA. Farmers are compensated financially for continuing to use traditional management methods. This includes continuing to manage hay meadows and maintain small fields (Younger and Smith, 1994).

On Exmoor and Dartmoor, cattle and ponies are used to manage moorland habitats (Smallshire *et al.*, 1996). The authors point out that these ecologically benign farming practices are only sustainable if the financial viability of the farms is maintained.

Bignal *et al.* (1999) discuss the ecological significance of cattle rearing in very low intensity systems and then describe in some detail examples of such systems on Islay and Mull. Highland cattle are used to graze extensive rough grazings with low inputs. The herd on Islay is fed in winter with sheaves of oats[1] which are grown on some of the farm's in-bye land. This in-bye land is also used to winter the young stock before they are transferred to a hill park of upland and coastal grazings. The cows remain on the hill all year round. On Mull, the herd is run in a similar fashion, but the young stock are sent for finishing to a farm in Perthshire. This is a good example of how environmental benefits can be achieved by co-operation between farms, even if they are a considerable distance apart.

[1] The recently introduced Tier 2 of Land Management Contracts provides payment for the harvesting of cereal crops by binder

On the Uists there is a scheme to encourage cattle production on the Islands, in response to a steady decline in cattle numbers, sometimes as high as 66% over a 10 year period. The report prepared by SAC (1997) describes the scheme and the benefits to the natural heritage of continuing to have cattle as part of the farming and crofting systems. The role of cattle in the natural heritage of the Scottish Islands is also mentioned by Badger (1999) in a report for RSPB Scotland.

## 5.6 Conclusion

Cattle can play an important and positive part in improving, enhancing and maintaining the natural heritage, but consideration has to be made of the way a cattle enterprise will fit into a whole farming system. Their effects on the natural heritage at the system level are generally positive, provided they are managed correctly and the objectives of cattle management are clear. The negative impacts usually concern issues of overgrazing and pollution, both of which can be controlled by appropriate management.

## 6 CONCLUSIONS

- Cattle are less selective in their grazing behaviour than other domestic herbivores.
- This results in different impacts on unimproved, semi-natural habitats compared to, for example, sheep. Compared to other domestic grazers, cattle result in:
  - a more structurally diverse sward;
  - a reduction in the cover of tussock forming species;
  - creation of more niches for plant regeneration.
- There is a lack of empirical objective information on the impacts of cattle grazing for many unimproved habitats.
- For the habitats for which there is empirical information, in most cases, grazing by cattle is either beneficial or at least neutral, *provided that the grazing is at an appropriate stocking density and seasonal pattern*.
- Cattle should not graze bog vegetation (blanket bog and raised lowland bog).
- There have been no scientific studies of foraging behaviour of different breeds of cattle.
- There is very little information on the effects of cattle grazing on priority species.
- As well as having a direct effect on habitats, cattle can affect the natural heritage by being part of the faming system.
- Potential negative effects of cattle farming systems include trampling and poaching, bank erosion, and pollution of water courses from farm yard manure, slurry and silage effluent. These impacts can all be minimised by adhering to good practice guidelines.
- Positive impacts of cattle farming systems include dung, where it supports high populations of invertebrates, fodder production which can result in hay meadows and small-scale cereal production.

## SUMMARIES OF PAPERS AND REPORTS COVERING THE EFFECTS OF CATTLE ON THE NATURAL HERITAGE

**Allen, S. (1999).** Cattle and the environment: A report on the impact of cattle in the crafting counties. Unpublished report to SNH.

*This collates information from the literature, supplemented by information gathered from technical experts on the impact of cattle on the environment in the crofting counties of Scotland. It covers the broad vegetation types found in the area. It concludes that, with appropriate management, cattle can provide environmental benefits to all habitats (apart from blanket bog) in the Crofting Counties, although it points out that for some habitats types, especially small scale woodlands and common grazings, there is a lack of information. Financial and social constraints are inhibiting the keeping of cattle in the Crofting Counties.*

**Andresen, H. *et al*. (1990).** Long-term changes of salt marsh communities by cattle grazing. *Vegetation*, **89**, 137–148.

*This was a nine year experimental study of the effects of reducing cattle grazing on vegetation and invertebrate assemblages. The background grazing was 2 cattle* $ha^{-1}$*, and three, unreplicated exclosures were set up with 1, 0.5 and 0 cattle* $ha^{-1}$*. As expected the vegetation increased in height with reduced grazing. However, sedimentation rates increased as well allowing invasion of upper marsh plant species. Reduced grazing also resulted in increased population densities, higher species richness and diversity of invertebrates. It also led to the invasion of upper marsh species and an indication that salt-tolerant species might be lost. The food-web also switched to one dominated by detritus feeding species rather than those feeding directly on plants. The conclusion, supported by the data, suggests that setting grazing levels at c. 0.5 cattle* $ha^{-1}$ *should be recommended for nature conservation purposes.*

**Anonymous (1995).** Biodiversity: the UK Steering Group report. *Meeting the Rio challenge and action plans. Volume 1. Introduction*. Her Majesty's Stationery Office, London.

*General description of habitats and their status categorized into Habitat Action Plans. Little or solely anecdotal information related to the role or effects of grazing but little reference specifically to cattle grazing.*

**Armstrong H. and Bullock, J. (2003).** Stock grazing of woodland part 2. *Biotype no. 25*, pp. 1–3.

*Non-peer reviewed summary of national survey of stock grazing in woodland.*

**Armstrong, H.M. *et al*. (2003).** A survey of cattle-grazed woodlands in Britain. Report of the Forestry Commission.

*This is a non-peer reviewed report of a questionnaire survey of grazing management practice applied to semi-natural woodlands. The survey revealed that most woodland in Scotland is grazed by cattle for commercial livestock production in contrast to the results from England and Wales which indicated that nature conservation was the primary objective of cattle grazing. The implications are that woodlands in Scotland are grazed at high stocking densities and will be ecologically degraded.*

**Ausden, M. *et al*. (2005).** The effects of cattle grazing on tall-herb fen vegetation and molluscs. *Biological Conservation*, **122**, 317–326.

*This was an experimental trial to see if the use of cattle grazing was capable of maintaining sites that had previously been managed by cutting but had subsequently been abandoned. Highland cattle were introduced to a small area of unmanaged tall-herb fen at Mid Yare RSPB Reserve, Norfolk with the aim of restoring and maintaining derelict fen. Grazing was light (average of 0.4 livestock units* $ha^{-1}$*) but there were problems maintaining animal condition. There was a shift in dominance from* Phragmites australis *to* Glyceria maxima, *and an increase in species richness of the vegetation. Both changes replicated that seen during cutting. However, grazing was detrimental to populations of a rare snail* Vertigo moulinsiana. *They concluded, rightly, from this work that light grazing in the summer was an appropriate management tool to increase species richness is previously derelict fen. Winter grazing was also advantageous, but was problematical as even hardy cattle such as Highlands can lose condition. However, even light grazing impacted on some invertebrate populations, though the same impact would be seen in a succession to woodland. It was recommended that very wet areas be left ungrazed to solve this issue.*

**Bacon, J.C. (1998).** Examples of current grazing management of lowland heathlands and implications for future policy. *English Nature Reports Number 271*.

*Unpublished report based on interview/survey of expert knowledge and management best practice on lowland heathlands. General recognition of role of grazing livestock in the maintenance of the conservation status of lowland heathlands, in particular the contribution of cattle and/or ponies in suppressing birch scrub and the competitive dominance of* Molinia.

