THE UPLAND ECOLOGY OF SCOTLAND:
A REVIEW OF THE FAVOURABLE CONDITION APPROACH IN RELATION TO
GRAZING AND CARBON STORAGE

Dr James Fenton, October 2014

This document is available as download from http://bit.ly/1s8bz7q
It is based on one originally commissioned by the Scottish Gamekeepers Association as part of their input to
the 2014 consultation on Scotland’s Wild Deer: A National Approach.

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Introduction
In recent years there has been much talk in conservation circles about overgrazing in the uplands, about there being too many deer. The underlying reason for this appears to be that deer eat trees, resulting in many sites being declared in ‘unfavourable condition’ owing to the browsing-induced tree mortality. Woodlands are seen as a key habitat so that any lack of regeneration must be rectified by reducing the herbivore population. Additionally trees are seen as important carbon stores so that their spread should be encouraged to help mitigate global warming. This document is a critique of the above topics and of the whole ‘favourable condition’ approach to the management of upland sites. At the same time it attempts to clarify many of the relevant ecological terms which are often loosely defined in common parlance. There cannot be full communication unless we agree with the meaning of words and of the underlying concepts.

Note that this document applies to what has traditionally been known as ‘hill land’, i.e. unimproved land above the head dyke: areas where there is a dominance of natural and semi-natural vegetation and designated sites can be seen as islands within a wider, unbounded landscape. The arguments presented here will not necessarily be applicable in the lowlands, where natural and semi-natural habitats are islands within a wider landscape of artificial habitats. Indeed, different approaches to conservation are needed in the uplands and lowlands.

In summary this document is suggesting there needs to be a change in mindset from ‘what habitats do we want’ to ‘what habitats would we expect in a naturally functioning ecosystem’; it also questions the assumption that additional trees will always mitigate climate change. The following topics are covered, although because there is overlap some repetition is inevitable.

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1. BIODIVERSITY

The word 'biodiversity' (shorthand for ‘biological diversity’) is a commonly used term nowadays, but in practice different people mean different things by it. Its meaning also varies depending on the geographic scale at which it is applied.

a. Diversity at the global scale: At a global scale, biodiversity can be defined as the indigenous plants, animals and habitats found in the different parts of the planet, together with their natural arrangement: some areas of the globe are species-rich, some species-poor, and it is this variety that provides the total global biodiversity. From this perspective, the biodiversity of Scotland is fixed and cannot be increased (except through natural immigration of species) although it can be reduced, and also restored if humans have previously reduced it. Where the natural ecological characteristic of an area of Scotland is to be relatively species-poor, then this characteristic contributes to the variety of global diversity; in this instance, any human activity to make it more species-rich will, in fact, be reducing the biodiversity of Scotland.

b. Synonymous with 'high species diversity': However the above is often not the definition of biodiversity used in common parlance. Instead it is used as shorthand to mean ‘high species diversity’, with the aim of ‘biodiversity conservation’ being to increase the diversity of plants, animals and habitats in a given area. It can be seen that in some instances increasing the biodiversity at the local level (in the sense of increasing the diversity of species and habitats) can damage the biodiversity at the global level (in the sense of maintaining an area’s natural relatively species/habitat-poor characteristics).

c. Synonymous with ‘nature conservation’: In a third meaning of the word, ‘biodiversity’ is often used as a substitute for the previously used term ‘nature conservation’, such as in the phrase ‘biodiversity objectives’ which is synonymous with ‘nature conservation objectives’.

Relevance to conservation management: To avoid confusion, particularly the mindset that maximum or high species or habitat diversity is always the optimum nature conservation aim, it is suggested that the word ‘biodiversity’ should be restricted to referring to Scotland’s plants and animals in a global context. In many cases, the word ‘biodiversity’ can be replaced by the word ‘diversity;’ for example, the vague phrase ‘grazing benefits biodiversity’ would be better expressed as ‘grazing can increase the diversity of species present’.

2. NATURAL HERITAGE

‘Natural heritage’ means the same as ‘biodiversity’ at the global scale: the indigenous plants, animals and habitats found in Scotland, together with their natural arrangement.

Relevance to conservation management: The term should be seen as synonymous with the term ‘biodiversity’ when the latter is used at the global scale, although note that it also includes aspects of the abiotic environment such as rocks and water.

Fig.1. The south side of Glen Coe illustrating a range of different habitats.
3. ECOSYSTEM

The word ‘ecosystem’ (shorthand for ecological system) is often used in terms such as ‘the ecosystem approach’, ‘ecosystem services’ and ‘ecosystem health’. It is important, therefore, to be clear about how a given ecosystem is defined. In the uplands, red deer are free-ranging animals which, in the course of a day, range across a variety of vegetation types. These vegetation types, often called ‘habitats’, have been classified in various ways; some are small, only a metre or two across (e.g. an upland spring) whereas others can be small or large in area (e.g. dry heath). This gives rise to a fundamental issue: should each vegetation type be viewed as an ecosystem in its own right, or is ‘the ecosystem’ the whole deer range?

Fig.2 below is a diagram of the vegetation pattern of Glen Coe (see Fig.1), an upland site with a wide range of different habitats. Apart from the steepest slopes and cliffs, the area is open to grazing throughout. What here constitutes the ‘ecosystem’? One approach would be to treat every identified plant community as an ecosystem in its own right, another to see the whole glen as a ‘system’.

There is probably no objective answer to this dilemma: it is for us to reach common agreement. Where deer are a key component, it makes sense to view the ecosystem on the scale of deer range, i.e. on a scale of kilometres rather than metres. In the example of Glen Coe, deer will range from the bottom of the glen to the top of the mountain ridges and hence it is sensible for the whole area to be seen as one ecosystem; there is a case, though, for the areas inaccessible to deer, such as the woodland on cliffs, to be seen as small ecosystems within this wider ecosystem.

Fig.2. The whole assemblage at Glen Coe is best considered as ‘the ecosystem’.
The approach of seeing the whole assemblage as an ecosystem is logical. This is because if each vegetation type is treated as a different ecosystem, then, bearing in mind the number and extent of different vegetation types in Scotland (many of which in any case intergrade), the whole process of determining the ecosystem approach, health and services will founder in complexity: see ‘Favourable Condition’ (page 9) where the impossibility of all habitat types being in favourable condition is discussed.

There have to be some limits set to the area covered by a given ecosystem, but again this will have to be accepted pragmatically because boundaries will in most cases be arbitrary. Most often these will be where large areas of different vegetation types adjoin, e.g. moorland and plantation forestry, or along watersheds.

**Relevance to conservation management:** The definition of a given ecosystem is of fundamental importance because such strong credence is given to the concepts of ‘the ecosystem approach’, ‘ecosystem health’ and ‘ecosystem services.’ It makes most sense in the uplands to use the term ‘ecosystem’ as the system at the landscape-scale, i.e. related to the deer range and containing a varied range of habitats.

### 4. ECOSYSTEM APPROACH

In the example of Glen Coe (Figs 1&2) this approach would mean looking at the whole glen in the round. In other upland sites, it would likewise mean looking at all the habitats together, rather than prioritising some habitats over others. Red and roe deer are key components of most Scottish terrestrial ecosystems, and the ecosystem approach should recognise the expected impacts of the presence of large herbivores.

Ecosystems can be dynamic entities over long timescales, and can go through cyclical changes, for example in east Glen Affric where the native pinewood has been shown to cycle wood-heath-wood (Paterson 2011) or through long-term successional changes, e.g. woodland to moorland.

**Relevance to conservation management:** Taking an ‘ecosystem approach’ means that account has to be taken of how the whole system operates at a landscape-scale, including long-term cyclical and successional changes in vegetation composition. See also ‘Favourable Condition’ (page 9).

### 5. ECOSYSTEM HEALTH

This is rather a vague term, but generally means that all aspects of an ecosystem are in balance and everything is working as it ‘should’ (it assumes we know how the ecosystem should be operating). However, in practice it can be difficult to know what it means: in the Glen Coe example, if the relict pinewood is treated as a separate ecosystem and is declining, it could be said to be ‘in poor health’. However, if the whole vegetation assemblage is seen as one ecosystem, than a decline in one aspect may be part of a natural process and so not indicate ‘poor health’. Another example might be a heather beetle attack on heathland: although during the attack the heather could be deemed unhealthy, it could well in fact be part of a natural process. The term ‘ecosystem health’ does take not into account the dynamism in ecosystems, e.g. a long term successional change from one vegetation type to another.

