Evaluation of the grazing management strategy proposed for Epping Forest

Dr Peter Dennis

The Queen's Anniversary Prizes 2008
EXCELLENCE WITH IMPACT
GREATEST CULTURE CHANGE
WINNER

Institute of Biological, Environmental and Rural Sciences,
Cledwyn Building, Penglais Campus,
Aberystwyth University, Ceredigion, SY23 3DD

Table of Contents

Evaluation of the grazing management strategy proposed for Epping Forest

Summary

- Grazing herbivores generally enhance the habitat structure and species diversity of semi-natural habitats, given suitable stocking densities and periods of grazing.
- Cattle are less selective than other herbivores and this quality is ideal for the management of abundant, competitive but less nutritious plant species in semi-natural habitats which would otherwise exclude rarer plant species.
- The proposed, phased expansion of cattle grazing to achieve conservation and landscape objectives across Epping Forest is supported by the evidence presented in the scientific literature of grazing ecology.
- Appropriate stocking densities and periods of grazing must be maintained for the effective management of the distinct mosaic of habitats at Chingford-Honey Lane Plain, Fernhill and Trueloves, Long Running and Woodbury Hollow, Sheppards Meadows, Wanstead Flats and Wanstead Park.
- The Grazing Strategy acknowledges the need to continuously alter stocking densities in response to limits of vegetation change and variations in weather and vegetation growth by season and year. The proposal includes practical measures of a livestock herdsperson, fencing (including a novel 'invisible' fence system) and sacrificial grazing areas to hold livestock in order to achieve appropriate grazing management for habitat and species conservation and landscape objectives.
- Baseline vegetation monitoring is already in place and the distribution and abundance of distinct plant species (e.g., Spiny rest-harrow, Pepper saxifrage, and Lousewort) can be evaluated, essential for decision making on adjustments to the indicative stocking rates and periods in the proposed put and take system of cattle grazing stated in the Grazing Strategy.
- The combination of fixed point photography, fixed quadrats for plant survey and field and GIS mapping of the distribution of plant species of conservation interest (e.g., Lousewort on Almhouse Plain) contributes to a suitable and effective monitoring programme, essential for any conservation management plan.
- Additional monitoring protocols for invertebrates (e.g., butterflies, ground beetles and ant colonies) and birds provide important additional information since changes in plant species often do not indicate the response of other taxa to grazing management.
- The combination of current and proposed monitoring methods is suitable for achieving the establishment of a Long Term Ecological Research site at Epping Forest under the UK Environmental Change Biodiversity Network.
- The scientific evidence related to grazing ecology supports the proposals set out in the Grazing Strategy and the phased nature of the plan over 20-30 years allows the modification of such general principles to local conditions, so that conservation objectives can be achieved through a precautionary, adaptive management approach.

1. Introduction

This report presents information to advise the Epping Forest and Commons Committee and Grand Committee on the suitability of the Epping Forest Grazing Rationale and Strategy, June 2006.

Epping Forest has an important multiple objective role including nature conservation, especially within nationally designated sites for nature conservation (Site of Metropolitan Importance for Nature Conservation (SMIC), Site of Special Scientific Interest (SSSI) and EC Natura 2000 Special Area for Conservation (SAC)). The Forest comprises 2500 ha plus an additional 750 ha of buffer land. The Forest is composed of woodland with a stock of 50 000 veteran trees; 300 ha of ancient oak, hornbeam and beech woodland; extensive wood pasture (1400 ha) with ancient or restored pollards; 80 ha scrub; 46 ha heathland; and 125 ha of open grasslands (mainly lowland calcifuge grassland). Designations: Site of Metropolitan Importance for Nature Conservation (SMIC), SSSI and SAC.

The purpose of this report is to present a review of the current knowledge base on the role of grazing in general and cattle grazing in particular as a management tool in habitat and species conservation. More specifically, to comment upon proposals set out in the Grazing Rationale and Strategy (June 2006) for a proposed expansion of cattle grazing where it is perceived to be an appropriate management 'tool' to meet general and specific nature conservation amongst other, broader objectives for Epping Forest and to scrutinise whether the design of the associated plant and invertebrate monitoring programme is appropriate to detect changes in abundance and distribution of populations so that progress towards the conservation objectives can be assessed at regular intervals.

a. Specific objectives

1. Review of the scientific evidence for the effectiveness of conservation grazing programmes.
2. Evaluate the current and proposed future expansion of grazing conservation management in Epping Forest.
3. Critically assess the established monitoring and survey methods as an effective means to gauge the effectiveness of the cattle grazing regimes at achieving nature conservation objectives for vegetation and invertebrates.
4. Proposed additional and nationally recognized monitoring methods and protocols were also evaluated where the intended objective was to develop a Long Term Ecological Research site at Epping Forest under the UK Environmental Change Biodiversity Network.

b. Fact finding visits and desk study

The current and proposed grazing management and general ecological monitoring across Epping Forest were evaluated during two visits in December 2010 and July 2011. During the second visit, there were two meetings with Forest management staff and wardens and a field tour of several key sites across Epping Forest, open grassland sites where the introduction of cattle grazing was proposed, and existing grazed sites and woodland and wetland sites where general ecological monitoring was already implemented. A desk-based outline review was carried out over later months to produce a summary of the scientific evidence currently available to substantiate the use of cattle grazing in conservation management of the types of habitat represented in Epping Forest. The established baseline monitoring was justified as a means to assess changes in rare or notable plants and invertebrates, especially within designated sites, and to inform progress towards nature conservation objectives, as an essential part of an adaptive management procedure (Alexander, 2008). A critical assessment was made of the alignment of the current monitoring programme with the need to detect favourable or detrimental effects on habitats and species of an expansion of cattle grazing across the Forest.

2. Review of scientific evidence supporting conservation grazing programmes

a. Role of grazing herbivores in ecosystems

Many global ecosystems have a long association with grazing by wild, and under more recent human influence, domesticated grazing animals (Vera, 2000). Temperate, Mediterranean, steppe and montane grasslands and savannas are all dependent on interactions with large herbivores (Gordon *et al*., 2004; Owen-Smith, 2002). Grazing animals have an essential social, economic and environmental role in such ecosystems (Gordon *et al*., 2004). Microbial, fungal, plant and animal diversity is strongly influenced by the effects of grazing herbivores on vegetation structure and composition, soil disturbance and nutrient cycling (Duffey *et al*., 1974; Van Wieren, 1991; McNaughton, 1985) and this has profound effects by increasing the productivity of grazed ecosystems (McNaughton *et al*., 1997) and the incidence of germination niches which facilitate recruitment of additional plant species (Crawley, 2009). The high stocking densities and extended periods of grazing of commercial grazing regimes for sheep, goat and cattle production was generally demonstrated to be detrimental to semi-natural habitats and rare or localised wild fungi (Griffith *et al*., 2002), plant (Bullock *et al*., 2001; Grime, 1973; Jones *et al*., 2001) and animal species (Dennis, 2003; Evans *et al*., 2006; Fuller & Gough, 1999; Gibson et al., 1992; Morris, 1978). The initial response of nature conservation organisations to exclude grazing herbivores by fencing, destocking or culling was eventually counter-productive because competitive exclusion reduced plant diversity and associated animal populations that represented the original nature conservation concern (Bullock *et al*., 2001; Crawley, 2009;

