TOWARDS A NEW PARADIGM FOR
THE ECOLOGY OF NORTHERN & WESTERN SCOTLAND

A Synthesis of Issues

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Imagine this scenario...

You are visiting the great Amazon rainforest and after walking miles and miles through interminable trees, you come across a natural clearing. You immediately see many species you have not seen before, and you enjoy the sunshine and the long views.

Soon, though, you are once more plunging through the jungle until, after many more interminable hours, you chance upon another clearing and again rejoice at the change of scene.

Over the next few weeks you encounter other clearings, each with its distinct array of species, and you begin to get a feeling of the rarity of this habitat...

Back home in your office you return to your strategic conservation planning, and look up the criteria for assessing nature conservation value and note that ‘rarity’ features highly in habitat assessment. So you get out your maps, and mark on them all the clearings and give them a star rating, these being the rarest habitat type.

Then, remembering the theories of island biogeography, you realise that the clearings and their species are threatened, being easy prey to extinction. You go back to your map and begin to mark swathes of rainforest that need felling to create networks and corridors to join up the isolated island clearings.

Then the chainsaws come out, and the felling of the great rainforest begins...

Now just open your mind, just a little, to at least the possibility that Scotland’s open moors and bogs are the rainforest equivalent, and the isolated native woods the clearings ...

Now imagine this scenario...

You are carrying out your global conservation planning at IUCN headquarters in Gland, Switzerland. You take out the map of global habitats, and also look up the criteria for assessing nature conservation value. ‘Rarity’ features highly in habitat assessment.

The map shows that temperate heathland and bog is one of the rarest habitat types on earth, and you note that Scotland is a world centre ...
Pine woods may be an endpoint, "before return to open moorland as a result of soil degradation."  Goodier and Bunce (1977)

The Great Wood of Caledon: "Roman descriptions do not allow the forest to be located with any exactitude; the sceptic might even doubt whether it ever existed, and that all we are dealing with is a myth repeated by many writers."  Breeze (1992)

"There is little evidence that there was extensive scrub on the mountains within the current climatic period."  Poore (1997)

"Let us begin with the Great Wood of Caledon. It is, in every sense of the word, a myth."  Smout (2000)

"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."  Svenning (2002)

"A combination of very low soil nutrient availability and high soil moisture provides very unfavourable conditions for colonisation of birch, rowan and Scots pine."  Thompson (2004)

"This interglacial cycle can be summarised as follows (from Birks 1986): in the immediate postglacial period there is a cold, cryocratic phase, followed, as the temperature warms, by a protocratic phase where shade-intolerant herbs, shrubs and trees immigrate and expand rapidly to form widespread species-rich grasslands, scrub and open woodlands growing on unleached, fertile soils of low humus content.

"Thereafter there is the mesocratic phase where temperate, deciduous woodlands develop on fertile, brown-earth soils, with shade-intolerant species rare or absent.

"Finally there is a telocratic phase of forest regression with open conifer-dominated woods, ericaceous heaths, and bogs growing on infertile, humus-rich podsol and peats. Local extinction of nutrient-demanding mesocratic plants occurs and some protocratic plants expand as a result of decreasing shade.

"This telocratic phase begins before the climatic deterioration that leads to the next glacial cycle, suggesting that soils ‘deteriorate’ independently of climate change; this phase of soil ‘regression’ before the onset of climate change has been called the oligocratic phase (Andersen 1966)."  Fenton (2008)

"The results suggest that blanket peat was common or abundant over much of the highland landscape within a few thousand years of the beginning of the Holocene period. Blanket peat developed either as an inevitable but rapid end-stage to soil development in this generally cold and wet climate or was promoted by climatic change. There is no evidence from this data-set that blanket peat developed as a result of anthropogenic activities. It is suggested, indeed, that farming communities successfully resisted the natural spread of peat across their fields.”  Tipping (2008)


“We should try to explain the past by causes now in operation without inventing extra, fancy, or unknown causes, however plausible in logic, if available processes suffice.”
Stephen Jay Gould 1987

Or more simply
“The present is the key to the past.”