**Badger, R. (1999).** Cattle and conservation in the Scottish Islands. *RSPB Scotland Report 1999*.

*This is a report of a series of seminars held by RSPB which looked into the role of cattle on the Scottish Islands. The publication mentions many of the benefits associated with grazing, particularly by cattle, but also puts the keeping of cattle in a farming systems context. For example, it includes aspects such as winter fodder, arable cropping and labour implications. The report makes much of the policy implications for cattle grazing and discusses agri-environment schemes.*

**Bakker, J.P. *et al*. (1997).** Options for restoration and management of coastal salt marshes in Europe. In: K.M. Urbanska, N.R. Webb and P. J. Edwards, eds. *Restoration Ecology and Sustainable Development*. Cambridge University Press, Cambridge. pp. 286–322.

*This is a review of the history, use and ecology of salt marshes with a focus on restoration and management. It concludes that grazing is necessary to maintain species richness, as cessation of grazing leads to the dominance of a small number of plant species, and that 'moderate' grazing levels should be maintained or introduced to manage salt marshes.*

**Beintema A.J. and Müsken G.J.D.M. (1987).** Nesting success of birds breeding in Dutch agricultural grasslands. *Journal of Applied Ecology,* **24**, 743–758.

*This peer reviewed paper explores the impact of predation and trampling of nests in agricultural grasslands in the Netherlands. Damage by trampling by domestic livestock was a simple function of stocking density and days of exposure. Of four types of grazing, dairy cattle grazing during the day only, dairy cattle grazing day and night, young cattle grazing day and night and sheep grazing day and night young cattle were the worst tramplers.*

**Bignal, E., McCracken, and Mackay A. (1999).** The economics and ecology of extensively reared Highland cattle in the Scottish LFA: An example of a self sustaining livestock system. *2nd International Conference of the LSIRD Network Livestock Production in the LFA's*, 3–5th December 1998, Bray, Ireland, Macaulay Institute, Aberdeen.

*This paper argues the case for cattle grazing on an extensive basis as being of significant benefit in terms of economics and culture as well as ecology. The authors look at whole systems of production rather than cattle simply being used as grazing tools. Two examples are given of extensive systems which are operated successfully in the Hebridean Islands of Mull and Islay.*

**Blake, S. *et al*. (1994).** Effects of habitat type and grassland management practices on the body size distribution of carabid beetles. *Pedobiologia* **38**, 502–512.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. Descriptive study provides some evidence that increased livestock stocking densities and grazing by cattle compared with sheep may select for smaller body sized ground beetles in grasslands.*

**Bokdam, J. and Gleichman, J.M. (2000).** Effects of grazing by free-ranging cattle on vegetation dynamics in a continental north-west European heathland. *Journal of Applied Ecology* **37**, 415–431.

*This is a report of work in Holland where grazing is being used to manage biodiversity in several grass-rich heathland habitats. Compared to ungrazed areas, species richness increased in grazed* Deschampsia *and* Molinia *areas. However at the stocking rates which were used, grazing did not stop the invasion of* Deschampsia *into* Calluna *habitat, although there was a significant recovery of* Calluna *in the grass heaths on podzolic and peat soils.*

**Bonte, D., Maelfait, J.P. and Hoffmann, M. (2000).** The impact of grazing on spider communities in a mesophytic calcareous dune grassland. *Journal of Coastal Conservation*, **6**,135–144.

*This was a survey of spider assemblages on a calcareous dune system in Belgium. The intensity of cattle grazing was a major determinant of the assemblage. Many of the rare species were associated with open, heavily grazed areas. However, many species had juvenile stages that required tall vegetation with a litter layer. The sensible conclusion was that management through extensive grazing that resulted in a patchy mosaic of different grassland structures was the most appropriate method to manage for spider diversity.*

**Bouchard, V. *et al*. (2003).** Sheep grazing as management tool in Western European saltmarshes. *Comptes Rendus Biologies*, 326 Supplement 1, S148–S157.

*This study combined an analysis of a natural experiment on the effects of sheep grazing on salt-marsh vegetation and an experimental study of the effects of grazing cessation. The evidence and hence their conclusions were that moderate grazing enhanced plant species richness and diversity, and that abandonment reduced the conservation value of salt marshes.*

**Brown, V.K., Gibson, C.W.D. and Sterling, P.H. (1990).** The mechanisms controlling insect diversity in calcareous grasslands. In: S.H. Hillier, D.W.H. Walton and D.A. Wells, eds. *Calcareous grasslands – ecology and management*, Bluntisham Books, Bluntisham, pp. 79–87.

*Non-peer reviewed secondary literature. Pseudo-replicated experiment (large plots without adequate replication or random allocation of treatments). Investigation of floristic and structural changes in vegetation following abandonment of cultivation and effects on invertebrates.*

**Buckingham, D.L., Peach, W.J. and Fox, D. (2002).** Factors influencing bird use in different pastoral systems. *Conservation pays? Reconciling environmental benefits with profitable grassland systems. Proceedings of the joint British Grassland Society/British Ecological Society Conference*, University of Lancaster, 15–17 April, 2002. BGS Occasional Symposium No.36, British Grassland Society, Reading, UK. pp. 55–58.

*This paper presents the results of a study into bird distribution in relation to grassland management practices. The study suggests that a switch from hay to silage could account for a decline in seed eating species, but cattle grazing appears to benefit some species. High nutrient inputs seemed to favour some species and there was no evidence that organically managed grassland cause any benefit to farmland birds. Grass field margins, such as those generated by the Countryside Stewardship Scheme were favoured by seed eaters.*

**Bunce, R.G.H. and Barr, C.J. (1988).** The extent of land under different management regimes in the uplands and the potential for change. In: M.B. Usher and Thompson, D.B.A. eds. *Ecological Change in the Uplands. Special Publication Number 7 of the British Ecological Society*. Blackwell Scientific Publications, London.

*Non-peer reviewed secondary literature. Structured ecological survey of contrasting habitats/management. No specific information on the effects of cattle grazing but results presented on the extent of different upland habitats and general anecdotal evidence of contemporary changes in management intensity.*

**Carvell, C. (2002).** Habitat use and conservation of Bumblebees (*Bombus* spp.) under different grassland management regimes. *Biological Conservation* **103**, 33–49.

*A study looking at different management regimes and their effects on the populations of bumble bees on military ranges in England. The results showed that grazing by cattle can have a positive effect on the habitat which is favoured by bumble bees and consequently on their numbers. The effect of the cattle was to maintain species richness by the removal of invasive species.*

**Cherrett, J.M. (1964).** The distribution of spiders on the Moor House National Nature Reserve, Westmorland. *Journal of Animal Ecology* **33**, 27–48.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. Results of the effects of sheep grazing rather than cattle grazing on vegetation structure and spider distribution and abundance. Demonstrated that tussock grass species can deter foraging sheep and protect the spiders in some areas from grazing disturbance, even at commercial stocking densities.*

**Cherrill, A.J. and Rushton, S.P. (1993).** The Auchenorhyncha of an unimproved moorland in northern England. *Ecological Entomology* **18**, 95–103.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. Study restricted to effects of sheep grazing on true bugs of moorland.*

**Common, T.G. *et al*. (1997).** The effects of *Molinia* utilisation on diet selection and herbage intake by cattle grazing *Molinia* grassland. *Grass and Forage Science*, **52**, 207–218.

*An experiment looking at two different utilisation rates of* Molinia *and the effects on both the cattle performance and the floristic diversity. It was found that at 33% utilisation of the* Molinia*, the proportion of* Molinia *in the swards was maintained as was adequate cattle performance. For a higher utilisation rate, there was a decline in the proportion of* Molinia *in the sward, although cattle performance remained acceptable.*

**Common, T.G., Wright, I.A. and Grant, S.A. (1998).** The effect of grazing by cattle on animal performance and floristic composition in *Nardus*-dominated swards. *Grass and Forage Science*, **53**, 260–269.