Grant & Maxwell, 1988; Luoto et al., 2003; Wallis De Vries *et al*., 1998). Increasingly, the role of intermediate stocking densities of grazing animals has been recognised as critical for the maintenance of plant and animal diversity and to sustain viable populations of key species of nature conservation concern (Hulme *et al*., 1999; Wallis De Vries *et al*., 1998; Watkinson & Ormerod, 2001).

i. Grazing management to achieve general conservation objectives

The responses of different flora and fauna to grazing management is not always correlated and consistent (Kruess & Tscharntke, 2002ab; Rambo & Faeth, 1999) and this is also demonstrated by the contrasting responses of various taxonomic groups of arthropods to particular grazing regimes (Dennis *et al*., 1998; 2001; 2002; Morris, 1978; Morris, 1991). It is therefore essential to clearly define the nature conservation objectives for a target site (whether for the benefit of habitat condition and biodiversity in general, to achieve habitat restoration or maintenance, or to recover populations of particular plant or animal species) in order to design an appropriate grazing management regime. For general conservation purposes, the objective of the grazing management is often to achieve a mosaic composed of patches of coarse grassland and shorter lawn areas (Van Wieren, 1991) which tends to encourage greater plant species composition and a heterogeneous structural appearance to the vegetation that supports a larger variety of arthropods and predatory animals that depend on arthropods in the food web (Dennis *et al*., 2008; Evans *et al*., 2006).

ii. Approaches to conservation grazing

Management of many of the smaller designated sites is often based on a 'put and take' system with grazed livestock requiring regular rotation around conservation sites or holding pastures of sown, agricultural grasses (Whyte, 2010). Larger sites such as National Nature Reserves have introduced free-ranging flocks of sheep or herds of cattle or ponies (e.g., Back to Purple Scheme, Stiperstones; Shropshire Wildlife Trust, no date) but although grazing can be sustained for a longer period across these larger sites, some rotation is desirable during the period of vegetation growth and removal to holding pastures during winter. Over commons and lowland and upland heaths, extensive agricultural management remains the main option for conservation management of priority habitats and wildlife with incentives from agri-environment schemes (Higher Level Stewardship, Exmoor; Natural England, no date). A more radical solution in areas where farming is no longer economically viable is to reinstate semi-wilded grazing animals with minimal intervention (Hodder *et al*., 2005). Naturalistic grazing would require derogation of animal husbandry, welfare, disease control and fallen stock legislation and possible compliance with Good Agricultural and Environmental Condition regulations. Stock management applicable to domesticated animals and continued intervention would be necessary to maintain such herds over winter and, in the absence of predators, to limit population sizes below the carrying capacity of the site to avoid degradation of habitat condition. The next section will

briefly explore the particular qualities of cattle compared with other grazing species when used for the role of conservation grazing.

b. Review of evidence supporting cattle as a suitable domestic herbivore in conservation grazing

The specific qualities of grazing by cattle compared with other domesticated herbivore species in conservation management is commonly supported by anecdotal reports (Dennis, 1998; Grazing Advice Partnership, no date; National Trust, 2011) rather than factual information substantiated by scientific experiments (Hodgson et al., 1991; Newton *et al*., 2009). The significant costs of securing suitable experimental sites, constructing fences, resourcing continuous livestock care and husbandry and the long period required to observe ecological responses are understandable reasons for a relative lack of experimental evidence (Ecological Continuity Trust, no date) with notable examples to illustrate these challenges (Dennis *et al*., 2008; Bullock & Marriott, 2000; Mitchell *et al*., 2008). Sufficient experimental studies and structured surveys have been carried out on which to base conclusions about the role of cattle in conservation grazing. This does not extend to any convincing case for the use of any particular cattle breed over another (Wright *et al*., 2006). A national survey of cattle grazing in 77 woodland sites across the UK recorded the use of 26 different breeds (Armstrong *et al*., 2003). Use of traditional or local breeds is often desirable to earn the consent of local stakeholders for the introduction of large herbivores to sites where there has not been grazing in recent living memory. Whether certain cattle breeds are more or less selective in their foraging for vegetation types that are competitive and abundant so that overall diversity is increased remains contentious. The use of cattle at low stocking densities for managing vegetation for nature conservation rather than production has significantly increased in the last decade (Armstrong *et al*., 2003; GAP News, 2008). In addition, the value of cattle grazing has been highlighted in extensive production systems in High Nature Farming areas, mainly due to the demise of such pastoral systems under increased economic duress (Andersen *et al*., 2004; La Canada, 2005).

i. Scientific evidence supporting use of cattle in conservation grazing

The interactions of cattle with semi-natural habitats and the consequences for vegetation structure, plant species composition and animal wildlife has been investigated in a considerable number of studies, but this has not yet accumulated into a comprehensive knowledge base for this topic (Wright *et al*., 2006). Scientific grazing experiments provide rigorous data to draw general conclusions about the interactions of cattle grazing with various plant and animal populations or species assemblages in various types of grassland and heathland (Wright *et al*., 2006) and comprehensive questionnaire surveys of site managers across the UK have recently provided information whether conservation management objectives were achieved through grazing, including by cattle in addition to

other herbivores, of heaths (Newton *et al*., 2009) and native woodlands (Armstrong *et al*., 2003).

Some general observations can be drawn from these studies. In general, cattle grazed at appropriate stocking densities and for periods each year which were sensitive to the target semi-natural habitat, had effects that were at least neutral and most often positive for habitat quality and associated biodiversity (Armstrong *et al*., 2003; Newton *et al*., 2009; Wright *et al*., 2006). Greatest contention about the suitability of cattle grazing in particular relates to the grazing of wetland habitats. The weight of individual bovines is considered unsuitable for the grazing of acid bogs, due to the damage that can be caused to the acrotelm or biologically active upper layer of *Sphagnum* peat (Wright *et al*., 2006). Cattle grazing has inconsistent effects on the invertebrate fauna of reed beds and fens, with a higher proportion of rare compared with widespread and common species of ground beetles colonising restored fen which was cattle grazed (Martay *et al*., 2012) whilst populations of rare molluscs (*Vertigo* spp.) associated with tall herb fens and reedbeds declined after cattle grazing, perhaps because snails are trampled or ingested, host plant numbers and leaf surface area are reduced or the more open fen vegetation is less humid (Ausden *et al*., 2005).