**Relevance to conservation management:** It is suggested here that the term is not used, but instead a term more focussed on the context. The term ‘naturally functioning ecosystem’, which assumes all the natural components are present, might be a better phrase to use.
6. ECOSYSTEM SERVICES

The benefits to humans provided by ecosystems. In common parlance it is normally used to mean the benefits from ecosystems comprised of natural or semi-natural vegetation rather than artificial habitats such as intensive farmland or forestry. Often the term is used generally, without defining the ecosystem/s in question. There is a large literature on the subject, but generally the services are classified into four categories:

1. Supporting (energy flow and nutrient cycling)
2. Provisioning (food and material used by humans)
3. Regulating (minimising impacts harmful to humans)

Relevance to conservation management: The term has wide credence, particularly in justifying the conservation of natural ecosystems; however, the ecosystem in question needs to be defined. It should be noted that in some instances the services attributed to upland ecosystems, such as flood control, erosion control and carbon sequestration, are speculation and have not been objectively verified.

7. NATURAL PROCESSES

These are the processes that take place within an ecosystem outwith the influence of humans. They are principally energy flow (via photosynthesis, grazing offtake, respiration and decomposition), nutrient cycling (carbon, nitrogen, phosphorus, etc.) and inter-species competition. There are also the associated climatic and geomorphological processes, such as cloud formation, precipitation, mountain building, erosion and deposition.

Relevance to conservation management: In natural ecosystems, i.e. ones where the indigenous components are still present, natural processes determine the direction of ecological change. If we wish to conserve such natural ecosystems, humans need to step back from their own objectives and let natural processes decide the pattern of vegetation and species, particularly in light of the uncertainty associated with global warming.

8. BALANCE (in balance with habitats)

An oft-stated phrase is in relation upland management is that ‘deer will be in balance with their habitats’. This is a key issue from a biodiversity perspective, and hence it is fundamental that there is agreement on this. The example of Glen Coe in Fig.2 shows that within the range of a population of red deer there may be a wide range of plant communities (habitats); in practice some of the plant communities retain their high species diversity through grazing, others can lose it by grazing. If an area of woodland is expanding, then by definition, the area of open ground on which the trees are colonising is declining – and vice versa. Such dynamism in Scottish upland ecosystems makes it difficult to determine what is meant by ‘balance’. The issue can be resolved in the Glen Coe example by viewing the whole assemblage of plant communities as one ecosystem, with changes in extent and species composition of a particular community being seen as part of a natural flux: this could be called taking the ecosystem approach (page 4).

Fig.3. Red deer are the main primary consumer in the uplands – a keystone species.
In relation to deer, one way to determine whether the ecosystem is in balance is to relate the amount of plant production in the ecosystem to the expected herbivore population. A standard model used in ecology is that of trophic levels: at the lowest level is the primary production, i.e. the biomass of plants produced through photosynthesis, with energy stored as chemical energy. Plants are eaten by the primary consumers (herbivores) which themselves are eaten by the secondary consumers (carnivores); in some food chains there can also be tertiary (and higher) consumers. As a rule of thumb, only 10% of the energy passes up to the next level. Thus for example, in a given area, every 100 kg of plant material produced annually will support 10 kg of herbivores and 1 kg of carnivores. Although a generalised and simplified model, this trophic level approach can be applied to the vegetation of upland Scotland as shown in Fig.4, which indicates a balanced ecosystem. The data comes from various sources (see ‘References’ at the end).

The plant production figure comes from whole ecosystem production studies carried out at Moor House National Nature Reserve in the northern Pennines in the 1970s as part of the International Biological Programme. This indicated net annual plant production averaged over a range of habitats as 635 g dry wt/m²/yr, range 491-868. This equates to a photosynthetic efficiency of 1%, i.e. 1% of usable solar energy is converted to biomass. The study site is further south than Scotland, although at 550m has a similar range of upland habitats. In Fig.4, a conservative value of 500 g dry wt/m²/yr has been used.

![Fig.4. Trophic level model for upland Scotland: a balanced ecosystem.](image)

The publication *The Grazing Behaviour of Large Herbivores in the Uplands* gives the daily food intake of red deer. An average value of 1.75 kg dry matter/day has been used. This figure gives a deer density of 78/sq km assuming 10% of the plant production passes to the primary consumers. This is a simplification in that it assumes that red deer are the only such consumer, whereas in practice there will be others, both vertebrate and invertebrate. However it does give an order of magnitude indication of the deer carrying capacity, which in practice will vary depending on the proportion and palatability of the actual vegetation types present as well as the presence of other herbivores.

The same method indicates a carrying capacity of 131 blackface sheep, 23 Highland cows or 1,000 mountain hares; voles can also be an important herbivore but are not considered here. The sheep figure equates well with St Kilda studies where the small Soay sheep in an unmanaged and unpredated environment have a varying density of 100-300 /sq km.

Fig.5 shows how the trophic levels would look, based on similar assumptions, when deer density is within the range 4-8 /sq km, the level which is recommended for tree regeneration. The order of magnitude difference between the herbivore density of Fig.4 and Fig.5 is one reason why it is so difficult (and unrealistic) to keep deer numbers low. This is an unbalanced ecosystem.

![Fig.5. Trophic level model for upland Scotland at 4-8 red deer/sq km: an unbalanced ecosystem](image)
A Review of the Favourable Condition Approach in Relation to Grazing and Carbon Storage

The publication *A Highland Deer Herd and its Management* (Milner *et al* 2002) looking at the Letterewe Estate takes a similar approach, although their calculations indicate a significantly lower ecological carrying capacity of deer than the above figures:

“Our model predicts ... that, in the absence of culling, the total population size would stabilise at ... 15.8-17.6 deer/sq km ... The annual vegetation offtake by the simulated population would be up to 15% or production” (pp.214-5).

This discrepancy may reflect the use of a different methodology and/or the lack of enough detailed studies of the productivity of native vegetation in upland Scotland: more studies are needed. However the key point is that the above calculations and the Letterewe study show that the ecological carrying capacity of deer is significantly higher than that which will allow trees to be become dominant. To quote the Letterewe study again, which modelled different red deer cull options:

“Under both high cull options, the average density is sufficiently low that there may be opportunities for the natural regeneration of trees in some localised areas. However, average densities of 6.5 deer/sq km and 8 deer/sq km would still be considered high for ... tree regeneration. Furthermore, the aggregation of deer on low ground during winter means wintering densities along the shore of Loch Maree will be far higher than these averages. Furthermore, heavy grazing of grassland along the woodland margins in all seasons is likely to limit the potential for regeneration in the oak woodlands.” (pp.210,211,214)

In fact in this location the landscape has been largely open for millennia [‘cal BP’ = years ‘Before Present’ (1950)]:

“Around Loch Maree fragmentation [of pinewood] began as early as c. 7400 cal BP (Birks 1972) and became more rapid around c. 4900 cal BP. *Pinus* percentages remain similar to the top of the core [i.e. modern pinewood distribution] suggesting only minor changes after that.” (Paterson 2011, p.58)

![Fig.6. The Letterewe Estate showing the woodlands along the shore of Loch Maree.](image)

It has been argued that extermination of the wolf in Scotland has resulted in deer population levels higher than a natural level. Estimated wolf figures are given in Fig.4, based on an average daily meat consumption of 5.53 kg/day (references indicate a range 2.77-10.4 kg/day) and 65% water content of the meat. Fig.4 also indicates that the presence of wolves amongst unmanaged red deer would not bring the density down to the 4-8/sq km needed in upland Scotland to allow trees to flourish. However, woodland declined in Scotland during the centuries when wolves were present: this shows that the reintroduction of wolves to Scotland will not result in the general recolonisation of the landscape by trees, although it may have some localised effect through deer disturbance. Currently the role of wolves is taken by stalking and culling.

This situation of large herbivores keeping the landscape open occurs in other parts of the world. For example, the environmental historian Kaplan (quoted in New Scientist, 16 November 2013, p.37), based at Geneva University’s Institute for Environmental Science, says that removal of large animal species by humans has had effects on the landscape that are apparent almost everywhere:

“A lot of land would be semi-open, kept partly open by these big herds of grazers and browsers and predators. It is important to keep in mind that landscape is also shaped by animals. These giant herds of bison would be trampling down little trees and keeping the landscape open.”