*Peer reviewed primary source literature – replicated experiment. Investigated the effects of two grazing intensiies by beef cows and their calves on* Nardus*-dominated grassland on animal performance and botanical composition. In early summer Blue Grey cows and their calves gained live weight, but from August cows lost live weight and their calves grew less well. Grazing for about eight weeks in early summer was recommended. The proportion of* Nardus *in the sward was reduced, especially at the higher grazing intensity.*

**Coulson, J.C. (1988).** The structure and importance of invertebrate communities on peatlands and moorlands, and effects of environmental changes. In: M.B. Usher and D.B.A. Thompson, eds. *Ecological change in the uplands*, Blackwell Scientific Publications, Oxford, pp. 365–380.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. Concerned only with the biomass and abundance of major invertebrate groups in moorland and acid grasslands of the uplands. Does not consider effects of cattle grazing.*

**Coulson, J.C. and Whittaker, J.B. (1978).** Ecology of moorland animals. In: O.W. Heal and D.F. Perkins, eds. *Production ecology of British moors and montane grasslands*, Springer, Berlin, pp. 52–93.

*Non-peer reviewed secondary literature. Structured ecological survey of contrasting habitats/management. Concerned only with the biomass and abundance of major invertebrate groups in moorland and acid grasslands of the uplands. Does not consider effects of cattle grazing.*

**Coulson, J.C. and Butterfield, J.E.L. (1985).** The Invertebrate Communities of Peat and Upland Grasslands in the North of England and Some Conservation Implications. *Biological Conservation*, **34**: 197–225.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. No information provided on cattle grazing of moorlands. Emphasis on the contrasts in invertebrate assemblages between acid grasslands, heather moorland and blanket bog.*

**Crofts, A. and Jefferson, R.G. (eds) (1999).** *The Lowland Grassland Management Handbook 2nd edition*. English Nature/The Wildlife Trusts.

*Published report reviewing primary and secondary literature on grassland management. Includes compendium of existing knowledge of grazing management for grasslands and provides many summary tables on appropriate stocking densities for cattle on these habitats. Relevant to information for Scottish grasslands.*

**Curry, J.P. (1994).** *Grasslands invertebrates. Ecology, influence on soil fertility and effects on plant growth*. Chapman and Hall, London, pp. 424.

*Published book reviewing primary and secondary literature on grassland invertebrates, including general interactions with grazing animals.*

**Dennis, R. (1999).** The importance of extensive livestock grazing for woodland biodiversity: traditional cattle in the Scottish Highlands. In: M.W. Pienkowski and D.G.L. Jones, eds. *Managing Farmland of high nature conservation value: policies, processes and practices*, European Forum on Nature Conservation and Pastoralism, pp. 62–66.

*Non-peer reviewed secondary literature. Anecdotal comments in discussion/essay on the role of cattle in the management of hill and woodland pastures in the highlands of Scotland. Many benefits for vegetation and birds are described for grazing cattle at low stocking densities in these habitats but there is no scientific validation of these statements. Neither is there scientific support for the recommendation to use traditional cattle breeds for these low intensity grazing systems.*

**Dennis, P. (2003).** Sensitivity of upland arthropod diversity to livestock grazing, vegetation structure and landform. *Journal of Food, Agriculture and Environment*, **1**, 301–307.

*Peer reviewed partly primary source literature, partly review. Effects of cattle mixed with sheep investigated only on* Nardus*-dominated of three acid grassland types. Full experimental design comprised treatments of livestock species x target vegetation height with an ungrazed control, replicated but with random allocation of sward height not livestock treatments to plots. Higher stocking density and cattle/sheep mix compared with sheep only reduced numbers of insect herbivores, web-spinning spiders and removed both larger beetles and those beetle species associated with a build up of plant litter. Concluded that cattle mechanically disturb spider webs because they do not avoid tussock patches as is the case for sheep. Cattle possibly compact soil and reduce its suitability by packing down crevices and air spaces that the larvae of large beetles depend upon.*

**Dennis, P. *et al*. (1997).** The response of epigeal beetles (Col.: Carabidae, Staphylinidae) to varied grazing regimes on upland *Nardus stricta* grasslands. *Journal of Applied Ecology* **34**, 433–443.

*Peer reviewed primary source literature. Effects of cattle mixed with sheep investigated on* Nardus*-dominated grassland. Full experimental design comprised treatments of livestock species x target vegetation height with an ungrazed control, replicated but with random allocation of sward height not livestock treatments to plots. About one third of variability in beetle species assemblages was ascribed solely to differences in grazing species or stocking density. Landform determined another third of the species composition, and an interaction between these two factors the remaining variability. Different species were associated with cattle/sheep, sheep and ungrazed treatments and the authors conclude that a mosaic derived from rotational and mixed grazing would support the greatest number of species.*

**Dennis, P., Young, M.R. and Gordon, I.J. (1998).** Distribution and abundance of small insects and arachnids in relation to structural heterogeneity of grazed, indigenous grasslands. *Ecological Entomology*, **22**, 253–264.

*Peer reviewed primary source literature. Effects of cattle mixed with other grazing animals investigated only on* Nardus*-dominated of three acid grassland types. Full experimental design comprised treatments of livestock species x target vegetation height with an ungrazed control, replicated but with random allocation of sward height not livestock treatments to plots. Money spiders, small beetle species and plant bugs all significantly increased in taller sward treatments, for certain species, grazed by sheep rather than cattle and sheep. A two-year ungrazed treatment yielded the highest densities for many of these arthropods.*

**Dennis, P., Young, M.R. and Bentley, C. (2001).** The effects of varied grazing management on epigeal spiders, harvestmen and pseudoscorpions of *Nardus stricta* grassland in upland Scotland. *Agriculture, Environment and Ecosystems*, **86**, 39–57.

*Peer reviewed primary source literature. Effects of cattle mixed with other grazing animals investigated only on* Nardus*-dominated of three acid grassland types. Full experimental design comprised treatments of livestock species x target vegetation height with an ungrazed control, replicated but with random allocation of sward height not livestock treatments to plots. Three types of sampling used to assess spider assemblages. Overall, densities of web spinners were higher in less grazed or ungrazed and in sheep rather than cattle and sheep for a specific sward height.*

**Dennis, P., Aspinall, R.J. and Gordon, I.J. (2002).** Spatial distribution of upland beetles in relation to landform, vegetation and grazing management. *Basic and Applied Ecology*, **3**, 183–193.

*Peer reviewed primary source literature. Effects of cattle mixed with sheep investigated on* Nardus*-dominated grassland. Full experimental design comprised treatments of livestock species x target vegetation height with an ungrazed control, replicated but with random allocation of sward height not livestock treatments to plots. Aggregations of beetle species were selected to represent the variability of all beetles sampled across the experiment indicated strong associations with particular treatments or site characteristics at greater scale than the experimental treatments. Larger, clumped distributions of* Calathus melanocephalus *on warm, insolated slopes represented species typical of fertile lowland pastures, similar large clumps of* Pterostichus adstrictus *on cooler slopes of northern aspect represented moorland species. Two species had aggregations of the same dimansions as the experimental treatments, the large beetle,* Carabus problematicus, *was clearly restricted to sheep rather than cattle and sheep treatments, whilst* Olophrum piceum *occurred solely within the ungrazed treatment characterised by the high proportion of plant litter.*

**Drake, C.M. (1995).** The effects of cattle poaching on insects living at the margin of the River Itchen, Hampshire. *British Journal of Entomology and Natural History*, **8**, 165–169.