ii. Bovine grazing behaviour and foraging ecology

Cattle grazing has positive effects for semi-natural grasslands and woodlands due to their specific grazing characteristics. Cattle tend to track the growth flushes of the available abundant vegetation (Gibson, 1997; Pratt *et al*., 1986). The choice of vegetation patch can be explained by a random allocation of cattle foraging time as much as specific vegetation preferences, certainly amongst tall grass, short grass and tall herbs, with less foraging observed on the latter, an alternative explanation is that choice is related to the relative energy content of each vegetation type (Wallis de Vries & Dalebondt, 1994; Wallis de Vries & Schippers, 1994). Cattle are also less selective and tear vegetation which generally results in greater depletion of abundant, less nutritious vegetation than observed under grazing by other herbivore species (Grant *et al*. 1985; 1987; Putman *et al*., 1987; Wright *et al*., 2006). Dung avoidance behaviour by cattle creates islets or a hummock-hollow appearance to grasslands (Duffey *et al*., 1974) which adds to the structural diversity and creates more microhabitats for arthropods (Helden *et al*., 2010). Hoof weight and trampling at intermediate to low stocking densities adds to the effect of forage intake to produce greater structural diversity in vegetation, especially gaps in tussock grasslands of acid grassland and fen habitats into which non-graminoid plants can colonise (Wright *et al*., 2006). In woodlands, shrub and field layer vegetation is opened up by cattle grazing to facilitate tree regeneration (Armstrong *et al*., 2003). The dense, shaded character of much of the UK's native woodland is considered to be a major factor in the observed declines of woodland birds (Eaton *et al*., 2011) and vernal plants (Plantlife, 2012). Timing of grazing is important to realise desirable changes in habitat structure (Dennis *et al*., 1997) whilst avoiding direct disturbance to target wildlife species such as ground nesting birds (Evans *et al*., 2006; Paine *et al*., 1996). Small mammals tend to increase in population size only at

very low stocking densities or complete removal of grazers, which has positive consequences for the food web leading to avian predator (raptor) populations (Evans *et al*., 2006; Redpath *et al*., 2002; Torrea *et al*., 2007). At higher stocking densities and sustained grazing periods, cattle can have adverse effects on soil physical properties, either culminating in compaction of soils of drier habitats or poaching of wet grassland, fen and wet heath (Pietola *et al*., 2005; Stephenson & Veigel, 1987).

iii. Ecological consequences of animal healthcare

Serious consideration is required in the choice of active ingredient and administration of veterinary pharmaceuticals to livestock for the control of gastro-intestinal parasites (roundworms) and ectoparasites (ticks). In the context of conservation grazing, residual toxicity in dung of some active ingredients can significantly delay the colonisation of dung by scavengers or cause population declines of key species both for dung dispersal and breakdown and as the source of fly and beetle food for bats (Williams *et al*., 2011) and rare birds such as Chough (McCracken & Foster, 1994). Cattle dung is particularly important for Lesser horseshoe bats in the winter months (Ransome & Priddis, 2004). Most concerns have been expressed over the avermectin group of anthelminthics (Strong, 1992; Strong & Wall, 1994; Wratten *et al*., 1993), especially when administered through a slow release bolus ingested by the cattle compared with occasional hypodermic, injected doses (Gover & Strong, 1996).

c. Effectiveness of cattle grazing for achieving habitat and species conservation objectives

Site managers were generally satisfied that cattle were achieving the desired conservation results in woodlands although sometimes at a slower rate than anticipated (Armstrong *et al*., 2003). Reviews have concluded mainly positive outcomes of cattle grazing when stocking densities are applied at appropriate levels for the kinds and extent of semi-natural habitat represented at a site (Table 2.c.1). Some important practical considerations have also been highlighted from these reviews. The target site must have a well maintained, stock proof boundary (fenced) otherwise there may be an incursion of vagrant grazers from adjacent land experiencing relatively higher stocking densities than the conservation grazing intensity of the target site. The population size of wild herbivores (wild deer and feral goats) must be understood and taken into account when calculating appropriate stocking rates of cattle. A distinction must be made between the grazing management regime required for the objective of habitat restoration and a suitable maintenance regime once the habitat restoration is successful. For instance, lower densities of cattle tend to contract into the more nutritious patches of vegetation for grazing, so that less nutritious vegetation may experience a low or no ‘effective’ stocking density with the consequence of rank grass, tussock grass, rush, bracken or scrub encroachment (Dennis *et al*., 2005).

Table 2.c.1. Perceived or measured benefits and disadvantages of cattle grazing for habitat and species conservation management

Habitat	Heathland and grassland	Woodland
Benefits	• Less selective than other livestock[4] • Create a more structurally diverse sward[4] • Reduce the cover of tussock forming species[4] • Create more gaps for plant regeneration[4]	• Benefits general biodiversity by the reduction of tree and scrub regeneration, opening up the shrub layer and in the maintenance of open habitats[1] • Benefits for individual species and taxonomic groups[1] • Encouragement of tree regeneration[1] • Maintain open glades of natural woodland structure[2] • Enhanced plant species composition and structure in woodland riparian zone[5, 6]
Detrimental effects	• Heavy on wet soils and damaging for wetland habitats[4] • Break stems and kill plants of *Calluna vulgaris* on heaths[4] • Pollution from access to watercourses on open or common land[4] • Diminished vertical structure of ericaceous shrubs, gorse cover and abundance of grass tussocks[3] • Formation of numerous trackways[3]	• Trampling sensitive plants[1] • Poaching soil[1] • Bank erosion[1] • Pollution of water courses[1] • Kill or damage tree seedlings[2] • Debark saplings and trees[2]

Derived from [1]Armstrong *et al*., 2003; [2]Hodder *et al*., 2005; [3]Newton *et al*., 2009; [4]Wright *et al*., 1996; [5]Humphrey & Patterson, 2000; [6]Huber *et al*., 1995.

i. Habitat effects

Experience from commercial grazing at high stocking densities on semi-natural habitats, which was encouraged by subsidy payments per grazing animal, 1970s-2000s, demonstrated the detrimental effects that can result from inappropriate management of grazing livestock. These effects were most evident in the loss of *Calluna vulgaris* dominated dwarf heaths, often replaced with white moor composed of *Nardus stricta* or *Molinia caerulea* acid grassland (Critchley *et al*., 2008; Grant & Maxwell, 1988; Mitchell *et al*., 2008). Overall, grazing, including by sheep, led to widespread habitat degradation of heath and semi-natural grasslands and recent experiences have also highlighted the significant challenge in reversing such changes. Simple reductions in stocking density are not sufficient for effective habitat restoration. In the example of *Molinia*-dominated white moor, a shift from sheep to cattle grazing in addition to an overall reduction in stocking density was necessary to restore plant densities of *Calluna vulgaris* (Common *et al*., 1997; Critchley *et*

al., 2008; Grant *et al*., 1985; 1996). Cattle grazed at 1 GLU (adult dairy cow equivalent grazing livestock unit) for two months each summer for consecutive years were sufficient to break up the cover of dead leaf matter and create gaps through trampling and poaching into which *Calluna* germinated and established (Mitchell *et al*., 2008). This required associated *Calluna* seed distribution and mechanical rotavation was equally effective as the cattle grazing in achieving effective restoration of dwarf shrub (Mitchell *et al*., 2008) and in other management experiments glyphosate herbicide was successfully used as the pre-treatment (Todd *et al*., 2000) although this was a measure for heathland restoration under agricultural rather than conservation management. Once dry heath is restored or where cattle are introduced to existing heath as part of the management, the action of free-ranging cattle alone is unable to prevent birch and pine regeneration, so occasional manual intervention will be required if the target is open heath rather than clumps of scrub-woodland interspersed amongst open *Calluna* patches (Bokdam & Gleichman, 2000).