**Old paradigm**: The current landscape consists of degraded ecosystems, largely through past and present human action. Hence ‘habitat restoration’ is a key activity.

**New paradigm**: The landscape of northern and western Scotland contains one of the most natural vegetation patterns in Europe with, for example, the current rarity of woodland in many localities being a key biodiversity feature. Hence the concept of ‘habitat restoration’ loses its meaning.

Author’s note
This document ranges across a huge swathe of interrelated issues, albeit in the barest outline, focusing on those where new thinking or approaches are needed. It should be seen as an essay rather than a referenced scientific paper – to provide an adequate suite of references would be a huge undertaking. Instead, photographs have been used to illustrate many of the points.
The issues are based on observations by the author over many years and relate to the area north of the Highland Boundary Fault, in particular to the unenclosed land beyond or above the head dyke – not to the inbye land traditionally used for agriculture. Whether they have applicability south of this area is left for the reader to decide. Some of these issues have not been raised before although a discussion of many can be found in:


The following paper is also relevant:

The term ‘biodiversity’ is here used to mean the habitats and species indigenous to an area, along with their natural arrangement.

This document presents, in the author’s view, a unified and internally consistent approach to nature conservation/biodiversity action within the area (based on the above definition of biodiversity), at the same time matching the ecological evidence. It is to be hoped that it will stimulate debate, encourage further research and instigate a review of current policies.

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Introduction

Many years ago, when I was coordinating an EU Project on upland grazing, we had a visit from the then head of the LIFE Nature unit. He asked why we called vegetation ‘upland’ when it occurred at sea level? I knew that, in the north, upland vegetation came down to sea level and I remember giving a complex ecological explanation about why it did — although I also remember being not totally convinced by my own arguments! However, as it was something that we British ecologists just knew to be true, I did not then pursue my own doubts: “An upland type of climate... descends to sea level in the cooler northwest.” (Averis et al. 2004. An Illustrated Guide to Upland Vegetation)

However, belatedly, 15 years later, I now realise that it was a valid question. Looked at objectively, if a vegetation type is common at sea level it is, by definition, lowland vegetation. Certainly, if you are brought up in England, vegetation found at sea level in northern Scotland is upland vegetation in, say, the Pennines. But someone from the north of Scotland could equally question why this vegetation type is termed ‘upland’ in England — would it not make equal sense to call the Pennine moors ‘lowland vegetation’?

It took me 37 years as a professional ecologist to unlearn what I knew! I now believe that calling plant communities found at sea level in northern Scotland ‘upland vegetation’ is both confusing and ecologically incorrect. It is an ecological shorthand which tends to hide the real ecological differences between the north and the south: to mask the truism that lowland vegetation in the north is ecologically distinct from lowland vegetation in the south.

In fact, over the last decade or so I have had to unlearn a lot of ecology, forced on me by conflicts between what I knew and what I observed direct from the natural environment. I now believe there is so much ‘unlearning’ to do that I have put together all the topics in this publication. I have been inspired by the ancient book of Lucretius On the Nature of the Universe, which shows how the structure and function of systems can be deduced from direct observation. Hence this document uses old-fashioned natural history observation to suggest a new understanding of the natural ecology of the area.

The pages that follow summarise many of the key concepts where I believe new thinking is needed. Many are interrelated: I see the rarity of woodland in the landscape, together with its disjunct distribution, as a defining ecological characteristic and a key biodiversity feature of this area (natural in origin); I see the concept of ancient woodland as rarely applicable, likewise the concept of balanced age classes of trees, the putative presence of montane scrub or a climatically-determined treeline. The concept of overgrazing needs serious questioning, as does the importance of muirburn on Calluna-heath. The question should be why are tree remains so rare in our post-glacial peat deposits rather than common; why are eroding peat bogs deemed ‘in unfavourable condition’ when an erosive phase is part of a natural long-term cycle: indeed the whole concept of habitat condition appears dubious when applied to dynamic systems in an expansive landscape...