*This paper looks at the effects of cattle poaching on the insect life of a chalk stream in England. It concludes that cattle grazing can have both positive and negative effects on invertebrate communities of streams and rivers. Positive effects are the promotion of a diverse fauna due to trampling. Negative effects are the damage done to specialised beetle fauna of stony rivers. This paper tries to address what the best management practices should be for chalk streams. It concludes that on balance the presence of cattle does more harm than good in terms of invertebrates.*

**Duffey, E. *et al*. (1974).** *Grassland Ecology and Wildlife Management*. Chapman and Hall, London.

*Published book reviewing primary and secondary literature.*

**English Nature (2001).** The Upland Management Handbook. English Nature, Peterborough.

*Published report reviewing primary and secondary literature on upland management. Includes compendium of existing knowledge of grazing management and provides many summary tables on appropriate stocking densities for cattle on different habitat types, where information is available in the literature.*

**Esselink, P. *et al*. (2000).** The effects of decreased management on plant-species distribution patterns in a salt marsh nature reserve in the Wadden Sea. *Biological Conservation*, **93**, 61–76.

*This was a survey based approach on a single salt marsh designed to link the distribution of cattle to that of vegetation as a means of designing appropriate restoration measures for ungrazed salt marsh. Cattle grazing with low to moderate stocking levels (0.47 cattle ha$^{-1}$) allowed selective grazing and induced a vegetation of enhanced botanical and structural diversity.*

**Eyre, M.E. *et al*. (1989).** Ground beetles and weevils (Carabidae and Curculionidae) as indicators of grassland management practices. *Journal of Applied Entomology*, **107**, 508–517.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. General relationships between groups of beetle species and grassland types, defined by management intensity but not with specific emphasis on the relative effects of cattle grazing.*

**Gander, A. *et al*. (2003).** Habitat use by Scottish Highland cattle in a lakeshore wetland. *Bulletin of the Geobotanical Institute ETH*, **69**, 3–16.

*This was a very small, unreplicated study of the distribution of grazing by highland cattle on a species-rich wetland community that had previously been mown. It indicates that cattle have a preference for certain vegetation* (Phalaris arundinacea > Carex *spp.* > Cladium mariscus) *and that there was a net transfer of nutrients from wetter areas to the dry areas where the cattle rested.*

**Gibson, C. *et al*. (1992a).** The response of invertebrate assemblies to grazing. *Ecography*, **15**, 166–176.

*Peer reviewed primary source literature but the study did not include cattle grazing. It is possible to infer some general effects of grazing management from this study of non-bovine livestock.*

**Gibson, C.W.D., Hambler, C. and Brown, V.K. (1992b).** Changes in spider (Araneae) assemblages in relation to succession and grazing management. *Journal of Applied Ecology* **29**, 132–142.

*Peer reviewed primary source literature but the study did not include cattle grazing. Reduced grazing increased the architecture of vegetation, and the benefits for web-forming spiders may be applicable to cattle grazing too.*

**Gimingham, C.H. (1972).** *Ecology of heathlands*. Chapman and Hall, London.

*Authoritative, published book that reviews the primary and secondary literature concerned with heather moorland. General effects of grazing inferred from non-bovine livestock.*

**Gimingham, C.H. (1995).** Heaths and moorland: an overview of ecological change. In: D.B.A. Thompson, A.J. Hester and M.B. Usher, eds. *Heaths and Moorland: Cultural Landscapes*. HMSO, Edinburgh. pp. 95–101.

*Authoritative, published book that reviews the primary and secondary literature concerned with heather moorland. No specific reference to cattle grazing in this context.*

**Grant, S.A. *et al*. (1982).** Effects of season and level of grazing on the utilisation of heather by sheep. 3. Longer-term responses and sward recovery. *Grass and Forage Science* **37**, 311–326.

*Peer reviewed primary source literature. Pseudo-replicated experiment (large plots without true random allocation of treatments). General effects of grazing inferred from non-bovine livestock.*

**Grant, S.A. *et al*. (1985).** Comparative studies of diet selection by sheep and cattle: the hill grasslands. *Journal of Ecology* **73**, 987–1004.

*Peer reviewed primary source literature investigating differences in foraging ability between sheep and cattle. Sheep were much more selective in their diet, and were better able to select preferred species than cattle, which were much more indiscriminate in their diet selection. Consequently, cattle also ingested a lot more dead material than sheep. The cattle also grazed higher up the sward than sheep.*

**Grant, S.A. *et al*. (1987).** Comparative studies of diet selection by sheep and cattle: blanket bog and heather moor. *Journal of Ecology*, **75**, 947–960.

*Peer reviewed primary source literature investigating the diet composition of sheep and cattle that grazed at different times of the year on both blanket bog and heather moorland. Cattle were less discriminating grazers and on heather moor tended to remove more shoot length and cause greater damage to heather. It was concluded that it was not appropriate to graze blanket bog with cattle due to the risk of severe poaching. Cattle may be useful in maintaining a satisfactory balance between* Calluna vulgaris *and* Molinia caerulea *on the fringes of blanket bog provided there are drier areas available.*

**Grant, S.A. *et al*. (1996a).** Controlled grazing studies on *Nardus* grassland: effects of between-tussock sward height and species of grazer on *Nardus* utilisation and floristic composition in two fields in Scotland. *Journal of Applied Ecology* **33**, 1053–1064.

*Peer reviewed primary source literature. Pseudo-replicated experiment (large plots without true random allocation of treatments). Effects of grazing by sheep, cattle and goats on* Nardus *swards investigated and it was shown that cattle or goat grazing significantly reduced* Nardus *cover compared with sheep grazing when the same intertussock sward height was maintained.*

**Grant, S.A. *et al*. (1996b).** Controlled grazing studies on *Molinia* grassland: effects of different seasonal patterns and levels of defoliation on *Molinia* growth and responses of swards to controlled grazing by cattle. *Journal of Applied Ecology* **33**, 1267–1280.

*Peer reviewed primary source literature. Pseudo-replicated experiment (large plots without true random allocation of treatments). Cattle were grazed to two levels of* Molinia *utilisation on* Molinia*-dominated grass. At a 66% utilisation rate over six years the cover of* Molinia *in the sward was reduced by 86%.*

**Grayson, F.W. (1999).** The use of native livestock breeds in restoring grazing to limestone grasslands abandoned by agriculture. In: M.W. Pienkowski and D.G.L. Jones, eds. *Managing farmland of high nature conservation value: policies, processes and practices*. European Forum on Nature Conservation and Pastoralism. pp. 62–66.

*This paper relates the story of the restoration of grazing on the limestone hills around Morcambe Bay in England. The area was abandoned as a grazing resource many years ago and became dominated by a mix of very coarse grassland and scrub. These was concern that the proportion of grassland was in serious* *decline because of encroachment by scrubland. Within the area, there were a number of nature reserves, managed by various agencies. Restoration of grazing was implemented, in partnership with local farmers who could bring the required stock management skills which the site managers lacked. The reintroduction of grazing by cattle was made financially viable because of the Countryside Stewardship Scheme. Native breeds of cattle were used and meat from these animals has been marketed as a niche product directly to the public which has been to the financial benefit of the system.*

**Hatch, D.J. *et al*. (2004).** Ammonium-N losses from Agriculture. Agriculture and the Environment, Water Framework Directive in Agriculture. *Proceedings of SEPA/SAC biennial conference, Edinburgh 24–25 March 2004.*

*Some of the environmental hazards associated with keeping cattle are highlighted in this report. Pollution of watercourses by ammonium N are related to spreading of slurry and manures, runoff from tracks used by cattle and from farmsteads and direct access by cattle to streams and watercourse. Many of these problems are more likely to be associated with high intensity agriculture, but their potential effects need to be borne in mind when considering livestock systems.*

**Hester, A.J. (1996).** Overgrazing in Upland Habitats: A literature review. Report for the Countryside Council for Wales.