Cattle grazing can be very effective in maintaining the structural and botanical species diversity of lowland grasslands (Crofts & Jefferson, 1999) and in preventing or retarding scrub encroachment onto chalk grasslands (GAP, no date). For grasslands that are managed with a reduction of stocking density following years of intensive grazing, certain plant species such as soft rush, bracken, purple moor grass and gorse can become a problem by increasing in ground cover to dominate a site. Episodic, high stocking densities of grazers may be suitable to open up such vegetation and restore the structural diversity and botanical composition of the vegetation. This can be particularly effective in the control of gorse, bracken or *Molinia* control. Such mob stocking must be followed by a change to a low to moderate in grazing regime to avoid degradation of soil or vegetation (Popay & Field, 1996). This approach has also been demonstrated to be effective at initial clearance of rank ground vegetation in neglected native woodlands, albeit by sheep grazed for blocks of five days in experimental plots within oak and ash woodland (McEvoy & McAdam, 2008). This can be considered as an occasional option for clearance of problem vegetation alongside the longer term grazing strategy. In this example, little significant damage was recorded to the trees although later shoots were browsed during October grazing and growth rate was slowed in relation to February grazing. Most of the rank herbage height was removed within the first 24 h of livestock introduction, with half the biomass removed after the full period with effects sustained for 4-6 months. Goats can also be considered as a suitable species of grazer for mob stocking in the initial clearance of problem vegetation alongside a maintenance grazing regime achieved with cattle (Merchant, 1993). This was demonstrated as an effective means to reduce soft rush in moist grassland with goats consuming 75% to 90% of the seasons growth of rush, with a dramatic reduction in the cover and vigour of the rushes. These effects were achieved when other grazing animals maintained the grazing lawns of palatable grasses at 4-5 cm or less, which is not suitable for all conservation grazing sites. The effects of cattle grazing on various semi-natural habitats were concluded to be favourable or at least neutral in impact by the review of Wright *et al*. (2006) where detailed accounts can be found. The single exception recognized in that review was the detrimental effect of grazing blanket bog or lowland raised bog with cattle. Cattle grazing was considered effective at achieving nature conservation objectives for other wetland types, e.g., reed beds and fen meadow (Sutherland & Hill, 1995).

ii. Wildlife responses

In general, no single cattle grazing prescription will meet the requirements for all fungal, plant and animal taxa and it appears desirable to manage for a mosaic, assuming a suitable area is available of each vegetation type to accommodate a variety of structural and seral vegetation stages (Coleoptera, beetles: Dennis *et al*., 1997; Woodcock *et al*., 2010 ; Araneae, spiders: Cherrett 1964; Dennis *et al*., 2001; Lepidoptera, moths and butterflies: Erhardt & Thomas, 1991 ; Littlewood, 2008; Poyry *et al.*, 2004 ; 2005 ; Homoptera, plant bugs: Dennis *et al*., 1998; Hollier *et al*., 2005 ; Waloff, 1980 ; birds: Fuller et al., 2006; Sutherland & Hill, 1995; plants: Pykala, 2005; fungi: Griffith *et al*., 2002). Invertebrate groups such as ground beetles have many species adapted to more or less disturbed or open habitats and that is why the response of these species as an assemblage can vary with management, larger species with larvae in the soil being most vulnerable to cattle grazing, whilst other species benefit from the opening up of the grassland into hummocks and hollows, or tussocks and inter-tussock lawns of calcifugous (Dennis *et al*., 1997; Dennis, 2003) and calcicolous grasslands (Woodcock *et al*., 2012).

3. Observations on Grazing Strategy and visits to selected sites across Epping Forest

The proposed, phased expansion of cattle grazing to achieve conservation and landscape objectives across Epping Forest is supported by the evidence presented in the scientific literature of grazing ecology. There is evidence to substantiate the arguments presented in the Grazing Strategy for cattle grazing wood pasture, lowland dry acid grassland, neutral grassland and wet and dry lowland heath. The particular sensitivities of heath to cattle grazing have been earlier reviewed. In summary, regular monitoring of the status of *Calluna* and light touch management are necessary. Physical damage from cattle treading can cause stem breakage and mortality to individual plants although heather is capable of rejuvenation through adventitious shoots in response to moderate grazing intensity (MacDonald *et al*., 1995).

Appropriate stocking densities and periods of grazing must be maintained for the effective management of the distinct mosaic of habitats at Chingford-Honey Lane Plain, Fernhill and Trueloves, Long Running and Woodbury Hollow, Sheppards Meadows, Wanstead Flats and Wanstead Park. The stated stocking densities should be treated as indicative values and will need to be varied according to prevailing conditions. Indeed, the Grazing Strategy acknowledges the need to continuously alter stocking densities in response to limits of vegetation change and variations in weather and vegetation growth by season and year. There is general scientific evidence about the importance of these parameters in conservation grazing but such general information must be carefully interpreted for application on a particular site and the variability of vegetation types present. The Grazing Strategy sets out appropriate prescriptions for habitat and species conservation and

landscape objectives and the means to carefully control these in response to observed changes.

- Fencing and or cattle herding/ rotation
- Monitoring (discussed in detail in the next section in relation to habitat mosaic and target plant species)
- Possible need for change in grazing strategy once primary objectives for achieving 'favourable condition' for the mosaic of vegetation. Often need to alter grazing management once the objectives change from restoration to maintenance regime.

The report accommodates the need to vary stocking density and periods of grazing to accommodate differences in productivity, nutritional value and sensitivity of vegetation type and soils to grazing. The introduction of a virtual fencing system to manage the target grazing areas is an innovative approach (Butler *et al*., 2006) not without risks inherent in applying a new technology (Anderson, 2007; Bishop-Hurley *et al*., 2007). This could be a very cost-effective and effective means to control the extent and duration of grazing across compartments of the complex mosaic of habitats and future reports of progress with implementation of this system are awaited with interest.

The review revealed that certain characteristics of cattle compared with other herbivore grazing are ideally suited to the objectives of attaining a unique vegetation mosaic in the Forest. Retention of tussock grass areas will require careful management since cattle will generally reduce the density and extent of such features after prolonged grazing. The increase in structural diversity of different kinds of vegetation and gap creation into which less common plant seeds can fall or germinate and establish, are highly favoured traits of cattle grazing.

Weather conditions are increasingly variable and the most recent climate models including atmospheric pollutants as well as Greenhouse gases suggest only that weather extremes are more likely in the next decades, hence a reactive mode of management is required especially in those habitats which are fen in character. This should also include grassland habitats which are periodically wet, should soil moisture increase after intensive precipitation.

The role of sacrificial grazing areas, perhaps adjacent amenity or intensified grassland is recognised as a vital part of grazing management of high nature value sites. A put and take system is clearly described in the Grazing Strategy as the main way to manage the vegetation effectively in order to achieve favourable condition throughout the Forest.

A further note is that management of domesticated herbivores cannot be addressed in isolation from the effects of wild, free-ranging herbivores and it essential to use the best available information on local deer populations to appreciate where downward estimates of stocking densities or durations of grazing access are necessary from values calculated and recorded in the Grazing Strategy.