I believe that northern Scotland is an area with one of the most natural vegetation patterns in Europe, rather than being comprised of largely degraded ecosystems.

I see one reason for this need to ‘unlearn’ what we ‘know’ being that ecologists have tended to see the north with the eyes of the south, unthinkingly transferring to the north what is valid understanding and or valid approaches further south (or east) — and we have all gone along with it. Fraser Darling is a prime exemplar, although he also saw our unproductive uplands through the eyes of an agriculturalist. Another reason is the lack of a long-term perspective on the linear or circular successional trends that characterise the area. Additionally, there are few places in the world with similar conditions: to understand this area, you cannot really extrapolate from the other, more extensive temperate, boreal or alpine ecosystems.

Some the topics listed here are being actively looked at, but many are not. I know from experience that there appears to be little appetite to question what is generally ‘known’, and there is a lot invested in the current paradigm. However, I firmly believe that action to safeguard the planet’s biodiversity has to be based on a sound understanding of the ecosystems in question, and this equally applies to Scotland. We do not want our actions in safeguarding biodiversity to damage what, to me, is a very special corner of this planet.

James Fenton
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APPENDIX Assessing herbivore carrying capacity using trophic levels
The pictures to the right suggest that there was a period of open peatland during which 90cm of peat accumulated before colonisation by Scots pine. The pine appear to have lasted one generation before a return to open peatland lasting until the present day.

Assuming 30 cm of blanket peat growth = 1,000 years, this suggests 3,000 years of peatland, followed by, say, 2-300 years of pine (judged by the size of the trees), followed by 5-8,000 years of open peatland. This illustrates that in this location woodland was but a short episode.

Reasons for the arrival and disappearance of pine could be:
- Dynamics of pine spread & regeneration.
- Climate variability: drier interlude allowing colonisation of peat.
- Direct or indirect effect of humans.
- Pine in fact present throughout, but conditions suitable for the preservation of sub-fossil remains only occur in one period.

At this location (at 400m on infertile granite & peat soils), a. &/or b. are the most likely. This was realised in 1866 by James Geikie who stated: “As it can be shown that the destruction of our ancient forests has not been primarily due to man…”

Much nature conservation action is predicated on a model of woodland being the climax vegetation, with the open landscape of today being largely anthropogenic.

Hence grazing management is designed to be at a level to allow tree regeneration, and other action is taken to increase tree cover and associated woodland species, e.g. new native woodland schemes, ‘recovery’ of woodland species.

However, there seems to be little evidence to support such an ‘anthropogenic woodland loss’ model, instead woodland only being episodes in a long history. If the open landscape is of natural origin, and mirrors the vegetation development of previous interglacials, then this action for restoration is actually damaging the area’s biodiversity value.

**Farquharson’s 1703 map of the Mar Lodge Estate shows no greater extent of native pinewood then than now. Any decline must have taken place well before then (in the presence of wolves).** From NTS 1995 Management Plan
It is often assumed uncritically that tree regeneration is inevitable if grazing levels are reduced (see next page). However, there are many factors controlling tree regeneration, and the generally acid, wet, podsolised, iron-panned, peaty soils and associated vegetation form a sub-optimal template.

In addition to grazing limiting tree establishment, other factors include competition from surrounding vegetation, soil conditions, including nutrient status, water content & mycorhizza, winter temperatures, and lack of a protective snow cover.

Over 10,000 years of leaching have resulted in the development of an impermeable iron-pan, low soil nutrient content, low pH and the general absence of earthworms. Together with the cool oceanic climate, the successional trends are towards peatland, often via wet or dry heath.