On a similar theme, Ian Macleod, manager of the Hebridean Mink Project, states in relation to predation (quoted in The Herald, 5 February 2014, p.10):

“The important factors are the climate and food available. If you looked at the savannah of Africa and saw a herd of 10,000 wildebeest walking across, and in the foreground there was a pride of lions, you would instinctively recognise the lions cannot control these numbers. It’s grass and water that do that.”

The authors of the Letterewe Study say the same:

“Over-grazing is a controversial term ... Its precise definition is dependent on management objectives ... Over-grazing is not generally applied to natural ecosystems, even under heavy grazing pressure, because wild herbivores are regulated by their food supply during the unfavourable season ... For example, there is no evidence of habitat degradation on St Kilda or the North Block of Rum where herbivore populations are naturally regulated.” (p.31).

It should be noted that in some areas of Scotland, woodland can expand even under high grazing levels; these are coastal areas in Argyll where the richer soils allows thorny shrubs such as sloe, hawthorn and bramble to grow, which protect young trees from grazing. At Burg on Mull, for example, ash trees can be seen regenerating in sloe scrub in spite of grazing by sheep, red deer, cattle and feral goats. These situations represent the woodland regeneration model applicable to temperate Europe suggested by Frans Vera (2000).

**Relevance to conservation management**: In summary, high numbers of red deer are no indicator of an ecosystem out of balance, but reflect the amount of grazing available. Note that even at, say, 78 deer per sq km (Fig.4), one hectare will be providing grazing for less than one red deer. The absence of trees does not mean that the wider ecosystem is out of balance.

A balanced ecosystem can be equated to a ‘naturally functioning ecosystem’, *i.e.* where natural processes determine the direction of ecological change. In such a system, humans need to step back from their own objectives and let nature decide the pattern of vegetation and species.
9. FAVOURABLE CONDITION

Protected sites are designated for nature conservation because they possess features (i.e. plants, animals and/or habitats) deemed to be important for Scotland. The relevant features for a given site are termed the ‘notified features’. The state of these notified features is assessed using a standardised process of ‘condition assessment’ [see ‘Common Standards Monitoring’ on the Joint Nature Conservation Committee website for the methodology]. As the statutory agency responsible for nature conservation, Scottish Natural Heritage (SNH) has an aim that the notified features in designated sites be in ‘favourable condition’ using standardised measures, i.e. their condition is stable or improving.

This approach looks separately at each species or habitat within a site; for example, in the diagram of Glen Coe (Fig.2) the condition of every habitat illustrated will be studied (if that habitat is on the list of notified features). However this approach assumes static ecosystem and does not allow for natural changes between different habitat types.

It also brings in a legal mindset that rarely makes sense in ecological terms: in the example of Glen Coe (Fig.2) because most of the area has been formally designated as a Site of Special Scientific Interest (SSSI) and also a Special Area of Conservation (SAC) under the EC Habitats Directive, SNH sees itself as having a legal obligation to keep the notified features in ‘favourable condition’; likewise, the EC Habitats Directive identifies some, but not all, of the habitats as important in European terms. This approach has a strength in that it simplifies complex ecosystems, breaking them into their individual units. But it also has many weaknesses: it assumes ecosystems are static and does not allow for long-term changes; it gives importance to some habitats over others based on legislation, which in the case of the Habitats Directive is 30 years old: this fossilises the ecological understanding of a now distant era and does not allow for new thinking and approaches about the conservation of Scotland’s upland ecosystems and the importance of different habitats.

However it should be noted that the EC Habitats Directive refers to a habitat’s ‘favourable conservation status’ not ‘favourable condition’: the EC is more concerned about the state of the habitat across its range, not at particular sites – a decline at one site might be balanced by an increase at another site. However this approach suffers from the same weakness of assuming that the ecology of upland Scotland is static, and of giving greater priority to some habitats over others: the need to keep what we...
have rather than allow natural change. The approach can result in ecosystems being permanently out of balance, particularly if environmental conditions change. It could be argued that it does not take the ‘ecosystem approach’ (page 4).

The approach also suffers from the weakness that significant areas of habitats recognised as important under the Habitats Directive are located outwith designated sites. Designating particular sites as important (SSSIs and SACs) again simplifies the process of nature conservation in that effort can be focussed on these sites rather than the whole landscape. But looked at objectively, habitats are no respecters of boundaries and whether an important habitat occurs within or without an SSSI/SAC will not affect its European importance: indeed, sites outwith SSSIs should contribute to the habitat’s favourable conservation status.

Fig. 8. It is suggested that ‘favourable condition’ should apply to the landscape as a whole and not be based on the most sensitive habitat. In the picture above, it makes little ecological sense for the grazing level to be determined by that necessary for the isolated trees to regenerate.

The ‘favourable condition’ approach adopted by SNH, and the rest of the UK, does simplify matters in that it is standardised and hence easy to undertake. However upland ecosystems are infinitely variable and such a standardised approach can be used to avoid the complexity of understanding the detail of a given area. The approach also uses measurements taken at a snapshot of time to determine long-term ecological trends. However experience suggests that this is rarely a straightforward exercise; detailed photographic monitoring of heavily grazed heather over ten years undertaken by the author on the island of Canna on behalf of the National Trust for Scotland, for example, did not give enough time to determine whether the area of heather was static, declining or expanding. And Milner et al (2002) state in relation to the Letterewe Estate:

“The impact categories used in these [habitat condition] assessments have not been equated to actual trends in parameters such as heather cover, height or growth rate, making the interpretation of condition surveys very subjective. In addition, the qualifying criteria for high, moderate or low grazing impact categories do not reflect well whether heather is declining, static or increasing. Furthermore, this method has never been calibrated in wet heath or blanket bog habitats and the calibration of dry heath may not be applicable to areas outside north-east Scotland.” (p.138).
This is reiterated in the SNH Commissioned Report No. 402 (Holland et al 2010):

“Field studies have shown that the response of upland vegetation to changes in grazing management is not always predictable.”

The statutory agencies, and indeed the conservation NGOs generally, need to review their whole approach to how legislation is interpreted and how the use of ‘favourable condition’ relates to the natural ecological dynamics of the whole ecosystem.

The weaknesses of the ‘favourable condition’ approach have in fact been realised by SNH in their Commissioned Report No. 402 Developing guidance for managing extensive upland grazing where habitats have differing requirements (Holland et al 2010):

“A single upland management unit will often contain habitat types that require very different grazing levels. If there are habitats in the same land management unit that require very different grazing pressures and are accessible to grazing animals then a conflict might arise (p.69).

“Some habitat types require very low levels of grazing (e.g. montane willow scrub), or little or no grazing at all (e.g. tall herbs), to be in favourable condition whereas others require moderate to high levels of grazing (e.g. calcareous grassland). The requirements of the other feature types lie somewhere between these extremes (p.68).

“When developing management plans the most important thing is the setting of clear objectives for the site. It may be hard to devise a management regime that will maintain all the habitats in favourable condition. In these situations some compromise may be required with priority given to one or more features. This will have to be done on a site by site basis (p.78).”

This illustrates the point that choosing a grazing level lower than the carrying capacity of the wider ecosystem will be arbitrary, depending on the priority given to a given feature, rather than consideration of how the whole ecosystem operates (the ‘ecosystem approach’).

In practice, at designated sites and in the upland landscape generally, SNH gives priority to woodland over other habitats. For example, at the Loch Hope SSSI the conservation objectives for the upland birchwoods are given in MacKenzie & Clifford (2010):

“The principal conservation objectives for the Ben Hope SSSI woodlands are to ensure that there is a continuous presence of mature trees across the majority of the site and that the biodiversity of the habitat is maintained in a favourable condition. In order to carry out these objectives sufficient established regeneration of all the relevant tree and shrub species must be distributed across the three woodland blocks.”