*Unpublished report reviewing primary and secondary literature with relevance to grazing practices in the Welsh uplands. General effects of grazing inferred mainly from studies of non-bovine livestock.*

**Hodgson, J. *et al*. (1991).** Comparative studies of the ingestive behaviour and herbage intake of sheep and cattle grazing indiginous hill plant communities. *Journal of Applied Ecology*, **28**, 205–227.

*This peer reviewed study investigated the ingestive behaviour and herbage intake of dry cattle and sheep grazing six different habitats, viz. sown grassland,* Agrotistis/Festuca *grassland,* Nardus*-dominated grassland,* Molinia*-dominated grassland and two dwarf shrub communities,* Calluna vulgaris–Eriophrum vaginatum *blanket bog and* Calluna vulgaris *moor. The results suggested that cattle were less selective in their diet than sheep and therefore were able to remove proportionately greater amounts of poorer quality vegetation. It was also suggested that sheep were less able to adapt to tall swards than cattle. Sheep grazed to a greater depth than cattle and were more selective in the diet they ingested.*

**Howard, C.L. and Wright, I.A. (1994).** Effects of mixed grazing by cattle and sheep on *Nardus stricta* dominated grassland. In: R.J. Haggar and S. Peel eds. *Grassland Management and Conservation, Occasional Symposium No. 28, British Grassland Society*. pp. 292–294.

*Summary of an experiment in which sheep only or mixed cattle plus sheep grazed on* Nardus*-dominated grassland. The liveweight gains of the sheep when they grazed along with cattle were higher than when they grazed as the sole species.*

**Hulme, P.D. *et al*. (1999).** The effects of controlled sheep grazing on the dynamics of upland *Agrostis–Festuca* grassland. *Journal of Applied Ecology*, **36**, 886–900.

*Peer reviewed primary source literature. Experimental design (treatments of habitat x sheep stocking density or target vegetation structure, appropriate control, replicated with random allocation of treatments to plots). General effects of grazing inferred from an experimental study of sheep grazing at three sward heights on* Agrostis–Festuca *grassland.*

**Humphrey, J.W. and Patterson, G.S. (2000).** Effects of late summer cattle grazing on the diversity of riparian pasture vegetaion in an upland conifer forest. *Journal of Applied Ecology*, **36**, 986–996.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. Investigated the contribution of cattle to plant species diversity of flush vegetation, acid grassland and rush pasture in upland forests of Northern Scotland. Cattle were successful in preventing a further decline in species richness on all three habitats in which previous fencing and tree planting had led to rank vegetation dominated by competitive plant species. Anecdotal conclusion that should cattle be used to management vegetation fenced in by forestry, such areas must be large enough to allow free-ranging and the development of a mosaic, and also to avoid localized detrimental effects.*

**Kirby, P. (1992).** *Habitat management for invertebrates: a practical handbook.* RSPB/Joint Nature Conservation Committee, Sandy, Bedfordfordshire.

*Published report reviewing primary and secondary literature. Anecdotal comments in discussion suggested that cattle as opposed to sheep grazing in woodland, grassland, lowland heaths, freshwater wetlands and coastlands create better habitat for invertebrates.*

**Kirkham, F.W. *et al*. (2003).** Review of stocking levels recommended for semi natural lowland grasslands. Report commissioned by CCW, English Nature, SNH and EHS (Northern Ireland).

*This work reviews stocking rates on a number of semi natural lowland grassland sites throughout the UK. The habitats included are: coastal and floodplain grazing marsh; lowland calcareous grassland; lowland dry acid grassland; lowland meadow (grazed only); purple moor grass and rush pastures; and species rich semi- improved grassland. Models were developed to study the relationship between sward heights and stocking levels. The report contains recommendations for stocking rates for each of the different habitats. Some cautions needs to be exercised however: the models assumed that the stocking rates were achieving the goals set for each of the sites and also sward height data was only available for a few of the sites.*

**Kooijman A.M. and Van der Meulen F.** Grazing as a control against "Grass encroachment" in dry dune grasslands in the Netherlands. 1996. *Landscape and Urban Planning*, **34**, 323–333.

*This paper reports on cattle and pony grazing on dune habitats in Holland. Ponies and cattle were used to attempt to control invasive tall grasses from encroaching onto open species in rich dune land. The conclusion was that grazing was a useful tool, but more information is needed on the mechanisms involved.*

**Kruess, A. and Tscharntke, T. (2002).** Contrasting responses of plant and insect diversity to variation in grazing intensity. *Biological Conservation*, **106**, 293–302.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. General effects of grazing inferred from comparisons of areas under different intensities of general livestock grazing.*

**Loucougaray, G., Bonis, A. and Bouzille, J.B. (2004).** Effects of grazing by horses and/or cattle on the diversity of coastal grasslands in western France. *Biological conservation*, **116**, 59–71.

*This report concerns the use of mixed grazing with cattle and horses on coastal grasslands in western France. It was found that the greatest species richness was achieved by grazing with both cattle and horses together rather than separately.*

**Luff, M.L. and Rushton, S.P. (1989).** The ground beetle and spider fauna of managed and unimproved upland pasture. Agriculture, *Ecosystems and Environment*, **25**, 195–205.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. General information on beetle and spider responses to grassland management intensity inferred from survey of sites mainly grazed by sheep.*

**Luff, M.L., Eyre, M.D. and Rushton, S.P. (1989).** Classification and ordination of habitats of ground beetles (Coleoptera: Carabidae) in north-east England. *Journal of Biogeography*, **16**, 121–130.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management with no specific detail on grazing management.*

**Luoto, M., Pykala, J. and Kuussaari, M. (2003).** Decline of landscape-scale habitat and species diversity after the end of cattle grazing. *Journal for Nature Conservation*, **11**, 171–178.

*This article examines the decline in species and habitat diversity at the landscape scale in SW Finland. One of the conclusions is that the cessation of cattle grazing was a significant cause. There was however no noticeable decline in the diversity of the bird populations.*

**MacDonald, A.J. (1993).** *Heather damage: A guide to types of damage and their causes. Research and Nature Conservation No. 28, 2nd edition*. Joint Nature Conservation Committee, Peterborough.

*Published report combining a review of primary and secondary literature and anecdotal information based on structured ecological survey of heather moorland under contrasting management. Highlighted deleterious effect of overgrazing, especially of cattle, on heather cover and vigour.*

**Macdonald, A.J. *et al*. (1995).** Regeneration by natural layering of heather (*Calluna vulgaris*): frequency and characteristics in upland Britain. *Journal of Applied Ecology*, **32**, 85–99.

*Peer reviewed primary source literature. Structured ecological survey of heather growth and condition. General information on heather moorland habitat but lacking a grazing context.*

**Matejkova, I., Diggelen, R. and van Prach, K. (2003).** An attempt to restore a central European species-rich mountain grassland through grazing. *Applied Vegetation Science*, **6**, 161–168.

*Non-peer reviewed secondary literature. Structured ecological survey of contrasting habitats/management. Study of foraging by Highland cattle grazing for eight years on a previously abandoned semi-natural mountain pasture in the Czech Republic. The cattle spent most of their time on species poor* Deschampsia *swards, moved to species rich* Violion *swards in mid-season and* Carex *spp. swards in late season. Species poor* Nardus *swards were only used as rest areas. Neither grazing nor exclusion encouraged increased species richness of* Deschampsia *grassland and this was in part due to the poor seed dispersal of species of nature conservation value.*

**Mayle, B. (1999).** Domestic stock grazing to enhance woodland biodiversity. Forestry Commission Information Note 28 (September 1999).