Indeed, peatland may well be the climax vegetation for most of lowland Scotland where, say, Flanders Moss and Auchencorth Moss are relics. The previous existence of these lowland mires in what is now prime agricultural land is remembered in numerous place names: Moss-side, Muirend, Muirtown.... In terms of human impact on Scotland’s natural vegetation, destruction of peat bogs rather than felling of woodland has possibly had more impact.

Regenerating Scots pine in the 1960s exclosure in Glen Affric. However, within this exclosure young trees tend to be restricted to certain areas, and the regeneration illustrated here is not necessarily representative of the whole area. Often regeneration is the result of suppressed growth taking off following the removal of grazing.

A Scots pine plantation adjacent to old growth Calluna. In spite of the extensive seed rain, regeneration is restricted to the disturbed ground of a forestry track, where mineral soil is exposed. The Calluna stand is resisting pine colonisation – the heather out-competing any potential pine seedlings.

Birch regenerating on the shores of Loch Broom, spreading out from a core area along the burn following reduction in grazing. Regeneration is often particularly successful at sea level on the west coast, with woods naturally commoner here, reflecting a favourable climate, with more overwintering green material (other than saplings) available for herbivores.
It is often assumed uncritically that tree regeneration is inevitable if grazing levels are reduced, with optimum red deer numbers in the range 4-8/sq km. However, with sub-optimal regeneration conditions (see page 9) it is not inevitable. Additionally, this is a very low herbivore density and the difficulty of maintaining it indicates this grazing level is way below the ecological carrying capacity.

As red deer are at home in both woodland and moorland (and take to the woods for shelter), reducing deer numbers to a low level to allow for tree regeneration will have to be permanent: in other words, deer densities have to be held an order below the ecological carrying capacity (as determined by vegetation productivity) to maintain woods in the landscape. The mismatch between the carrying capacity and that of maximum benefit to trees is a reason why the landscape is naturally open (see Appendix page 47)

Heavy grazing followed by removal of grazing often gives optimal woodland regeneration conditions, as repressed young trees can get away (this maybe the case in picture 1.). It is said that bringing wolves back into the landscape will cause woodland expansion through their controlling deer numbers. But several thousand years of woodland loss with wolves present suggests otherwise, although there may have been localised effects around dens.

A birch woodland showing a belt of young trees at the edge of the wood, with no young trees in the area of mature trees. This is a common situation with native woods of birch, Scots pine and oak, and results in the woods moving around the landscape – as the original core dies and reverts to grassland or heathland.

Red deer are well adapted to both moorland and woodland and thrive in the area. They also browse young trees and so can prevent woodland regeneration. With the soil conditions unsuitable for thorny shrubs (such as hawthorn, sloe or brambles), which would otherwise protect young trees, the presence of deer means that woodlands can easily die out.

Wolves were present throughout the Holocene, apart from the last 250 years. Their presence would have made large-scale grazing of domestic stock impractical. The large sheep farms post-dated the extinction of the wolf – and were created when woodland was already rare in the landscape, as indicated on the Roy Maps of 1747-55.
There is no *a priori* ecological principle which states that woodland must be the climax vegetation over much of the Highlands and Islands. Ecological mechanisms can be suggested that can explain both woodland expansion and contraction – processes that can both be observed today.

Pollen analysis, together with the presence of sub-fossil pine stumps (and oak in lowland bogs), indicates that there were more trees in the landscape thousands or years ago. However, it is very difficult from pollen analysis to determine the actual proportion of the wider landscape that had woodland cover.

There is little evidence to support landscape-scale anthropogenic woodland loss over much of the area, and the question has to be put: if the trees were cut down, why did they not regrow again – particularly as wolves would have been present to move herbivores around? In any event, there are huge swathes of land at mid to high altitude where human impact is likely to have been minimal. In some areas humans have ensured the persistence of woodland in the landscape through its economic value, and this may have been a more common situation than anthropogenic loss. Even where human populations once existed, the vegetation can quickly revert to a natural pattern once the population has left.