The final remark must draw attention to the importance of welfare and nutrition of the cattle since these livestock may require breaks from the grazing in some of the less

productive vegetation types since this may not sustain the nutritional requirements of cattle if driven solely by the nature conservation motive for grazing. The role of the herds person is essential for balancing the conservation sensitivities of the vegetation with the health and welfare of the livestock at times when the condition of animals is not likely to be sustained by the poor forage quality of the semi-natural habitats.

The phased nature of the Grazing Strategy is a sensible, gradual and precautionary approach which, combined with the monitoring, provides ample opportunity to review and adjust management to achieve objectives. With these cattle management measures in place, there is a realistic opportunity to achieve and maintain the stated objectives of the Grazing Strategy over the next 5-20 years:

- Restore and maintain the favourable condition of key forest habitats using good forest management.
- Conserve the Forest as a special mosaic landscape distinct from surroundings.
- Maintain cultural tradition and protect common rights of pasturage.

The report is justified in recognizing the validity and particular benefits of choosing a cattle grazing strategy beyond maintaining a local cultural tradition.

4. Evaluation of existing monitoring programme and methods

a. Sites proposed for phasing in of grazing management

Baseline vegetation monitoring is already in place and the distribution and abundance of distinct plant species (e.g., Spiny rest-harrow, Pepper saxifrage, and Lousewort) can be evaluated, essential for decision making on adjustments to the indicative stocking rates and periods in the proposed put and take system of cattle grazing stated in the Grazing Strategy.

The combination of fixed point photography, fixed quadrats for plant survey and field and GIS mapping of the distribution of plant species of conservation interest (e.g., Lousewort on Almhouse Plain) contributes to a suitable and effective monitoring programme, essential for any conservation management plan.

i. Whitehall Plain

No grazing has been applied to this site since the 1990s. Annual hay cuts have been used for interim vegetation management. The established monitoring with three grazing exclosure plots paired with future grazed plots is appropriate for assessing the general changes in vegetation structure and botanical composition. The two species plots also provide the capability to assess changes in some of the conservation sensitive plant species after the reinstatement of grazing management.

Modification of management at one preparatory site is necessary where mowing was ceased to protect the Spiny rest harrow population. This has resulted in bramble and tree

regeneration which has compromised the future use of this replicate plot for pre- and post-grazing monitoring. Options available:

1. clear woody material and resume mowing to achieve comparable replicate of mown vs grazed split plot at onset of cattle grazing.
2. Leave scrub but create four plots giving grazed vs mown open grass and grazed vs hand clearance/ mown scrub plots.
3. Displace plots to adjacent open grassland area perhaps with some overlap of existing quadrat locations. This gives the opportunity for at least a further pre-grazed set of botanical data to check against initial run of data prior to commencement of grazing. There are two advantages in this option. The conflict of interest between monitoring and species conservation in former plots with *Ononis spinosa* L. (Spiny restharrow) is removed and vegetation can be appropriately managed to maintain or enhance this small population. The influence of path encroachment onto the monitoring plots can also be tackled in this relocation of monitoring plots.

ii. Deershelter plain

Lies outside of the main grazing area. Area of 5 ha electric fenced with test of 'invisible' fenceline. A 'put and take' grazing management system was already in operation. The scrape of topsoil has successfully restored dry heath habitat with sedges, purple moor grass and other acid heath plants evident in the field layer. The random grid sampling approach proposed by Wilde (2006) using photographs and direct measurements of vegetation seems appropriate for monitoring the vegetation response to the top soil removal and follow up grazing management.

iii. Almshouse Plain

A complex site with several important species of open habitats threatened by development of rank vegetation and expansion of bramble and thorn. Particular species of interest include *Pedicularis sylvatica* L.; Lousewort in an open area with evidence of bramble encroachment. *Achillea ptarmica* L., Sneezewort and *Genista anglica* L., Petty whin were also present on the open grassland. Considerable effort has to been applied to map and monitor changes in the distribution and abundance of these species.

Site also included a wetter *Carpinus betulus* L., hornbeam pollarded site with *Molinia caerulea*; purple moor grass dominating the field layer. An adjacent site of pollarded hornbeam was associated with field layer of *Holcus lanatus,* Yorkshire fog and sedges. Much work has been undertaken to restore the pollarded hornbeam across the site but the field layer vegetation will require careful additional management with a good prospect of benefits from cattle grazing.

iv. Chingford Plain

This is an existing Long horn cattle grazed site and appeared during the site visit to be a general favourable state with a patchwork of shrub, tussock grass of *Deschampsia flexuosa,*

wavy hair grass, with grazing lawns composed of more nutritious *Agrostis-Festuca* grasses apparent throughout the site, indicative of a low to moderate stocking density.

b. Sites monitored for broader conservation management objectives

The combination of current and proposed monitoring methods is suitable for achieving the establishment of a Long Term Ecological Research site at Epping Forest under the UK Environmental Change Biodiversity Network.

Observations and comments about various sites are given in the order of visits.

i. Yardley Plain and Yate's Meadow

This is an outlier isolated from the main part of the Forest by an extensive golf course. Scrub clearance has been undertaken to restore a species rich meadow with plant species such as *Silaum silaus* (L.), Pepper saxifrage present.

Hay making current management approach but the ambition is to graze the aftermath with cattle in the near future. This should indeed restore the botanical interest that was probably developed from historic management for hay meadow or dairy pasture. Require evidence of a benefit of the alternative management approach for both botanical and invertebrate diversity.

The mowing has also been necessarily selective in extent due to the difficult micro-topography of the site and the presence of colonies of the yellow meadow ant mounds. This can generate foci for bramble and regeneration of scrub and trees which has become a significant problem in several management blocks across the site. This provides a compelling case for cattle grazing, especially given the mix of bramble and tall herbs that require control and the maintenance of facilitation of grazing by rabbits that provides useful bare soil and short sward patches for Bird's foot trefoil establishment.

Pimpinella saxifraga (Burnet-saxifrage) is currently absent from the site but re-establishment of a population is a realistic conservation target. This winter-green, perennial species flowers May to September hence mowing can be detrimental to such a population. Cattle grazing with moderate stocking densities may be more appropriate than mowing, not least because seed can survive consumption by cattle and this can aid dispersal to new sites. Later summer grazing may best benefit other flowering species at the site and the exact timing and rotation of grazing to favour Bird's foot trefoil and Pepper saxifrage should be reviewed based on scientific evidence and Best Practice at other sites.

Additional monitoring protocols for invertebrates (e.g., butterflies, ground beetles and ant colonies) and birds applied to this and other sites site provides important additional information since changes in plant species often do not indicate the response of other taxa to grazing management.

ii. Sunshine Plain to Rushey Plain

Ancient *Fagus sylvatica*, beech coppice stools and pollards. Much litter and wood mulch and partially vegetated with bracken abundant in transition following thinning, crown reduction and pollarding (less so to allow trees to adapt to initial crown reduction). Currently limited forage available for the successful introduction of cattle into this woodland site.