*This is a guide to the use of different grazing animals within semi natural woodlands. It gives information on the grazing and foraging characteristics of each species of domestic livestock and their preferences for different plant species. Also discussed are the effects of trampling on different habitats. Recommendations are made for the grazing management of different types of woodland. There is a good list of references.*

**McGechan, M. (2002).** Modelling phosphorous leaching to watercourses from extended autumn grazing by cattle. *Grass and Forage Science*, **58**, 151–159.

*This peer revived paper draws on modelling work investigating the flows of phosphorous from animal waste through soils to field drains. The results suggest that extending grazing into late autumn presents substantial risk of pollution if the soil is at or near to field capacity. This is supported by experimental results. The model also suggests that pollution is unlikely under dry conditions, so pollution would be unlikely to ocurr via this route if cattle are housed before the soil becomes sufficiently wet.*

**Miles, J. (1988).** Vegetation and soil in the uplands. In: M.B. Usher and D.J.A. Thompson, eds. *Ecological change in the uplands*. Blackwell Scientific Publications, Oxford. pp. 57–70.

*Published book/report reviewing primary and secondary literature. General effects of grazing can be inferred from information on general livestock grazing.*

**Milne, J.A. *et al*. (1998).** The impact of vertebrate herbivores on the natural heritage of the Scottish Uplands – a review. *Scottish Natural Heritage Review No 95*.

*This comprehensive review considers the impacts of a range of wild and domestic vertebrate herbivores on vegetation, soils, invertebrates and vertebrates. It covers theoretical aspects of grazing and foraging behaviour as well as reviewing empirical studies on the effects of herbivores. It covers all the main upland vegetation types. It considers the effects of grazing pressure and seasonality of grazing rather than detailed differences among herbivore species. It identifies areas for further research.*

**Morris, M.G. (1971).** Differences between the invertebrate faunas of grazed and ungrazed chalk grasslands. IV Abundance and diversity of Homoptera: Auchenorhyncha. *Journal of Applied Ecology*, **8**, 37–52.

*Peer reviewed primary source literature. Experimental design (treatments of habitat x sheep stocking density or target vegetation structure, appropriate control, replicated with random allocation of treatments to plots). General effects of grazing can be inferred from studies primarily of sheep grazing.*

**Morris, M.G. (1990).** The effects of management on the invertebrate community of calcareous grassland. In: S.H. Hillier, D.W.H. Walton and D.A. Wells, eds. Calcareous grasslands – ecology and management. Bluntisham Books, Bluntisham. pp. 128–133.

*Non-peer reviewed secondary literature. Experimental design (treatments of habitat x sheep stocking density or target vegetation structure, appropriate control, replicated with random allocation of treatments to plots). General effects of grazing can be inferred from studies primarily of sheep grazing.*

**Morris, M.G. (1991).** The management of reserves and protected areas. In: F.F. Spellerberg, F.B. Goldsmith, M.G. Morris, eds. *The scientific management of temperate communities for conservation*. Blackwell Scientific Publications, Oxford, pp. 323–347.

*Published book/report reviewing primary and secondary literature. General effects of grazing can be inferred from studies primarily of sheep grazing.*

**Mountford, E.P., Page, P.A. and Peterken, G.F. (2000).** *Twenty-five years of change in a population of oak saplings in Wistman's Wood*, Devon. English Nature Research Reports. English Nature, Peterborough, UK.

*Report reviewing primary and secondary literature. Survey of expert knowledge and management best practice. Report on the 25 year history of an Wistman's Wood oak woodland on Dartmoor, Devon. Cattle had grazed the wood at an unrecorded stocking density for many years and had been detrimental to plant diversity. The grazing damaged the moss cover on boulders, caused an increase in competetively dominant species and prevented regeneration of oak saplings.*

**Norris, K. *et al*. (1998).** Is the density of redshank *Tringa totanus* nesting on saltmarshes in Great Britain declining due to changes in grazing management? *Journal of Applied Ecology*, **35**, 621–634.

*This research was based around a survey of 77 salt marsh sites around Great Britain. From the survey, statistical models were constructed of the factors controlling redshank breeding density. The conclusions from this large dataset was that densities were lowest on heavily grazed plots and highest on lightly grazed ones, though grazing was assessed only as a categorical variable (0, 1, 2, 3). There were habitat preferences for* Juncus geradii *and* Elymus pycnanthus, *which increase at low grazing levels. The evidence of this model was backed by analysis of breeding density change over an 11 year period. Sites which had seen an increase in grazing had seen the most marked decrease in breeding density.*

**Olff, H. *et al*. (1997).** Vegetation succession and herbivory in a salty marsh: changes induced by sea level rise and silt deposition along an elevational gradient. *Journal of Ecology*, **85**, 799–815.

*This was a study of the long-term changes (200 year) in salt marsh vegetation that occur as a result of sedimentation. Cattle grazing reduces the dominance of* Elymus athericus *and maintains early successional species. These in turn have a higher nutritional value and in turn attracted Brent geese. Their grazing, in turn, shifted the vegetation to one associated with lower down the salt marsh.*

**Olsen, H. and Schmidt, N.M. (2004).** Impacts of wet grassland management and winter severity on wader breeding numbers in eastern Denmark. *Basic and Applied Ecology*, **5**, 203–210.

*This paper examines the effects of grazing and winter flooding on wading bird populations in Eastern Denmark. The effects of cattle grazing vary depending on the species of birds concerned. Some birds thrived under grazed conditions, eg Lapwing and Avocet, due to an increase in the number of nesting sites and/or improved predator detection. On the other hand Oystercatcher numbers declined under cattle grazing due to poorer food supply and increased risk of predation.*

**Putnam, R.J., Fowler, A.D. and Tout, S. (1991).** Patterns of use of ancient grassland by cattle and horses and effects on vegetational composition and structure. *Biological Conservation*, **56**, 329–347.

*This paper describes the bahaviour of horses and cattle when they graze two ancient grasslands. Both species had distinct latrine and feeding areas, which led to differences in plant species composition.*

**Pykala, J. (2003).** Effects of restoration with cattle grazing on plant species composition and richness of semi-natutral grasslands. *Biodiversity and Conservation*, **12**, 2211–2226.

*This paper reports on work in Southern Finland where cattle were used to restore the floristic diversity of areas of mesic grassland which had been previously abandoned.The results showed that improvements in floristic diversity were observed in all the sites studied. However some doubt was expressed about the management regimes which were imposed as part of the agri-environment schemes. It is suggested that management should be defined more precisely.*

**Ratcliffe, D.A., (1977) Ed.** *A Nature Conservation Review*. Cambridge University Press, Cambridge.

*Published book reviewing primary and secondary literature. General information on upland habitat status but lacking detail on grazing management, especially by cattle.*

**Rodwell, J.S. (1992a) ed.** *British Plant Communities. Volume 2. Mires and Heaths*. Cambridge University Press, Cambridge.

*Published book reviewing primary and secondary literature. General descriptions of upland habitat classification with anecdotal information on the contribution of grazing to the extent and condition of habitats but lacking detail on the grazing management, especially by cattle.*

**Rodwell, J.S. (1992b) ed.** *British Plant Communities. Volume 3. Grasslands and montane communities*. Cambridge University Press, Cambridge.

*Published book reviewing primary and secondary literature. General descriptions of upland habitat classification with anecdotal information on the contribution of grazing to the extent and condition of habitats but lacking detail on the grazing management, especially by cattle.*

**Rosen, E. and van der Maarel, E. (2000).** Restoration of alvar vegetation on Oland, Sweden. *Applied Vegetation Science*, **3**, 65–72.