A native woodland on a steep coastal slope. It is not inevitable that the wood will retain its current size: it could either expand or contract.

Core woodland area in gully
Bracken & deep heather outcompete seedlings
No regeneration under closed canopy
Deer shelter here & eat saplings

Pollen analysis can over-emphasise the previous extent of pine and birch in the landscape. Pollen tide-lines in this corrie pool show a huge pollen-rain, and analysis of a nearby peat bog might indicate pine woodland nearby. In fact this is an open landscape with the nearest pine trees 4km downslope.

The human population of the Highlands has been higher, particularly along straths and glens. However, on the departure of humans the vegetation can relatively quickly regain a natural pattern, although it takes longer on the inbye land.
For many years ecologists have looked across the water to Norway, noticed the woodland cover and, assuming the same ecological parameters, have used it as a model of what Scotland ‘should’ be like, whether with more broadleaved and conifer woodland, or sub-alpine scrub.

Although there are similarities with Scotland, particularly along the coastal fringe, close observation shows significant differences, for example the lesser dominance of *Calluna* and the abundance of bog rosemary, bog blueberry (*Vaccinium uliginosum*) and dwarf cornel, even at sea level – species with a much more restricted distribution in Scotland. Other differences relate to the nature of the topography, the differences in climate (more Boreal, less Atlantic), the presence of a large landmass immediately east (rather than the North Sea), winter snow cover, herbivore density and human history.

Instead of celebrating Scotland’s unique ecological characteristics, much conservation action is devoted to trying to create a ‘mini-Scandinavia’, resulting in an increasing homogenisation of European landscapes.

Species-rich willow and birch scrub in central Norway. It is often uncritically assumed that this is how upland Scotland ‘should’ look – if only humans had not ‘devastated the ecology’, to create, in Fraser Darling’s terms, ‘a wet desert’. However, there are many natural ecological differences between the two countries. This is the wrong model.

Birch woodland in the mountains south of Trondheim (Norway) showing development of blanket peat amongst the trees – a process that has been more dominant in much of Scotland.

A winter scene in central Norway. One example of the difference between the boreal woodlands of Scandinavia and the Atlantic woodlands of Scotland: long periods of winter snow cover that restricts the number of over-wintering herbivores, reducing browsing pressure on seedlings, saplings and shrubs.
There are perhaps no vascular plants obligate to woodland in northern Scotland, particularly as shaded gorges, cliffs and boulder fields can provide similar habitat. Many plants seen as woodland species (e.g. wood anemone) have a wide ecological amplitude and are equally at home on moorland. Someone from the Highlands could, with validity, say of ‘wood anemone’ when seeing it woodland for the first time: “strange to see it growing in woodland, we call it ‘moorland anemone’ at home”!

The concept of ‘ancient woodland’ relies on woodlands being static, whereas woodlands in upland Scotland, other than in the small core areas, have tended to migrate around the landscape. This relates to the fact that the woods regenerate best at the edges rather than where trees are currently found. See also page 10, picture 1.

This can be seen today at, for example, Balmacara, where old sessile oak woodland is not regenerating in situ (which is the location of a designated site) owing to absence of suitable conditions; but there is ample regeneration of oak in deep, dry heather in the wider landscape (albeit outwith the site designated for oak).
Montane scrub has probably always been rare in Scotland, related to soil type and lack of winter snow cover to protect willows for grazing. There is a lot of high level blanket peat in Scotland, and at the base of many bogs there is no sub-fossil evidence of scrub.

It is probably a relict habitat type dating from colder, post-glacial conditions, perhaps with expansion during colder epochs such as the Little Ice Age.

Willows are highly sought after by herbivores. Many areas have been fenced off to encourage regeneration, but it is hard to see how the fences can ever be taken down: once removed, the willows be targeted by any herbivores present.