5. Future monitoring

The current emphasis of monitoring is on the open herbaceous and meadow areas. Cattle are known to reduce shrub and woodland cover by physically opening up the shrub layer as they graze and browse and by reducing later rates of shrub and tree regeneration (Table 2.c.1). It is therefore desirable to monitor such changes in these closed or partially open habitats in order to inform management of the appropriate timing and stocking densities of cattle. Emphasis should be placed on assessment of the botanical species composition along transects in the transition zones between open herbaceous and closed wooded habitats, for example from Rushey Plain to Sunshine Plain in the north of the extensive grazing area. Further visits are proposed in 2013 to decide upon the precise location of these transects and to discuss and develop further appropriate monitoring methods. During the visits, supplementary monitoring to assess changes in other taxonomic groups will be considered and the overall breadth of monitoring methods reviewed in relation to the aspiration to achieve the range of monitoring protocols consistent with the UK Environmental Change Biodiversity Network (ECN, no date).

6. Closing comment

The scientific evidence related to grazing ecology supports the proposals set out in the Grazing Strategy and the phased nature of the plan over 20-30 years allows the modification of such general principles to local conditions, so that conservation objectives can be achieved through a precautionary, adaptive management approach. Recent scientific experiments and reviews support the role of cattle grazing in pasture woodland sites and the introduction of cattle to several of the parcels in Epping Forest would be effective at achieving greater structural diversity and species composition in the field layer. Parcels such as Sunshine Plain probably require some period of vegetation recovery into the mulch generated from the recent crown reduction and pollard work before grazing should be introduced.

7. References

Alexander, M. (2008). Management planning for Nature Conservation. A theoretical and practical basis. London, Springer-Verlag, 425 pp.

Anderson D.M. (2007). Virtual fencing – past, present and future. The Rangeland Journal 29: 65–78.

Andersen, E., Baldock, D., Bennett, H., Beaufoy, G., Bignal, E., Brouwer, F., Elbersen, B., Eiden, G., Godeschalk, F., Jones, G., McCracken, D., Nieuwenhuizen, W., van Eupen, M., Hennekens, S. & Zervas, G. (2004). Developing a High Nature Value farming indicator. Final Report. Brussels, Institute for European Environmental Policy, pp. 76. Available at: http://www.ieep.eu/work-areas/agriculture-and-land-management/high-nature-value-farming.

Armstrong, H.M., Poulsom, L., Connolly, T. & Peace, A. (2003). A survey of cattle-grazed woodlands in Britain. Final Report. Woodland Ecology Branch, Forest Research, Northern Research Station, Roslin, Midlothian, Scotland.

Ausden, M., Hall, M., Pearson P. & Strudwick T. (2005). The effects of cattle grazing on tall-herb fen vegetation and molluscs. Biological Conservation 122: 317-326.

Bishop-Hurley , G.J., Swain, D.L., Anderson, D.M., Sikka, P., Crossman, C. & Corke, P. (2007). Virtual fencing applications: implementing and testing an automated cattle control system. Computers and Electronics in Agriculture 56: 14–22.

Bokdam, J. & 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.

Bullock, J.M. & Marriott, C.A. (2000). Plant responses to grazing, and opportunities for manipulation. In: Rook, A.J. &Penning, P.D. (eds) Grazing management: the principles and practice of grazing, for profit and environmental gain, within temperate grassland systems. Proceedings of the British Grassland Society Conference, Cairn Hotel, Harrogate, 29 February-2 March 2000, pp. 17-26.

Bullock, J.M., Franklin, J., Stevenson, M.J., Silvertown, J., Coulson, S.J., Gregory, S.J. & Tofts, R. (2001). A plant trait analysis of responses to grazing in a long-term experiment. Journal of Applied Ecology 38: 253-267.

Butler, Z., Corke, P. Peterson R Ruset D (2006). From robots to animals: virtual fences for controlling cattle. International Journal of Robotics Research 25: 485-508.

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

Common, T.G., Grant, S.A., Armstrong, R.H. & Torvell, L. (1997). The effects of level of *Molinia* utilization on diet selection and herbage intake by cattle grazing *Molinia* grassland. Grass and Forage Science 52: 207-218.

Crawley, M.J. (2009). The Structure of Plant Communities, in Plant Ecology, Second Edition (ed M.J. Crawley), Blackwell Publishing Ltd., Oxford, UK. doi: 10.1002/9781444313642.ch14.

Critchley, C.N.R., Adamson, H.F., McLean, B.M.L. & Davies, O.D. (2008). Vegetation dynamics and livestock performance in system-scale studies of sheep and cattle grazing on degraded upland wet heath. Agriculture Ecosystems & Environment 128: 59-67.

Crofts, A. & Jefferson, R.G. (1999). The Lowland Grassland Management Handbook. 2nd edition. Peterborough, English Nature/ The Wildlife Trusts, pp. 508.

Dennis, P., Young, M.R., Howard, C.L. & Gordon, I.J. (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.

Dennis, P., Young, M.R. & 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.

Dennis, P., Young, M.R. & 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.

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

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

Dennis, P., Elston, D., Evans, D.M., Evans, S.A., Gordon, I.J., Grant, M., Kunaver, A., Marquiss, M., Mayes, R., McCracken, D.I., Pakeman, R., Pearce-Higgins, J., Redpath, S.M., Skartveit, J., Stephen, L., Benton, T. and Bryant, D. (2005). Effects of grazing management on upland bird populations: disentangling habitat structure and arthropod food supply at appropriate spatial scales (GRUB). Final report to the Scottish Executive Environment and Rural Affairs Department, Edinburgh, 58 pp.

Dennis, P., Skartveit, J., McCracken, D.I., Pakeman, R.J., Beaton, K., Kunaver, A. & Evans, D.M. (2008). The effects of livestock grazing on foliar arthropods associated with bird diet in upland grasslands of Scotland. Journal of Applied Ecology 45: 279-287.

Dennis, R. (1998). The importance of traditional cattle for woodland biodiversity in the Scottish Highlands. Highland Foundation for Wildlife, Inverness-shire.

Duffey, E., Morris, M.G. & Sheail, J., Ward, L.K., Wells, D.A. & Wells, T.C.E. (1974). Grassland Ecology and Wildlife Management. London, Chapman and Hall.

Eaton, M.A., Balmer, D.E., Cuthbert, R., Grice, P.V., Hall, J., Hearn, R.D., Holt, C.A., Musgrove, A.J., Noble, D.G., Parsons, M., Risely, K., Stroud, D.A. & Wotton, S. (2011). The state of the UK's birds 2011. RSPB, BTO, WWT, CCW, JNCC, NE, NIEA and SNH, Sandy, Bedfordshire, pp. 46.

Ecological Continuity Trust (no date). Available at: http://ecologicalcontinuitytrust.org/ECT/HOME.html. Accessed on: 16 August 2012.

ECN (no date). UK Environmental Change Network – Environmental Change Biodiversity Network. Available at: http://www.ecn.ac.uk/what-we-do/science/projects/ecbn/ecbn. Accessed on 18 October 2012.

Erhardt, A. & Thomas, J.A. (1991). Lepidoptera as indicators of change in the semi-natural grasslands of lowland and upland Europe. In: N.M. Collins & J.A. Thomas (eds). The conservation of insects and their habitats. London, Academic Press Ltd, pp. 213-236.