*Alvar grassland vegetation in Sweden is under threat from scrub vegetation due to the decline of grazing. This paper looks at a number of restorative measures, including the re-introduction of grazing. The results suggest that the intensity of grazing is crucial to avoid overgrazing. Overgrazing was found to reduce species richness compared to abandonment of grazing. Sheep grazing caused damage to some species which were selectively grazed and cattle grazing cause trampling damage to some other sensitive species, especially in dry and frosty conditions.*

**Rook, A.J. *et al*. (2004).** Matching type of livestock to desired biodiversity outcomes in pastures – a review. *Biological Conservation*, **119**, 137–150.

*This review paper examines the effects of grazing animals on the biodiversity of pastures. One of the main conclusions is that the mechanism by which grazers effect pastures is by altering the structure of the sward. The authors also conclude that there is a need to investigate why different animals behave as they do. There is a suggestion that there are breed differences, for example, but it is not known how much of their foraging behaviour is genetic and how much is learned.*

**Rushton, S.P., Luff, M.L. and Eyre, M.D. (1989).** Effects of pasture improvement and management on the ground beetle and spider communities of upland grasslands. *Journal of Applied Ecology*, **26**, 489–503.

*Peer reviewed primary source literature. Structured ecological survey of contrasting management on grassland. General information on beetle and spider responses to grassland management intensity inferred from survey of sites mainly grazed by sheep.*

**Rushton, S.P., Luff, M.L. and Eyre, M.D. (1991).** Habitat characteristics of grassland *Pterostichus* species (Coleoptera: Carabidae). *Ecological Entomology*, **16**, 91–104.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. General effects of grazing on beetle species could be inferred from non-bovine livestock grazing.*

**SAC (1997).** *Uist Cattle Scheme. Report prepared for SNH.*

*This unpublished report considers cattle keeping on Uist. Listed are the advantages of cattle towards the environment. These are, trampling, dunging, grazing, the need to make winter fodder and cropping to provide animal feed. The report then goes on to give details of the Uist cattle scheme.*

**Sanderson, R.A. *et al*. (1995).** Soil, vegetation and space: an analysis of their effects on the invertebrate communities of a moorland in north-east England. *Journal of Applied Ecology*, **32**, 506–518.

*Peer reviewed primary source literature. Pseudo-replicated experiment (large plots without adequate replication or random allocation of treatments). Emphasis on soil and vegetation structure resulting from sheep grazing.*

**Scottish Natural Heritage (1998).** *Machair. Scotland's living landscape series*. Scottish Natural Heritage.

*An SNH booklet explaining what machair is, how it is formed, its place in the natural environment and its relationship with man. The machair grasslands are rich and fertile and support many important and diverse species. The importance of cattle, especially being outwintered is highlighted, as their dung adds organic matter to the soil and helps to stabilise it. Also farming systems involve collecting seaweed from the beaches to spread as manure on the soil. This allows the cultivation of crops which feed the livestock. This cultivation is important in itself in that it encourages wild flowers to develop. Without cattle, there would be little need to cultivate. Soils tend to be low in some trace elements, so if cattle are to be kept exclusively on machair, mineral supplements will be required. Cattle are seen as an important part of the machair system, providing good habitats for a number of species and creating a range of grassland structures.*

**Siemann, E., Tilman, D. and Haarstad, J. (1999).** Abundance, diversity and body size: patterns from a grassland arthropod community. *Journal of Animal Ecology*, **68**, 824–835.

*Peer reviewed primary source literature. Structured ecological survey of contrasting habitats/management. General information on arthropods of habitats associated with grazing but with no specific information on cattle grazing.*

**Smith, R.S. and Rushton, S.P. (1994).** The effects of grazing management on the vegetation of mesotropic (meadow) grassland in Northern England. *Journal of Applied Ecology*, **31**, 13–24.

*This paper reports an experiment to examine the management of a haymeadow in the Yorkshire dales. The experiment examined the species composition of a hay meadow which was subject to four different grazing/cutting regimes. These were:*

*(i) no grazing;*

*(ii) no grazing after hay was cut until January 1st;*

*(iii) no grazing from January 1st until hay cutting; and*

*(iv) control plots with a normal grazing regime.*

*Both cattle and sheep were used as the grazers. All the ungrazed treatment showed a decline in species richness.*

**Spedding, C.R.W. (1971).** *Grassland ecology*. Oxford University Press, Oxford.

*Published book reviewing primary and secondary literature. General information on habitats lacking detailed information on grazing.*

**Stammel, B., Kiehl, K., Pfadenhauer, J. (2003).** Alternative management on fens: response of vegetation to grazing and mowing. *Applied Vegetation Science*, **6**, 245–254.

*This paper discusses work carried out in Germany comparing mowing and grazing with cattle on fen habitats. The results suggest that grazing significantly reduced species richness compared to mowing. The authors suggest that grazing is preferable to abandonment, but is not as effective as mowing.*

**Strong, D.R., Lawton, J.H. and Southwood, T.R.E. (1984).** Insects on plants. Community patterns and mechanisms. Blackwell Scientific Publications, Oxford.

*Published book reviewing primary and secondary literature. General information on insect-plant interactions, some relevant to grazed habitats lacking detailed information on interactions with grazing.*

**Sutherland, W.J. and Hill, D.A. (1995).** Managing habitats for conservation. Cambridge University Press, Cambridge, 399 pp.

*Published book reviewing primary and secondary literature. General information on habitat management for conservation and providing some anecdotal information on grazing, including cattle grazing effects on habitat structure.*

**Tallowin, J.R.B., Rook, A.J. and Rutter, S.M. (2005).** Impact of grazing management on botanical diversity of grasslands. *Proceedings of the British Society of Animal Science, 2005*, pp. 244.

*This abstract reports brief information on a five-year experiment in which neutral grassland was grazed by cattle. After five years of grazing by cattle at different grazing pressures there was no difference in botanical diversity, but differences in vegetation structure emerged. The cover of Poaceae increased under more lenient grazing pressures, but the abundance of Fabaceae increased under higher grazing pressures. Abundance of Heretoptera, bumble bees and spiders all increased under lower grazing pressures.*

**Tansley, A.G. (1939).** *The British Islands and their vegetation*. Cambridge University Press, Cambridge.

*Seminal published book reviewing primary and secondary literature related to the major vegetation types of the uplands, with anecdotal information on the role of grazing.*

**Thomas, J.A. (1990).** The conservation of Adonis blue and Lulworth skipper butterflies – two sides of the same coin. In: S.H. Hillier, D.W.H. Walter and D.A. Wells, eds. *Calcareous Grasslands: Ecology and Management*. Bluntisham Books, Huntingdon. pp. 112–117.

*Published book reviewing primary and secondary literature and providing a review of grazing effects on butterfly populations in grasslands. Structured ecological survey of contrasting management. Highlighted importance of general grazing for maintaining thermal ecological conditions of host plants to allow successful growth and development of caterpillars.*

**Thompson, D.B.A. and Miles, J. (1995).** Heaths and moorland: some conclusions and questions about environmental change. In: D.B.A. Thompson, A.J. Hester and M.B. Usher, eds. *Heaths and Moorland: Cultural Landscapes*. SNH/HMSO, Edinburgh. pp. 362–385.

*Published book chapter reviewing other chapters of book and primary and secondary literature. Moorland grazing by domestic and wild herbivores highlighted as a concern but no specific details are described.*

**Tolhurst, S. (1997).** Investigation into the use of domestic herbivores for fen grazing managment – A document for discussion. Report for the Broads Authority, English Nature and the Norfolk Wildlife Trust.