Sub-alpine willow scrub in western Norway, with several species of willow present, as well as juniper and dwarf birch. The rarity of this habitat type in Scotland has resulted in significant effort being put into its ‘restoration’.

A section of upland blanket peat at the side of a track. Note the absence of sub-fossil tree/shrub remains at the base of the peat, indicating that scrub was rare or absent when peat growth started. This is the case over much (?most) of upland Scotland. [Note also the natural sub-peat ‘pipes’, indicating how patterned bogs can naturally drain – see page 21]

The open nature of these hills is a natural situation. Unlike much of Norway, there is not guaranteed snow cover which helps keep herbivore numbers low and protects montane scrub from grazing. Additionally, most Scottish cliffs are of acidic rock, making them unsuitable for most species of scrub willow.
It is possible that the concept of a climatically determined treeline is not correct for upland Scotland. Bogs and heaths can descend to sea-level in some places (i.e. the treeline is at sea-level), and in others there may be pockets of high altitude woodland and scrub.

In Scotland’s relatively low hills, the climatic limit of trees is near the summits: there are not significant areas above this putative treeline to which herbivores could migrate to graze; and the main herbivore, red deer, can easily travel the full altitudinal range in a day.

Herbivores tend to graze at the putative treeline, causing direct competition with woodland. This is because mineral flushing here results in higher palatability of vegetation, and midges cause animals to seek high ground. Additionally, there is no guaranteed snow cover to protect any trees from grazing during the winter, when palatable vegetation is rare. Herbivores include mountain hares and voles in addition to red deer.
The general altitudinal natural zonation of vegetation in upland Scotland is:

Woodland, scrub, bracken, heath or grassland on the coastal slopes (see also picture 1. on page 11.).

Blanket peat and wet heath at lower altitudes on level or gently sloping ground; woodland, scrub, bracken, dry heath or grassland on the steeper slopes.

Dry heath or grassland on the upper steep slopes, grading to acid grasslands and prostrate heaths on the summit ridges.

The presence of peatland at sea level as shown in the first picture, indicates that here the actual tree-line is near sea level. The level heads of sea lochs and the glen floors would be naturally be raised bogs, although, as these have been the locations where people have tended to live, these have largely disappeared. However remnants are visible at, for example, Kilmartin, Kentra, North Connel, Corpach, Strathcarron and Kinlochewe.

Woodland may or may not be present on drier steep slopes, dependent on the presence of core areas or chance. Woodland or scrub is particularly abundant on coastal slopes, where it can persist in spite of relatively heavy grazing.
Current approaches are to analyse individual vegetation types and assess the ‘condition’ of each, the idea being to achieve ‘favourable condition’ for all, or at least selected ones. The bottom right picture shows that this can be impossible: two vegetation types are being colonised, and the other is going through an erosive phase in one area (see Peat Cycling page 21). Here, the concept loses meaning. ‘Favourable condition’ is predicated on a static environment, and a study of the history of Scottish vegetation shows continual dynamism.

In lowland Britain, where the last vestiges of natural and semi-natural vegetation are often islands within a landscape of intensive land use, then maintaining ‘favourable condition’ is a necessity – otherwise swathes of species could be lost to the locality. See Approaches to Nature Conservation on page 45.

However, in upland Scotland, where most of landscape consists of natural vegetation, choosing particular localities, or particular vegetation types, becomes an arbitrary exercise. The use of ‘favourable condition’ in the uplands will become more problematic with anthropogenic climate change, other than at the gross landscape scale.
‘Overgrazing’ is a much used word, and only has meaning with respect to a desired outcome. For example, if woodland is desired and grazing is suppressing trees, then this can said to be overgrazing with respect to woodland. In natural ecosystems, grazing is limited by availability of food in the limiting season, and ‘overgrazing’ without qualification has little meaning. Grazing is also key in maintaining nutrient cycling in ecosystems.