Evans, D.M., Redpath, S.M., Evans S.A., Elston D.A., Gardner, C.J., Dennis P. & Pakeman, R.J. (2006). Low intensity, mixed livestock grazing improves the breeding abundance of a common insectivorous passerine. Biology Letters 2: 636-638.

Evans, D.M., Redpath, S.M., Elston, D.A., Evans, S.A., Mitchell, R.J. & Dennis, P. (2006). To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. Journal of Applied Ecology 43: 499-505.

Fuller, R. & Gough, S. (1999). Changes in sheep numbers in Britain: implications for bird populations. Biological Conservation 91: 73-89.

Fuller, R.J., Atkinson, P.W., Garnett, M.C., Conway, G.J., Bibby, C.J. & Johnstone, I.G. (2006). Breeding bird communities in the upland margins (ffridd) of Wales in the mid-1980s. Bird Study 53: 177-186.

GAP News (2008) Newsletter No. 42 of the Grazing Animals Project, Natural England, Salisbury, Wiltshire, pp. 50.

Gibson, C. (1997). The effects of horse and cattle grazing on English species-rich grasslands. Peterborough, English Nature, pp. 48.

Gibson, C.W.D., Brown, V.K., Losito, L., Gavin, G.C. (1992). The response of invertebrate assemblies to grazing. Ecography 15: 166-176.

Gordon, I.J., Hester, A.J. & Festa-Bianchet, M. (2004). The management of wild large herbivores to meet economic, conservation and environmental objectives. Journal of Applied Ecology 41: 1021-1031.

Gover, J. & Strong, L. (1996). Determination of the toxicity of feces of cattle treated with an ivermectin sustained release bolus and preference trials using a dung fly *Neomyia cornicina*. Entomologia Experimentalis et Applicata 81: 133-139.

Grant, S.A. & Maxwell T.J. (1988). Hill vegetation and grazing by domesticated herbivores: the biology and definition of management options. In: M.B. Usher and D.J. Thompson (eds) Ecological change in the uplands. Oxford, Blackwell Scientific Publications, pp. 201-214.

Grant, S., Suckling, D., Smith, H.K., Torvell, L., Forbes, T.D.A. & Hodgson J (1985). Comparative studies of diet selection by sheep and cattle grazing individual hill plant communities as influenced by season of the year. 1. The indigenous grasslands. Journal of Ecology 73: 987-1004.

Grant, S., Torvell, L., Smith, H.K., Suckling, D.E., Forbes, T.D.A. & Hodgson, J. (1987). Comparative study of diet selection by sheep and cattle: blanket bog and heather moor. Journal of Ecology 75: 947-960.

Grant, S.A., Torvell, L., Common, T.G., Sim, E.M. & Small, J.L. (1996). 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.

Grazing Advice Partnership, no date. Available at: http://www.grazinganimalsproject.org.uk/. Accessed 14 August 2012.

Griffith, G.W., Easton, G.L. & Jones, A.W. (2002). Ecology and diversity of waxcap (*Hygrocybe* spp.) Fungi. Botanical Journal of Scotland 54: 7-22.

Helden, A.J., Anderson, A., Sheridan, H. & Purvis, G. (2010). The role of grassland sward islets in the distribution of arthropods in cattle pastures. Insect Conservation and Diversity 3: 291-301.

Hodder, K.H., Bullock, J.M., Buckland, P.C. & Kirby, K.J. (2005). Large herbivores in the wildwood and modern naturalistic grazing systems. English Nature Research Report no. 648, Peterborough, English Nature.

Hodgson, J., Forbes, T.D.A., Armstrong, R.H., Beatie, M.M. & Hunter, E.A. (1991). Comparative studies of the ingestive behaviour and herbage intake of sheep and cattle grazing indigenous hill plant communities. Journal of Applied Ecology 28: 205-227.

Hollier, J.A., Maczey, N., Masters, G.J. & Mortimer, S.R. (2005). Grassland leafhoppers (Hemiptera: Auchenorrhyncha) as indicators of habitat condition – a comparison of between-site and between-year differences in assemblage composition. Journal of Insect Conservation, 9, 299-307.

Huber, S.A., Judkins, M.B., Krysl, L.J., Svejcar, T.J. & Hess, B.W. (1995). Cattle grazing a riparian mountain meadow - effects of low and moderate stocking density on nutrition, behavior, diet selection and plant-growth response. Journal of Animal Science 73: 3752-3765.

Hulme, P.D., Pakeman, R.J., Torvell, L., Fisher, J.M. & Gordon, I.J. (1999). The effects of controlled sheep grazing on the dynamics of upland *Agrostis-Festuca* grassland. Journal of Applied Ecology 36: 886-900.

Humphrey, J.W. & Patterson, G.S. (2000). Effects of late summer cattle grazing on the diversity of riparian pasture vegetation in an upland conifer forest. Journal of Applied Ecology 37: 986-996.

Jones, B., Gliddon, C. & Good, J.E.G. (2001). The conservation of variation in geographically peripheral populations: *Lloydia serotina* (Liliaceae) in Britain. Biological Conservation 101: 147–156.

Kruess, A. & Tscharntke, T. (2002a). Grazing intensity and the diversity of grasshoppers, butterflies, and trap-nesting bees and wasps. Conservation Biology 16: 1570-1580.

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

La Canada (2005). Newsletter of the European Forum for Nature Conservation and Pastoralism. No. 19, Portree, Skye, UK. Available at: http://www.efncp.org/publications/la-canada/.

Littlewood, N.A. (2008). Grazing impacts on moth diversity and abundance on a Scottish upland estate. Insect Conservation and Diversity 1: 151-160.

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

Martay, B., Hughes, F. & Doberski, J. (2012). A comparison of created and ancient fenland using ground beetles as a measure of conservation value. Insect Conservation and Diversity 5: 251-263.

MacDonald, A.J., Kirkpatrick, A.H., Hester, A.J. & Sydes, C. (1995). Regeneration by natural layering of heather (*Calluna vulgaris*): frequency and characteristics in upland Britain. Journal of Applied Ecology 32: 85-99.

McCracken, D.I. & Foster, G.N. (1994). Invertebrates, cowdung, and the availability of potential food for the chough (*Pyrrhocorax pyrrhocorax* L.) on pastures in north-west Islay. Environmental Conservation 21: 262–266.

McEvoy, P.M. & McAdam, J.H. (2008). Sheep grazing in young oak Quercus spp. and ash Fraxinus excelsior plantations: vegetation control, seasonality and tree damage. Agroforestry Systems 74: 199-211.

McNaughton, S. J. (1985). Ecology of a grazing ecosystem - the Serengeti. Ecological Monographs 55: 259-294.

McNaughton, S. J., Zuniga, G., McNaughton, M.M. & Banyikwa, F.F. (1997). Ecosystem catalysis: soil urease activity and grazing in the Serengeti ecosystem. Oikos 80: 467-469.

Merchant, M. (1993). The potential for control of the soft rush (*Juncus effusus*) in grass pasture by grazing goats. Grass and Forage Science 48: 395–409.