This illustrates a loose use of the word ‘biodiversity’: presumably in this context it means ‘the current diversity of plants of and animals’. However the objective itself needs to be questioned: birchwoods are dynamic entities with episodic regeneration at the woodland edge (Fig.9), and they can expand or die out at a given location. Often there is a small ungrazed core area of woodland on a cliff or steep slope, from which woodland can expand if conditions are favourable (Fenton 1985): the objective of maintaining the current geographical area of wood does not take account of this dynamism or of the functioning of the wider ecosystem. The situation at the Loch Hope SSSI is very similar to that at the Ardvar Woods SSSI (see Beck 2009).
Fig. 9. Birchwoods generally show episodic regeneration at the edge of the mature wood. This can result in the woods moving around the landscape. Woods can die out if conditions are never favourable for regeneration.

Research also indicates that native pinewood moves around the landscape, in many cases declining eventually to extinction. For example, Paterson (2011, pp. 60-1) states:

“A small population [of pinewood], in constant flux, has remained on Rannoch Moor on ‘the extreme west of the area of Pine dominance in the Grampian mountains’ (Walker & Lowe 1981, page 475). At the Rannoch and Corrour Stations and Kingshouse sites, Pinus disappeared by the mid-Holocene, probably as a result of increasingly wet conditions and competition from Alnus (Walker and Lowe 1981).”

Undoubtedly, deer can damage woodland habitats through preventing regeneration but this damage is merely a natural process within the wider ecosystem.

Loch Hope SSSI is an example of where priority is given to woodland over other habitats, which appears to be the case in most SSSIs where the wood is a notified feature. However, to ensure woodlands remain in situ without fencing means that the whole ecosystem has to be put out of balance to achieve this (see ‘Balance’, page 8) – through reduction of grazing to that significantly below the ecological carrying capacity. This can be difficult, if not impossible, to achieve in the long term. At the Ben Hope SSSI, as at many others, there has been some birch regeneration in recent years, so it is not as though woodland is going to die out completely from the locality: determining how much woodland is ‘enough’ is arbitrary.

**Relevance to conservation management:** ‘Favourable condition’ should mean the condition of the wider ecosystem and should not be determined by the condition of the habitat most sensitive to grazing, *i.e.* woodland and montane scrub. There needs to be an extensive review of the ecological validity of the whole ‘favourable condition’ approach when applied at the landscape scale in the uplands.
10. APPROPRIATE VEGETATION COVER
An ecosystem in balance (see ‘Balance’, page 8) will have a level of grazing determined principally by the ecological carrying capacity of the vegetation. The resultant pattern of vegetation will be the ‘appropriate’ one. In other words, the appropriate vegetation cover is determined by the natural factors of climate, soils, grazing, inter-species competition and chance.

If an ecosystem where natural processes dominate is not the one being sought, then the ‘appropriate vegetation cover’ will be the one that fulfils the agreed management objectives (e.g. the retention of woodland or species-rich grassland), which may or may not be underlain by statutory requirements.

Relevance to conservation management: There needs to be a change of mindset from ‘what habitats do we want’ to ‘what habitats would we expect in a naturally functioning ecosystem.’ As discussed under ‘Favourable Condition’ (page 9), it is important to note that the statutory requirements, or at least how they are currently interpreted, may not be in keeping with the natural characteristics of the wider ecosystem; in this case it will difficult to achieve and sustain the desired vegetation cover over the long-term.

11. APPROPRIATE LEVEL OF GRAZING AND TRAMPLING
This means maintaining the grazing and trampling levels within a range that will maintain the appropriate vegetation cover.

Relevance to conservation management: If the ‘appropriate vegetation cover’ does not reflect the natural characteristics of the area, then it will be difficult to sustain over the long term the ‘appropriate’ level of grazing and trampling.

12. IMPACTS OF DEER ON THE ENVIRONMENT
Red and roe deer are an integral part of Scotland’s biodiversity. By definition, any grazing animal is going to impact on the plants it eats and the ground it walks over.

The distribution and foraging activity of red deer are affected by a number of factors, the result of which is that they are likely to be unequally distributed across the landscape. The palatability of vegetation is a key determinant. Research on Rum, for example, illustrates the area of ‘greens’ (areas of grassland on better soils) has a major influence on the overall deer population. In the Cairngorms it is the areas underlain by the base-rich soils which have the highest grazing impact:

“The main concentrations of moderate to heavy impacts were on the vegetation of the base-rich Moinian and Dalradian rocks surrounding the acid granite core in Upper Deeside, Goldie Burn, Glen Quoich, Gleann an t-Slugain, Glen Feshie, Pityoulish, Dorback Burn-Braes of Abernethy, Inchrory, Craig Leek and Glen Clunie.” (Horsfield, 2009).

However grazing of these areas will help maintain both the vascular plant diversity and the fertility of the soil through enhanced nutrient cycling and keeping the pH high enough to allow earthworms to thrive (resulting in mixed, ‘mull’ soils rather than unmixed ‘mor’ soils that dominate most of the uplands and where nutrient cycling, and hence soil fertility, is limited).

In addition to the quality of the forage, red deer distribution is also affected by time of day (diurnal migration), weather (sheltered areas being favoured), snow cover, disturbance by humans (whether by walkers or stalkers), biting insects, sexual behaviour (e.g. differential grazing by stags and hinds, movement of young males) and habit (hefting). Hence it is to be expected that the impact of deer may well be concentrated in some areas, with low impacts in other areas.
“On areas where sheep have been removed red deer numbers are likely to increase as a result of the increase in available herbage, reduced competition from grazing livestock and lower levels of disturbance. These increases in red deer may in part compensate for the loss of livestock; however there are differences in the foraging behaviour of sheep and deer and their numbers and geographical distribution are likely to be much more variable both seasonally and annually (p.70).” (Holland et al 2010)

Hence the presence of ‘high impact’ areas is likely to be a natural feature of the wider ecosystem: aiming for low impact everywhere is likely to be going against the natural characteristics and result in an ecosystem out of balance (see ‘Balance’, page 8).

Deer, of course, impact on the distribution of trees: see ‘Balance’ and ‘Favourable condition’ for further discussion of this topic. However the absence of trees over much of the Highland landscape appears to have been brought about by natural causes. For example Paterson (2011, pp.58-9) states:

“In core areas [of pinewood], woodland is subject to fragmentation from as early as c. 7500 cal BP; fragmentation is diachronous and is believed to have been earliest in the west (Tipping 1994, Huntley et al. 1997). Human activity is sometimes implicated in woodland fragmentation but is more often cited as reinforcing the effects of a maritime climate preferentially affecting Pinus dominated woodlands ... Only in Speyside is human activity thought to initiate disintegration.

“In west Glen Affric, Pinus began to decline at c. 4000 cal BP with woodland continuing to fragment until c. 2000 cal BP (Davies 2003a and b, Shaw 2006), by which time the valley consisted of the ‘apparently monotonous treeless landscape’ seen today (Davies 2003b, page 75).

“Arrival of Pinus at Geldie Lodge [Mar Lodge Estate] is undated but occurs before c. 7550 cal BP. Woodland is always more open; Pinus is co-dominant with Betula, showing affinity with other peripheral areas. Pinus woodland fragments at all Mar Lodge sites from c. 3900 cal BP, disappearing from Geldie Lodge by c. 2800 cal BP and White Bridge by c. 1900 cal BP. Calluna replaces Pinus as the dominant species at all three sites. The disappearance of Pinus is thought to relate to regional climatic change toward wetter conditions.”

Environmental historians such as Paterson generally view vegetation change as being caused by changing climatic conditions and rarely mention the role of animals, which is surprising considering that red deer are one of the determinants of woodland survival in Scotland today. However Svenning (2002) has reviewed the open landscapes of temperate Europe and concluded that the opening up of the landscape, i.e. a reduction of tree cover, is a natural process to be expected at this stage of a post-glacial era:
“Vegetation development during the preceding [pre-Holocene] interglacials ... suggests that open woodland or even heath vegetation can develop on nutrient-poor soils. Numerous interglacials show expanding NAP [non-arboreal pollen] percentages ... This development is interpreted as caused by acid, infertile soil conditions and perhaps increasing rainfall... The ability of large herbivores to open up the vegetation would probably also be stronger on poor soils.”

A key point is that bringing woodland back to these open landscapes appears to be going against the natural processes, including grazing, which has resulted in a generally unwooded landscape. The absence of trees, together with the impact of deer, can be seen as a natural characteristic of the ecosystem.