*This report is a review of grazing on wetland habitats. The report concludes that cattee and ponies are the best species for grazing fen type habitats because they produce good structural diversity, don't eat flower heads of species such as orchids, create poached areas, browse on scrub and can cope with wet conditions, flooding and biting insects. The report also includes details on the age structure of herds which best suit conservation grazing and the usefulness of different breeds, although the basis on which these conclusions are reached is not clear. The advantages and disadvantages of cattle, sheep and horses are discussed in relation to the grazing of wetlands.*

**Tolhurst, S. and Oates, M. (2001).** *The Breed Profiles Handbook*. English Nature.

*This handbook is a manual to assist managers in the selection of livestock for grazing of vegetation to achieve environmental objectives. It has been produced as part of the Grazing Animals Project (GAP). It describes the characteristics of a range of cattle breeds, including grazing characteristics. It is not clear how many of these descriptions were derived, nor to what extent comments made about particular breeds are unique to that breed.*

**Tscharntke, T. and Greiler, H.-J. (1995).** Insect communities, grasses and grasslands. *Annual Review of Entomology*, **40**, 535–558.

*Peer reviewed literature review dealing with grazing effects on insects. Little grazing information provided that is specifically related to cattle grazing. Instead, the emphasis is on the effects of structural and floristic diversity that results from grazing on insect abundance and distribution.*

**UK BAP website** – http://www.ukbiodiversity.org.uk/

*Lists of action plans for priority habitats given, many of which include descriptions of over-grazing but without providing detailed information on the species of grazers or appropriate stocking densities for each type of habitat.*

**Usher, M.B. and Gardner, S.M. (1988).** Animal communities in the uplands: how is naturalness influenced by management? In: M.B. Usher and D.B.A. Thompson, eds. *Ecological change in the uplands*. Blackwell Scientific Publications, Oxford. pp. 75–92.

*Published book chapter reviewing primary and secondary literature concerned mainly with invertebrate populations as affected by habitat and management in the uplands. No specific information on cattle grazing.*

**Van Wieren, S.E. (1991).** The management of populations of large mammals. In: F.F. Spellerberg, F.B. Goldsmith and M.G. Morris, eds. *The scientific management of temperate communities for conservation*. Blackwell, Oxford. pp. 103–128.

*Published book chapter reviewing primary and secondary literature concerned mainly with bird populations as affected by habitat and management in wetlands of the Netherlands. Effects of cattle mixed with horses described for case study at Slikken van Flakkee where the area was divided and one half grazed, the other ungrazed, where grazing increased the numbers of breeding pairs of birds, although effects on numbers of species was less pronounced.*

**Vinten, A.J.A. *et al*. (2004).** Evaluating the impact of buffer strips and rural BMP's on water quality and terrestrial biodiversity. In: *Agriculture and the Environment, Water Framework Directive in Agriculture. Proceedings of SEPA/SAC biennial conference, Edinburgh 24–25 March 2004.*

*This paper evaluates the effects on water quality of buffer strips next to a stream in an arable area, and fencing of a stream in a livestock area. Cattle were excluded, by fencing, from a stream in Ayrshire and comparisons made of the level of pollutants within the watercourse upstream and downstream of the fenced area. Two factors make it difficult to draw meaningful conclusions from the work. Firstly, the measurements were made just after the cattle were housed for the winter, making it unlikely that differences would be detected and secondly, the fenced area suffered a greater increase in pollution load after a storm which was traced to uncontrolled runoff from farm steadings.*

**Waloff, N. (1980).** Studies on grassland leafhoppers (Auchenorrhyncha: Homoptera) and their natural enemies. *Advances in Ecological Research*, **11**, 82–215.

*Peer reviewed primary source literature. Increases of plant bugs to increased height of vegetation described for lowland acidic grasslands, but in relation to rabbit rather than cattle grazing.*

**Warren, J., Christal, A. and Wilson, F. (2002).** Effects of sowing and management on vegetation succession during grassland habitat restoration. *Agriculture, Ecosystems and Environment*, **93**, 393–402.

*This experimental study investigated restoration of a semi-natural grassland by sowing a seed mixture of desirable species. The plots were then managed in different ways: cutting regimes and grazing with either cattle or sheep. Measurements were taken to examine the persistency of the species which had been sown. The results suggest that only the cattle-grazed plots experienced no decline in the number of sown species present, while the plots grazed by sheep became species poor. The authors suggested that the reason for the decline in species richness in the non-cattle-grazed plots was due to either competitive exclusion or selective grazing by sheep.*

**Whittaker, J.B. and Tribe, N.P. (1998).** Predicting numbers of an insect (*Neophilaenus lineatus*, Homoptera) in a changing climate. *Journal of Animal Ecology*, **67**, 987–991.

*Peer reviewed primary source literature. Structured ecological survey of plant bug responses to altitudinal gradients on upland habitats.*

**Wildig, J. (2000).** Mynydd y Ffynnon-towards and new integrated vision for the uplands. *Aspects of Applied Biology*, **58**, 158–166.

*This paper is a report on an integrated environmental initiative undertaken in the Cambrian Mountain ESA scheme in Wales. The scheme aims to restore dwarf shrub heath communities in the uplands which have declined because of more intensive agriculture, particularly sheep grazing. The result is that* Calluna *has been replaced in much of the uplands by grassy species such as* Nardus *and* Agrostis *and areas of* Molinia*. One of the aims of the project was to enhance the ecological value of areas which have become dominated by* Molinia *by the introduction of controlled grazing by Welsh Black Cattle. A grazing trial was initiated on 24ha of* Molinia*-dominated grassland which was successful after three years in creating structural diversity. One of the motivations for this work, was to find a way of controlling the rank vegetation which has resulted from cessation of grazing which has been advocated as part of ESA schemes.*

**Wright, I.A., Dalziel, A.I.J. and Ellis, R.P. (2002).** *The status of traditional scottish animal breeds and plant varieties and the implications for biodiversity.* Report for Scottish Executive Environment and Rural Affairs Department, Agriculture and Biological Research Group.

*This published review examined the status of traditional animal breeds and crop varieties in Scotland and their role in biodiversity. The review covers the benefits of grazing animals in maintaining biodiversity and the role of traditional crops in farming systems. It makes recommendations for further research and indicates how traditional breeds, crops and farming systems could be promoted.*

**Wright, I.A., Davies, D.A. and Vale, J.E. (2000).** In: A.J. Rook and P.D. Penning, eds. Grazing of permanent pasture and *Molinia*-dominated pasture by different genotypes of cattle. In: *Grazing Management, Occasional Symposium No 34*, British Grassland Society, Reading, UK, pp. 167–168.

*A report of an experiment looking at the productive performance of two breeds of cattle grazing a* Molinia-*dominated pasture in south Wales. Welsh Black steers, a traditional breed, performed better when grazing such pastures than Charolias-cross animals, while there was little difference when the breeds grazed permanent pasture. This provides some evidence that there may be breed differences in the ability to utilise low quality pastures.*

**Wright, I.A. and Whyte, T.K. (1989).** Effect of sward surface height on the performance of continuously stocked spring-calving cows and their calves. *Grass and Forage Science*, **44**, 423–432.

*A peer reviewed experimental study which demonstrated that on sown pastures the optimal performance of beef cows and their calves was achieved when they grazed a sward height of 8–10cm.*

**Zahn, A. and Hirschberger, P. (2001).** Dung beetles in cattle pastures in Upper Bavaria. [In German]: 219–224.

*The study compared dung beetle populations at two sites where cattle were grazed. One of the sites has been grazed since 1995, while on the other, grazing has only started more recently. In general the population densities of dung beetles was greater on the site where grazing had been taking place for longer.*

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