Mitchell, R.J., Rose, R.J. & Palmer, S.C.F. (2008). Restoration of *Calluna vulgaris* on grass-dominated moorlands: The importance of disturbance, grazing and seeding. Biological Conservation 141: 2100-2111.

Morris, M.G. (1978). Grassland management and invertebrate animals - a selected review. Scientific Proceedings of the Royal Society of Dublin Series A 6: 247-257.

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

National Trust (2011). National Trust - Peatlands for the Future 2009 – 2012. Progress Report For Second Year, Biffaward ref 5002. Available at: http://www.nationaltrust.org.uk/servlet/file/store5/item717628/version1/biffa_2nd_annual_progress_report.pdf. Accessed: 14 August 2012.

Natural England (no date). Higher Level Stewardship Scheme, Exmoor. Available at: http://www.naturalengland.org.uk/Images/hlstargeting/Exmoor.pdf. Accessed on:17 August 2012.

Newton, A., Stewart, G.B., Myers, G., Lake, S., Bullock, J. & Pullin, A.S. (2009). How does the impact of grazing on heathland compare with other management methods? Collaboration for Environmental Evidence, Systematic Review No. 14. School of Conservation Sciences, Bournemouth University, Poole, Dorset, pp. 34.

Olff, H. & Ritchie, M. (1998). Effects of herbivores on grassland plant diversity. Trends in Ecology and Evolution 13: 261-265.

Owen-Smith, R.N. (2002). Adaptive herbivore ecology: from resources to populations in variable environments. Cambridge, Cambridge University Press, 375 pp.

Paine, L., Undersander, D.J., Sample, D.W., Bartelt, G.A. & Schatteman, T.A. (1996). Cattle trampling of simulated ground nests in rotationally grazed pastures. Journal of Range Management 49: 294–300.

Pietola, L., Horn, R. & Yli-Halla, M. (2005). Effects of trampling by cattle on the hydraulic and mechanical properties of soil. Soil and Tillage Research 82: 99-108.

Plantlife (2012). Forestry Recommissioned: Revitalising the woodlands of Wales. Salisbury, Plantlife.

Popay, I. & Field, R. (1996). Grazing animals as weed control agents. Weed Technology 10: 217-231.

Poyry, J., Lindgren, S., Salminen, J. & Kuussaari, M. (2004). Restoration of butterfly and moth communities in semi-natural grassland by cattle grazing. Ecological Applications 14: 1656-1670.

Poyry, J., Lindgren, S., Salminen, J. & Kuussaari, M. (2005). Responses of butterfly and moth species to restored cattle grazing in semi-natural grasslands. Biological Conservation 122: 465–478.

Pratt, R.M, Putman, R.J., Ekins, J.R. & Edwards, P.J. (1986). Use of habitat by free-ranging cattle and ponies in the New Forest, southern England. Journal of Applied Ecology 23: 539-557.

Putman, R.J., Pratt, R.M., Ekins J.R. & Edwards, P.J. (1987). Food and feeding behaviour of cattle and ponies in the New Forest, Hampshire. Journal of Applied Ecology 24: 369-380.

Pykala, J. (2005). Plant species responses to cattle grazing in mesic semi-natural grassland. Agriculture, Ecosystems and Environment 108: 109-117.

Rambo, J.L. & Faeth, S.H. (1999). Effect of vertebrate grazing on plant and insect community structure. Conservation Biology 13: 1047-1054.

Ransome, R.D. & Priddis, D.J. (2004). Slaughter of grazers due to foot and mouth disease confirms the importance of *Aphodius* dung beetles to the greater horseshoe bat, *Rhinolophus ferrumequinum*. Bat Research News 45(3): 143-144.

Redpath, S.M., Thirgood, S.J. & Clarke, R. (2002). Field vole *Microtus agrestis* abundance and hen harrier *Circus cyaneus* diet and breeding in Scotland. Ibis 144: 33–38.

Shropshire Wildlife Trust (no date). The Siperstones Back to Purple Scheme. Available at: http://www.wildlifetrusts.org/living-landscape/schemes/stiperstones-back-purple-and-beyond. Accessed on 17 August 2012.

Stephenson, G.R. & Veigel, A. (1987). Recovery of compacted soil on pastures used for winter cattle feeding. Journal of Range Management 40: 46-48.

Strong, L. (1992). Avermectins: a review of their impact on insects of cattle dung. Bulletin of Entomological Research 82: 265-274.

Strong, L. & R. Wall (1994). Effects of ivermectin and moxidectin on the insects of cattle dung. Bulletin of Entomological Research 84: 403-409.

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

Todd, P.A., Phillips, J.D.P., Putwain, P.D. & Marrs, R.H. (2000). Control of *Molinia caerulea* on moorland. Grass and Forage Science 55: 181-191.

Torrea, I., Dıaz, M., Martınez-Padilla, J., Bonal, R., Vinuela, J. & Fargallo, J.A. (2007). Cattle grazing, raptor abundance and small mammal communities in Mediterranean grasslands. Basic and Applied Ecology 8: 565-575.

Van Wieren, S.V. (1991). The management of populations of large mammals. In: I. Spellerberg, F. Goldsmith and M.G. Morris (eds). The scientific management of temperate plant communities for conservation. Oxford, Blackwell Scientific Publications, pp. 103-128.

Wallis de Vries, M. F. & Dalebondt, C. (1994). Foraging strategy of cattle in patchy grassland. Oecologia 100: 98-106.

Wallis de Vries, M.F. & Schippers, P. (1994). Foraging in a landscape mosaic: selection for energy and minerals in free-ranging cattle. Oecologia 100: 107-117.

Wallis De Vries, M.F., Bakker, J.P. & Van Wieren, S.E. (1998). Grazing and Conservation Management. Dordrecht, The Netherlands, Kluwer Academic Publishers, pp. 370.

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

Watkinson, A. and Ormerod, S. (2001). Grasslands, grazing and biodiversity: editors' introduction. Journal of Applied Ecology 38: 233-237.

Whyte, A. (2010). Establishment of a mobile sheep flock to maintain and improve mesotrophic species rich grasslands in Fife and Falkirk, Scotland. Conservation Evidence 7: 44-51.

Williams, C., Salter, L. & Jones, G. (2011). The winter diet of the lesser horseshoe bat (*Rhinolophus hipposideros*) in Britain and Ireland. Hystrix-Italian Journal of Mammalogy 22(1): 159-166.

Woodcock, B.A., Pywell, R.F., Roy, D.B., Rose, R.J. & Bell, D. (2012). Grazing management of calcareous grasslands and its implications for the conservation of beetle communities. Biological Conservation 125: 193–202.

Wratten, S.D., Mead-Briggs, M.A., Gettinby, G., Ericsson, G. & Baggott, D.G. (1993). An evaluation of the potential effects of ivermectin on the decomposition of cattle dung pats. Veterinary Record 133: 365-371.

Wright, I.A., Pakeman, R.J., Dennis, P., Dalziel, A. & Milne, J.A. (2006). The effects of cattle on the natural heritage of Scotland. Inverness, Scottish Natural Heritage, pp. 84.

Vera, F.W.M. (2000). Grazing Ecology and Forest History. Wallingford, CABI International.