Deer themselves are a component of the natural heritage and just by eating any plant will ‘impact’ on other aspects of the natural heritage:

“Deciding whether deer have had a negative impact on the ‘natural heritage’ depends on one’s definition of natural heritage. There would certainly be more trees in a landscape that had neither deer nor sheep........ But the existing, relatively bare, Highland landscape is the ‘natural heritage’ that has been passed between generations for several centuries.” (Milner et al 2002, p.139)

The habitat impact assessment approach (site condition monitoring) of SNH has rarely found deer causing high impact on the habitats present in upland landscapes. Examples are given below:

From SNH Commissioned Report 322 (Horsfield 2009)

**Cairngorms Core Area**: The Cairngorms Core Area was found to be generally not heavily impacted; almost 74% of 3,903 0.25 km squares were assessed as light or light to moderate impact, with 15% moderate or light to heavy, while there were only about 11% of squares assessed as moderate to heavy or heavy (p.3).... Generally, heavy grazing and trampling impacts, where the habitats were likely to suffer damage and deterioration, were localised (p.ii).

![Fig.11. Part of the Cairngorms core area.](image-url)
From SNH Commissioned Report 402 (Holland et al 2010)

Beinn Heasgarnich SSSI/SAC: Grazing impacts were generally low or low to moderate for all feature types (p.19).

Meall na Samhna SSSI/SAC: Grazing impacts were generally low or low to moderate for all the feature types (p.19). The HIA data suggests that the current level and patterns of grazing on Meall na Samhna appear to be appropriate for the flushes on the site but may be too low for the smooth grassland and too high for the wind-clipped heath. The data provides some evidence of real conflicts in achieving the nature conservation objectives for these different features (p.29).

Beinn Dearg SSSI/SAC: Beinn Dearg is a large site with large areas of alpine moss-heath, montane grass-heath and blanket bog which in some places are experiencing higher impacts than is desirable for those habitats. The species-rich grassland occupies a much smaller area but unlike the other feature types is experiencing lower impacts than is desirable over much of its area. This is creating a potential conflict, with the grazing level in some areas too high to achieve favourable condition for the alpine moss-heath, montane grass-heath and blanket bog and yet too low for the grassland (p.40).

Fannich Hills SSSI/SAC: Grazing impacts of Moderate to Very High were recorded at almost 15% of the feature type locations. Over 23% of the dry heath locations were assessed as Moderate to Very High (p.52).

Cairngorms (East): Most of the feature locations in the two estates on the eastern side of the Cairngorms SAC (Eastern Cairngorms SSSI) were assessed as having low or low-moderate grazing impacts (p.56).

From SNH Commissioned Report 425 (Dayton 2011)

Ben Loyal SSSI/SAC: Across the higher, exposed ground and peatland areas, impacts to alpine heath, blanket bog and wet heath are Moderate or Low, and trend indicators suggest a stable situation, with a few exceptions to the south-west and through the Bhealach Claíns Ceap. Grazing and trampling impacts on dry heath are, however, mostly high.

From SNH Commissioned Report 451 (Dayton & O’Hanrahan 2011)

Foinavon SAC/SSSI: Over 84% of blanket bog squares, 59% of wet heath squares and 55% of dry heath, squares had trampling and grazing impacts in the ranges ‘Low’ or ‘Low to Moderate’. However there was some locally heavy trampling and browsing of all three habitats.

From SNH Commissioned Report F99AC402 (McLeod 2002)

This report presents the results of counts conducted of sheep, red deer Cervus elaphus, and mountain hare Lepus timidus in the summers of 1987 - 1999 on 47 sites in the montane zone of the Highlands of Scotland... Overall, however, it was apparent that many sites are probably not experiencing levels of grazing that represent a threat to the future of protected montane plant communities.

From SNH Commissioned Report 410 (Cummins et al 2011)

[Studies of peat erosion in the Ladder Hills SSSI, Monadhliath SSSI and four peatland SACs in Caithness and Sutherland show] there was no clear evidence to indicate that densities of large herbivores were associated with the incidence, severity or type of erosion... If herbivores are a main driver of erosion, it is possible that this is due to local concentrations of animals that are detectable only by detailed field studies (p.iv).

The above studies do not indicate levels of deer grazing that are having a major impact on upland plant communities, although there are localised areas where impact is heavy, such as the Moine Mhor in the Cairngorms. However, as discussed above, it would not be expected for deer to be evenly distributed across the site, with concentrations in some areas. Neither is there evidence that red deer are instigators of peat erosion on a significant basis; in any case, most peatlands will go through a natural millennial-scale cycle of growth and erosion.
Red deer should be seen as a ‘keystone species’. Their grazing generally increases plant diversity at the local scale, although affects the distribution of plants such as trees at the wider scale. Their grazing of the greens helps maintain fertility of these areas, making the whole ecosystem more productive. Their trampling provides seed beds for many plants. Carcasses through natural mortality are important sources of food for many species.

**Relevance to conservation management:** The above indicates that there is no strong case based on habitat impact for a general reduction in deer numbers if an ‘ecosystem approach’ (page 4) is taken, i.e. the whole landscape is viewed in the round. However this is not to say that deer are not impacting woodland habitats.

13. HABITAT NETWORK

This is generally applied to any grouping of natural or semi-natural habitats which are linked geographically to form a network that species can use to move around the locality without encountering barriers of artificial habitats.

However, the term is often used to mean specifically ‘woodland networks’, i.e. the linking together of woodlands across the landscape. If a new woodland network is created through areas of open moorland then it will result in fragmentation of the existing moorland network. In the lowlands, where artificial habitats are the norm, then a habitat network may consist of a range of relict or new habitat types, e.g. hedges, woods, grassland, wetlands.

**Relevance to conservation management:** To avoid confusion in terminology it is suggested the term ‘habitat network’ is not used when referring to networks in upland Scotland. If a woodland network is meant, then the term ‘woodland network’ should be used, if a moorland network then the term ‘moorland network’.

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The phrase ‘A high quality, robust and adaptable environment’ is often included in government policies. These words, however, can be hard to define; an analysis of each is given below.

14. HIGH QUALITY ENVIRONMENT

‘High quality’ is rather a vague term which can be hard to define. It has most meaning when referring to the aesthetic experience of a given landscape, in which case a high quality environment would be one with the minimum number of detractors of landscape character. For example, the special qualities of all Scotland’s National Scenic Areas and of both National Parks have been identified (see Scottish Natural Heritage 2010), so in these areas a ‘high quality environment’ would be one where these special qualities are retained. However for areas not designated as National Scenic Areas or National Parks there is no agreed list of special qualities against which to determine whether a given area is a ‘high quality environment’ or not.

However SNH’s Landscape Policy Framework does identify a general quality of Scotland’s hills and moors as ‘Distinctive landscapes of upland, hills and moors, recognised for their openness and quality of wildness.’ The extent of wildness has recently been mapped by SNH [see the ‘Mapping Scotland’s Wildness and Wild Land’ pages of the SNH website].

**Relevance to conservation management:** The term should be restricted to meaning that the identified special landscape qualities of a locality are being retained. Where the special qualities have not been identified (i.e. outwith National Scenic Areas and National Parks), there is a case for identifying them using the methodology devised by SNH (Scottish Natural Heritage 2008). However, ‘openness’ and ‘wildness’ are two recognised qualities of Scotland’s hills.
15. ROBUST ENVIRONMENT, ROBUSTNESS OF HABITATS

A robust environment, or a robust habitat, is one which is relatively resilient if the forces acting on it change. An example might be a habitat which will remain constant across a high range of grazing pressures or different climates. The ecological history of upland Scotland indicates that woodland is one of the least robust of habitats owing to its sensitivity to grazing and climate change. The moorland communities of upland Scotland appear to be the most robust as they persist over a high range of grazing levels and the high water content of their organic soils means that they are also relatively resistant to drought.

The robustness of a habitat can vary; for example woodland growing on a crag will be robust owing to the mineral enrichment and absence of grazing; however, the same woodland type growing on gentle ground will not be robust owing to poorer soils and the presence of large herbivores.