All that can be said with certainty for upland Scotland is that different grazing levels result in different plant communities. Scale is also an issue: high grazing will generally increase vascular plant diversity at the small-scale, but, by keeping trees at bay, can result in reduced diversity of habitat types at the large-scale. Grazing also reduces litter build-up and encourages nutrient cycling, particularly nitrogen and phosphorus which are limiting over most of upland Scotland. On optimal sites, woodland expansion can be occasionally observed even where there is heavy sheep grazing.

Plants have always had to put up with grazing – if they cannot, they disappear. The Vera cyclical model explains how temperate woodland can persist with high herbivore density (trees regenerate in thorny scrub), and this can be seen, for example, on basalt soils on Mull, where ash is regenerating within sloe scrub; but his model will not apply to most of upland Scotland owing to its ecological unsuitability for thorny shrubs.

It has been stated since at least the 1930s that ‘there are too many deer’, that they are ‘causing overgrazing’ and ‘damaging habitats’ – all questionable concepts. Current conservation-based deer management is centred around keeping deer populations at a low enough level to allow for woodland regeneration (c.4-8/sq km). See also Appendix page 47.

Sheep have had a bad press in conservation circles, often being blamed for the decline in woodland, for ‘devastating the ecology’, and causing overgrazing. However, most woodland decline in Scotland took place well before large-scale sheep farming became possible (after the elimination of wolves). Sheep play a similar role to red deer.

Where animals are fenced-in and forced to graze in a small area, then grazing impacts can be obvious: here it is causing an increase in vascular plant diversity. On unenclosed land, grazing is limited by the winter availability of forage (there is a summer excess). There is little evidence of a red deer-only system (without winter feeding) causing, for example, generalised Calluna loss.
Eroding peat hags are common in many areas of upland Scotland and there has been much debate about the cause of the erosion. Looked at logically, if a soft material is accumulating (increasing in depth) on slopes in a wet climate, then the greater the depth the greater the probability that it will become unstable. If the vegetated surface layer is broken through to the soft peat below (the top layer gaining its strength from the binding of plant roots), then erosion become inevitable. The surface layers can be broken by a range of causes, both natural and human-induced.

Human causes include moor-gripping (ditching), track- and path-side ditches, vehicle wheel imprints, pools dug for grouse, excessive muirburn, human trampling, and excessive trampling from domestic stock.

Natural causes include flood events, cutting-back of natural water-courses, drainage of bog pools (through sub-peat pipes, flood events or animal trampling), gravity-induced downslope movement, animal trampling, red deer rutting hollows, and deer wallows.

In much of upland Scotland, where human influence has been minimal, natural causes predominate – although moor-gripping was common even in remote areas in the past and is a major cause.

The eroding peat face in this picture is anthropogenic, caused by a moor grip (ditch) dug many years previously. Hence peat erosion can be instigated by human activity, although is probably inevitable eventually as peat accumulates on sloping ground.

In contrast, this picture shows an eroding moss peat bank in Antarctica in the absence of a human population or grazing animals. This illustrates that peat erosion can have a natural origin even in the absence of animals.

Peat erosion can be catastrophic as shown here – one of the many peat slides that occurred in southern Shetland in 2003 after torrential rain (the blanket peat here is about 1.5m thick).
The next page shows how, over long time-scales, peatland in Scotland goes through cycles (previously unpublished observations).

Erosion of peat can have a range of causes (see previous page), but natural drainage of patterned bogs appears to be a major cause. Once pool systems begin to develop, then an erosive phase is drawing near (albeit possibly decades or centuries away). Larger pools can possibly cause erosion through taking oxygen-rich water into deeper levels, hence promoting peat oxidation. The Highlands of Scotland are littered with peat hags arising from drainage of pools.

Because they are seen as ecologically interesting, designated peatland sites are generally those with pool systems. However, because peatlands cycle, then choosing any particular phase to designate becomes an arbitrary decision. Why are peatlands in an erosive phase less valuable than those in a growing phase? They all contribute to peatland biodiversity, for which Scotland is internationally important.