An example of a particularly robust habitat is bracken which, once established, can be hard to dislodge, although at low altitude in the southwest Highlands it can be colonised by thorny scrub, and eventually woodland (the Vera model – see Vera 2000). Habitats which are not robust include montane scrub, as it is very sensitive both to grazing and lack of snow cover (which would protect it from grazing), and montane moss heath which is susceptible both to invasion by vascular plants and to erosion (owing to the lack of roots in mosses and the extreme mountain-top climate). Blanket peat is generally a robust habitat in the early centuries of its growth, but the deeper it gets the higher the probability that erosion will set in: i.e. it becomes less robust as the peat accumulates over time.

In a given locality, such as Glen Coe as illustrated in Fig.2, there are likely to be some habitats which are robust, and some not – resulting in long-term dynamism in the wider ecosystem. There will always be a range of habitats present in such areas, with the extent of a given habitat fluctuating over time. Hence, taking this wider view, the environment here will be robust in that there will still be plants and animals present, albeit varying over time. Hence it is not clear that the term is particularly useful in relation to habitats or the wider environment.

When referring to a population of a plant or animal, a robust population is one large enough to make the chances of extinction low. Hence the term is best used only with specific reference to a population of a given species.
Relevance to conservation management: The habitats we currently value most may not be the most robust ones. The term ‘robust’ term needs to be used with caution. It is perhaps best if it is restricted to reference to populations of a given species.

16. ADAPTABLE ENVIRONMENT
An adaptable environment would be one that responds to any changes imposed on it. However all environments will respond to change in one way or another, so it is not clear if the term is particularly useful. A robust habitat will be one that is resistant to change, i.e. stays the same, whereas an adaptable habitat will be one that adapts (i.e. changes) – the opposite of a robust environment. Hence the conjunction of the words ‘robust’ and ‘adaptable’ can result in contradictions.

Relevance to conservation management: The environment will always adapt to changing conditions, but perhaps not always in ways we like. The term does not seem to be particular useful in relation to upland management.

17. CARBON STORAGE AND SEQUESTRATION
Carbon sequestration in the upland context means taking of carbon out of the atmosphere through photosynthesis and thereafter permanently storing this biomass on land in live or dead plant material; this is a natural process carried out by plants.

If plants are colonising a new site, or woodland has been planted on a previously unwooded site, then as the plants grow the amount of carbon sequestered increases as the total plant biomass increases. In most ecosystems a steady state will be reached, when the amount of carbon taken out of the air by photosynthesis is balanced by the amount lost to the air through respiration, and the death and decomposition of the plant material. In this case the whole ecosystem will contain a store of carbon but will not be actively sequestering it.

The exception to this rule is peat bogs where more and more carbon can be stored as the peat depth increases, peat consisting of a store dead plant material – see Fig.14. Hence peat bogs can sequester carbon throughout the life of the peat bog. However a given peat bog in upland Scotland will not last for ever with the probability of erosion increasing as the peat depth increases. However peat bogs will take carbon out of the atmosphere for thousands of years, and hence mitigate global warming.

Fig.13. The dead plant material retained in peat bogs comprises a large store of carbon – an order of magnitude more than the amount stored in a forest of equivalent area.
Carbon is stored both in plant (and animal) material and the soil. The majority of Scottish soils are unmixed ‘mor’ soils, the soils being too wet and/or acidic to allow earthworms to be present. Hence the surface layers of the soil consist of organic material comprised plant of litter and humus, with deeper soils containing peat as well, although in practice there is no clear cut-off point separating humus-rich and peat soils.

Research indicates that such soils can often store of the order of 300-600 tonnes of carbon per hectare (Artz et al 2014, p.37) with the vast majority storing at least 200 tonnes/ha and deep peats storing significantly more than 1,200 tonnes/ha (ECOSSE report, Scottish Executive 2007, p.26). In comparison the average mass of carbon in a forest of yield class 12 averaged over the lifetime of the forest of 50 years is only 80 tonnes/ha (yield class 24 would be 160t); the forest will also have a store of carbon in the soil beneath the trees. See Appendix 2 which shows the results of a rapid fieldwork assessment of the amount of carbon stored in different habitat types and which illustrates the above points.

However trees planted on organic soils can cause the soil to become drier and through oxidation release the stored soil carbon to the atmosphere (Fig.15) – i.e. contribute to global warming. This has shown to be the case when trees are planted on deep peats, but there is little data to confirm this is the case generally on organic-rich soils such as wet heath. The ECOSSE report (p.98) states:
“In conclusion, the overall effects on soil organic carbon stocks of land use change from semi-natural, extensively grazed vegetation to forestry on organo-mineral soils can be summarised as follows:

• There have been few directly relevant studies of the effects on soil organic carbon stocks of afforestation of organo-mineral soils, so all conclusions about the likely effects of land use change to forestry are inferential from related studies on UK peatlands and studies from abroad.

• It is not possible yet to identify likely effects on soil organic carbon stocks down to individual soil types or even broad categories of freely and non-freely drained soils.

• The overall conclusion (as assumed by UK carbon balance models) is that afforestation probably has little net effect on soil organic carbon stores in organomineral soils, but this is a very uncertain statement.” [emphasis added]

The Forestry Commission report on the issue (Morison et al 2010) echoes this uncertainty:

“It is very difficult to quantify the extent to which tree planting on peat soils results in loss of soil organic carbon (p.3).”

Although it goes on to conclude that

“It is very probable that moderate and high productivity forests planted on shallower peat soils with limited disturbance provide a net carbon uptake over the forest cycle, because uptake of carbon dioxide by the forest exceeds emissions from soil decomposition (p.4).”

But also states:

“There is therefore considerable uncertainty in the conclusions presented here (pp.3-4).”

A crucial missing issue here is the fate of any harvested trees: if, for example, they are burnt in a biomass boiler, then all the carbon stored by the trees has been released back into the atmosphere, so that the net effect will be that carbon released by decomposition in the soil will result in an overall release of carbon to the atmosphere; in other words, the trees only act as a temporary store. If the fate of the trees is for structural timber, then the carbon will be taken out of circulation for a long period.

In practice, not all the carbon fixed by photosynthesis (primary production) enters the soil because grazing animals remove some of it. Fig.4 indicates that an average is for 10% of the primary production to be eaten by herbivores. This is a relatively small percentage of the overall primary production. Thus
even what are thought of as high densities of red deer will not significantly affect the amount of carbon entering the soil, *i.e.* will not contribute to global warming. The exception would be the favoured areas of grassland (‘greens’) where continuous grazing will be removing a significant proportion of the primary production and, through enhanced nutrient cycling, create soils which store less carbon than the habitats in the wider landscape underlain by carbon-rich soils.

**Relevance to conservation management:** It is by no means certain that encouraging woodland onto open moorland, through grazing reduction or tree planting, will mitigate climate change: it could even accelerate climate change through causing carbon stored in the soil to be released to the atmosphere, particularly from wet heath. Additionally, many current areas of moorland could succeed to peat-forming ecosystems in the long-term, hence eventually storing more carbon than is possible in a forest. It should be noted that planting trees on the mineral rich soils of the lowlands will help mitigate climate changes because there is little carbon stored in these soils.

**18. DEER WELFARE**

Red and roe deer are wild animals, *ferae naturae*, owned by no-one: humans are not responsible for the welfare of deer – *i.e.* like other wild animals they are subject to the vicissitudes of nature. Hence they are different from domestic stock such as sheep and cattle where the owner has direct responsibility for their welfare. There is a danger that wider society may blur this distinction and begin to insist that deer are treated in the same way as domestic stock, for example that they must be managed to minimise natural mortality: nobody likes the sight of a lot of dead deer after a hard winter even though this will be a natural event.

An example of the different approaches taken with domestic and wild stock can be seen with the St Kilda flock of feral Soay sheep. Here the sheep are treated as if they were *ferae naturae* with no management and large mortality every few years, owing to the population increasing beyond that which the vegetation can support. This approach would not be tolerated where sheep where being managed on a farm, but would be where deer die for similar reasons.

Where humans are managing deer, or our activities are impacting on deer, then welfare does become an important consideration: culling should be carried out to minimise suffering, fences should be designed to minimise harmful impacts such as loss of essential grazing, and roads designed to minimise deer mortality.

**Relevance to conservation management:** Deer should continue to treated as wild animals with different standards applied to their welfare than domestic animals.
19. SUMMARY OF KEY POINTS

To avoid confusion, particularly the mindset that maximum species or habitat diversity is always the optimum nature conservation aim, it is suggested that the word biodiversity should be restricted to referring to Scotland’s plants and animals in a global context. In many cases, the word can be replaced by the word ‘diversity.’ The term natural heritage should be seen as synonymous with ‘biodiversity’ when the latter is used at the global scale (although natural heritage also includes aspects of the abiotic environment).

The definition of an ecosystem is of fundamental importance because such strong credence is given to the concepts of ‘the ecosystem approach’, ‘ecosystem health’ and ‘ecosystem services.’ It makes most sense to use the term ‘ecosystem’ as the system at the landscape-scale, i.e. related to the deer range and containing a varied range of habitats. Hence taking an ecosystem approach means that account has to be taken of how the whole system operates at a landscape-scale, including long-term cyclical and successional changes in vegetation composition. Owing to its vagueness, it is suggested here that the term ecosystem health is not used, but instead a term more focussed on the context. The term ‘naturally functioning ecosystem’, which assumes all the natural components are present, might be a better phrase to use. In terms of ecosystem services, the ecosystem/s in question need/s to be defined, although it should be noted that in some instances the services attributed to upland ecosystems, such as flood control, erosion control and carbon sequestration, are speculation and have not been objectively verified.

In natural ecosystems, i.e. ones where the indigenous components are still present, natural processes determine the direction of ecological change. If we wish to conserve such natural ecosystems, humans need to step back from their own objectives and let natural processes decide the pattern of vegetation and species, particularly in light of the uncertainty associated with global warming.

High numbers of red deer are no indicator of an ecosystem out of balance, but reflect the amount of grazing available. The absence of trees does not mean that the wider ecosystem is out of balance. A balanced ecosystem can be equated to a ‘naturally functioning ecosystem’, i.e. where natural processes determine the direction of ecological change.

Favourable condition should mean the condition of the wider ecosystem and should not be determined by the condition of the habitat most sensitive to grazing, i.e. woodland and montane scrub. There needs to be an extensive review of the ecological validity of the whole ‘favourable condition’ approach when applied at the landscape scale in the uplands. There needs to be a change of mindset from ‘what habitats do we want’ to ‘what habitats would we expect in a naturally functioning ecosystem’ – the latter would be the appropriate vegetation cover. If an ecosystem where natural processes dominate is not the one being sought, then the appropriate vegetation cover will be the one that fulfils the agreed management objectives, which may or may not be underlain by statutory requirements.

It is important to note that the statutory requirements, or at least how they are currently interpreted, may not be in keeping with the natural characteristics of the wider ecosystem; in this case it will difficult to achieve and sustain the desired vegetation cover over the long-term because the whole ecosystem is out of balance. The appropriate grazing and trampling level will be that which will sustain the appropriate vegetation cover. If the ‘appropriate vegetation cover’ does not reflect the natural characteristics of the area, then it will be difficult to sustain over the long term. There is no strong case based on habitat impact for a general reduction in deer numbers.

To avoid confusion in terminology it is suggested the term habitat network is not used when referring to networks in upland Scotland. If a woodland network is meant, then the term ‘woodland network’ should be used, if a moorland network then the term ‘moorland network’.
Recognised general qualities of Scotland’s hills and moors are ‘openness’ and ‘wildness’. However, for a given locality, unless work has been undertaken to identify the special landscape qualities, the term **high quality environment** can be hard to define.

In terms of the **robustness of the environment**, the habitats we currently value most may not be the most robust ones. The term ‘robust’ term needs to be used with caution. It is perhaps best if it is restricted to reference to populations of a given species. Likewise the phrase **adaptable environment** needs to be used with caution: the environment will always adapt to changing conditions, but perhaps not always in ways we like. The term does not seem to be particular useful in relation to upland management.

It is by no means certain that encouraging woodland onto open moorland through grazing reduction or tree planting will **mitigate climate change**: it could even accelerate climate change through causing carbon stored in the soil to be released to the atmosphere, particularly from wet heath. Additionally, many current areas of moorland could succeed to peat-forming ecosystems in the long-term, hence eventually storing more carbon than is possible in a forest. It should be noted that planting trees on the mineral rich soils of the lowlands will help mitigate climate changes because there is little carbon stored in these soils.
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Data sources for trophic level calculations (Figs 4 & 5)
Armsrong H, 1996. The grazing behaviour of large herbivores in the uplands. Scottish Natural Heritage Advisory Note 47.


Note on the author
Dr James Fenton graduated with a degree in botany, and subsequently undertook research on peat growth, gaining a PhD in the process. Thereafter, after teaching field-based ecology for five years, he set up as one of the first ecological consultants in Scotland. In 1991 he became the National Trust for Scotland’s first Ecologist, carrying out ecological surveys, providing ecological advice across the whole NTS landholding, and contributing to NTS policies on woodland and grazing. During this period he coordinated a 2-year EU-LIFE project on upland grazing, which was a partnership of NTS, Scottish Natural Heritage, Scottish Wildlife Trust, the then Institute of Terrestrial Ecology and the then Macaulay Land Use Institute. This resulted in a grazing handbook, and also grazing management plans for four sites. In 2005 he left NTS and joined SNH to work on landscape policy. From 2011-2013 he moved to the Falkland Islands to become CEO of the NGO Falklands Conservation. He is now an independent Ecological Consultant. He has written extensively on ecological issues in upland Scotland.
APPENDIX 1. EXTRACTS FROM A HIGHLAND DEER HERD AND ITS MANAGEMENT

Below are extracts from the publication A Highland Deer Herd and its Management: A study of the red deer population and its impact on the habitat of the Letterewe Estate, Wester Ross; by Jos Milner, Jim Alexander, Cy Griffin. Published by Red Lion House, London 2002.

The reason these extracts have been included is that this is one of the few locations (see Fig.6) where studies have taken a scientific and an objective look at the role of deer within the landscape as a whole. The findings reinforce much of the content given above.

Page numbers in the original document are given in brackets.

Chapter 2. The Size of the Red Deer Herd

1. In rough terrain, helicopter counts appear to give greater accuracy than foot-based counts; helicopter counts appear to become more accurate with practice.

2. Red deer density on the Letterewe Estate is currently of the order of 14-15/sq km. (p.99) There are also c.600 sheep in the Heights of Kinlochewe area.

3. Taking sheep and deer together, the overall density for the estate is “0.25 sheep equivalents/ha, which is well below the 0.5 ewes/ha stocking rate for northern and western moors at which heather moorland is thought to change to grassland or sedge-dominated bog.” (p.91)

Chapter 3. Deer Impact on the Habitat

4. “Over-grazing is a controversial term…. Its precise definition is dependent on management objectives…. Over-grazing is not generally applied to natural ecosystems, even under heavy grazing pressure, because wild herbivores are regulated by their food supply during the unfavourable season…. For example, there is no evidence of habitat degradation on St Kilda or the North Block of Rum where herbivore populations are naturally regulated.” (p.31)

5. “…..This comparison lends further support to our argument that there are no adverse effects of grazing on plant species diversity at Letterewe.” (p.132)

6. “Our study did not include a systematic survey of heather condition but the heather at Letterewe did not appear to be in poor condition as a result of grazing.” (p.137)

7. “There could have been benefits to using the habitat condition assessment methods favoured by SNH, which combine heather utilisation with criteria such as the occurrence of shaped heather. However, the impact categories used in these assessments have not been equated to actual trends in parameters such as heather cover, height or growth rate, making the interpretation of condition surveys very subjective. In addition, the qualifying criteria for high, moderate or low grazing impact categories do not reflect well whether heather is declining, static or increasing. Furthermore, this method has never been calibrated in wet heath or blanket bog habitats and the calibration of dry heath may not be applicable to areas outside north-east Scotland. Heather occurring in wet heath communities and in the west of the country tends to be less robust, more leggy and have a more open habit, than heather in drier environments. These factors, together with older age, are likely to increase susceptibility to grazing and presumably to damage from other agents. On the low ground at the Heights where sheep are kept, there has been some loss of heather-cover and heather die-back, possibly associated with a combination of grazing, heather beetle damage, the weather and age.” (p.138)
8. “There was little evidence of over-grazing of grassland or heath communities at Letterewe...... There was significantly lower flower density, and so reduced input seed input, in grazed areas. However, recruitment from seed is extremely uncommon in heaths and grasslands and most species in these communities are not seed-limited in most years...... resilience of the vegetation does not depend upon a constant input of large numbers of seeds.” (p.138)

9. “Plant species diversity at Letterewe is not unusual and grazing by deer probably helps to maintain the diversity, especially within the grassland communities. Abundant evidence from many parts of the world suggests that removing vertebrate herbivores from heath and grassland communities can cause substantial reductions in plant diversity in the medium- to long-term.” (p.138)

10. “Deciding whether deer have a had a negative impact on the ‘natural heritage’ depends on one’s definition of natural heritage. There would certainly be more trees in a landscape that had neither deer nor sheep....... But the existing, relatively bare, Highland landscape is the ‘natural heritage’ that has been passed between generations for several centuries.” (p.139)

Chapter 5. Management Options and their Consequences
Low, medium, high and zero hind cull scenarios:

11. Models indicate that a 5% cull of the deer population “show the population remaining at roughly the 1999 level, fluctuating between 14.3-16.5 deer/sq km.... The population size would be about 95% of the ecological carrying capacity with hind numbers at approximately 80% of their maximum. At ecological carrying capacity the population is in equilibrium and has no long-term negative impacts on the vegetation......

“The population would consume about 13% of the edible biomass produced each year. Density would be too high to allow natural regeneration of trees.” (pp.205-6)

12. “A hind cull of 11%, with a high calf cull of 18%, and a stag cull of 8% [as has been carried out on the estate since 1998].... show the population size decreasing steadily to about 70% of maximum sustainable numbers after 30 years.

“The average grazing pressure of the simulation population after 20-30 years would be the consumption of about 10% of the annual plant production....... but deer density would still be too high for the natural regeneration of trees.” (pp.207,210)

13. “Two different approaches to increasing the hind cull were modelled:
(1) The current hind and calf culls are doubled to 22% and 36% respectively, while the stag cull is maintained at 8%..... The population experiences a gradual decrease to 6.5/sq km.
(2) A 50% hind and calf cull for two years to dramatically reduce deer numbers, and thereafter a lower culling effort of 15% of hinds and calves. Stags are culled at 10% throughout...... The population size drops sharply to about 10 deer/sq km in the first two years and thereafter decreases slowly to about 8/sq km.

“The grazing pressure, in terms of percentage offtake of vegetation production, is 6-7%. Under both high cull options, the average density is sufficiently low that there may be opportunities for the natural regeneration of trees in some localised areas. However, average densities of 6.5 deer/sq km and 8 deer/sq km would still be considered high for...... tree regeneration. Furthermore, the aggregation of deer on low ground during winter means wintering densities along the shore of Loch Maree will be far higher than these averages. Furthermore, heavy grazing of grassland along the woodland margins in all seasons is likely to limit the potential for regeneration in the oak woodlands.” (pp.210,211,214)

14. “Finally we examine the situation in which neither stags nor hinds are culled...... it allows a theoretical comparison to be made between the dynamics of culled populations and a self-regulating population, fluctuating around the ecological carrying capacity...... Our model predicts a slight rise in numbers at Letterewe and suggests that, in the absence of culling, the total population size would
stabilise at... 15.8-17.6 deer/sq km..... The annual vegetation offtake by the simulated population would be up to 15% or production.” (pp.214-5).

15. “We believe a long-term (20-30yr) rotation of 12 to 18 small exclosures (2ha), sited along the woodland margins and in large gaps, is the most realistic option to ensure regeneration [of the Loch Maree oakwoods]. The tendency for deer to aggregate on low ground in winter and heavily graze the grassland along the woodland edges in all seasons means that a cull of 85% of the lochside population ...would be required for regeneration to have a chance of occurring without fences........ Not only would a cull of this scale be difficult to implement, but it is also incompatible with the stalking interests of the estate in the longer term.” (p.195)

**Chapter 6. Deer in the Highlands**

16. “The research at Letterewe emphasises the need to provide a definition of the ‘natural heritage’ that DCS and SNH are charged to maintain. Is this the open moorland and bare hillsides that have been typical for much of the Highlands for the last three or four hundred years? Or the ancient forest that proceeded it, before climatic change, clearance, burning and domestic stock caused its demise? Or a diversity of landscape with different management objectives?....

However, it is not clear that existing deer populations are incompatible with the maintenance of biodiversity in the open landscapes that have characterised much of the Highlands for the past few centuries. If this is Scotland’s natural heritage, wild red deer form an important component of the system and there may be little to fear from traditionally managed populations of Scotland’s largest and most striking mammal.” (p.251)

**Afterword**

17. “There is no scientific indication from this study that there are too many deer on the open hill at Letterewe, even if the population were to rise. Total offtake by mouths is lower than annual plant production and species variety has not been negatively affected. The estate with no sheep has a deer per ha. density that is half that recommended for sheep equivalents per ha.” (p.263)

18. “The deer numbers at Letterewe are not excessive. A culling policy of minimum to moderate impact – as has been done over the past 20 years – will be continued. The numbers to be culled can change from year to year and will vary from 4-12% of the population, depending on weather and economics. The aim will be for the higher percentage.

“Several fenced-off exclosures in the oak woods, primarily where there has been a wind break, and other suitable areas, will provide the possibility of natural regrowth of oakwoods.” (p.271)

19. “We predict that an ever repeated appeal for more deer to be shot will not be effective. Deer are part of the total herbivore fauna and therefore a decrease in sheep is likely to stimulate a growth of the deer herd. The increase of deer in Scotland is and will be directly affected by the long-term decline in sheep numbers.” (p.260)
APPENDIX 2. FIELD ASSESSMENT OF CARBON STORES

Extract from FIELDWORK RESULTS (from the course ‘Conservation Management in the Uplands: Principles into Practice,’ 23-25 September 2014, Wester Ross, tutored by Dr James Fenton)

Basis of calculations (assumptions)
Humus/peat: 80% water.
Live/dead plants: 60% water.
Live wood: 50% water.
Dry weight humus/peat: 90% organic.
Organic matter: 55% carbon.
Trees: annual carbon storage based on Yield Class (cubic metres wood produced/hectare/year)
Trees: average standing crop over life of wood = half standing crop when wood felled/trees die.
The figures should be seen as order of magnitude only owing to the assumptions made and the small sample size; in practice the humus/peat depth will vary across sites.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Amount of carbon (tonnes/hectare), assuming organic matter is 55% carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Humus/peat(^2) Depth (cm)</td>
</tr>
<tr>
<td>Peat(^7)</td>
<td>&gt;180</td>
</tr>
<tr>
<td>Wet heath</td>
<td>40</td>
</tr>
<tr>
<td>Scots pine old planting(^5)</td>
<td>13</td>
</tr>
<tr>
<td>Downy birch woodland(^6)</td>
<td>11</td>
</tr>
<tr>
<td>Dry heath</td>
<td>4</td>
</tr>
<tr>
<td>Bracken(^10)</td>
<td>4</td>
</tr>
<tr>
<td>Grassland (10cm sward height)</td>
<td>3.5</td>
</tr>
</tbody>
</table>

1 Based on weighing a known volume and assuming the bulk density remains the same down the peat profile.
2 Based on weighing the full depth of litter collected from a known area.
3 Based on cropping all live material within a quadrat 1mx1m (1mx50cm for dry heath).
4 Calculated from estimate Yield Class of the trees.
5 As the Scots pine were growing over dry heath, the dry heath figures were used for above ground live, litter and soil.
6 As the downy birch were growing over grassland, the grassland figures were used for above ground live, litter and soil.
7 As the vegetation on the peat bog was similar to the wet heath, the wet heath figures were used for above ground live, litter and peat bulk density.
8 Based on estimated Yield Class of 4.5, and trees living for 150-200 years.
9 Based on estimated Yield Class of 4, and trees living for 100 years.
10 This is a relatively recent colony of bracken which has invaded dry heath; an older colony might store more carbon.

CONCLUSION

The humus/peat under wet heath, and the peat in peat bogs, stores by far and away the most carbon. The wet heath at the site studied had a humus/peat depth of 40 cm and the table indicates that wet heath of 13cm depth would hold a similar amount of carbon to that of woodland.