Bearing in mind the importance of peat in the carbon cycle, in future it may be necessary to designate more peatlands in the their ‘carbon sink’ phase. [see next page and page 41]
Millennium-scale Peat Cycling in Scotland

1. Acid soils (dry/wet heath, acid grassland, ?rush pasture):
   *Mineral soils*

   *Peaty podsols*

3. Low decomposition rates cause accumulation of organic matter (low pH, cool & humid climate):
   *Blanket peat, raised bogs*

4. A. Peat deepens and pools develop (origins often unclear)
   B. Gully develops & cuts back;
   C. A vertical edge forms, through e.g. erosion at streamside, animal rubbing

5. A. Pools continue to grow & merge, normally orientated at right angles to slope. Pools can expand by oxidation of deeper anaerobic layers & wind/wave action: *Patterned bogs*
   B. Gullies cut back & branch
   C. Vertical edge slowly moves back

6. A. Pools drain through break of surface layers or ‘pipes’ at base
   B. Gullies continue to expand: *Peat hags*
   C. Vertical edge continues moving back, with vegetation recolonising at base

7. A, B. Final erosive stage, return to mineral soil or redistribution of peat;
   C. Vertical edges continues its progress: area of erosion remains

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**CARBON SINK PHASE**
- Period of greatest carbon storage potential, but often low plant diversity

**CARBON STORE PHASE**
- Although likely to have the greatest diversity of species and micro-habitats, the rate of peat accumulation (carbon storage), will be slowing and could become zero or negative. However it is the period with largest carbon store

**CARBON SOURCE PHASE**
- Erosion/oxidation results in return of stored carbon to the atmosphere. The situation with pathway C (cutting back of a single vertical edge) is less clear

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Note: As peatlands go through cycles of growth and decay, then all parts of the cycle could be seen as equally important in nature conservation terms (except at sites where erosion is anthropogenic). However this will not the case in relation to carbon storage and sequestration, where the earlier stages are more important.
Although gorse *Ulex europeaus* is native to Scotland, it is not native everywhere. Human action appears to be hastening its spread, often resulting in a loss of grasslands and heaths.

This is through both a reduction in grazing levels and opportunities to colonise along roads and tracks; for example, gorse is being introduced to the landscape along the whole 19-mile length of the road to Achiltibuie from the main road at Drumrunie (below Stac Pollaidh).

Gorse is a particular fast invader, whose rate of advance may increase with warmer winters. In many parts of the Highlands it has been humans who have introduced it: for example, Osgood Mackenzie into an area of Wester Ross in the 19th Century; and introduction to Coll, Tiree, the Western Isles, Orkney and Shetland where it is not native.

Its nitrogen fixation ability results in long-term soil changes on colonised sites. Further research and thinking is needed on the ecological role and status of gorse in the north and west of Scotland.

Gorse species are likely to benefit from a warmer climate, with, for example, dwarf gorse *Ulex gallii* heading north.

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**Gorse Ulex europeaus colonising dry and wet heath at 240m.**

*See also picture 3 on page 26 showing how track and roadsides provide a linear corridor for gorse to colonise a new locality.*

**A nearby area showing recent complete gorse colonisation of heather moorland, and colonisation by occasional rowan trees.**

**Coastal heath and grassland near Plockton colonised by dense gorse, making the coastline inaccessible, and reducing species diversity. This appears to be an increasingly common situation in many coastal areas.**
Bracken is an equivocal species, but palynology shows it to have been present throughout the Holocene. However, as it rarely spores, its previous abundance is unclear.

Often forming large monospecific stands, and able to colonise the better soils, it is generally viewed as being of little biodiversity value, but does create a habitat for climbing corydalis and certain invertebrates. However, its presence tends to contradict the oft-quoted ecological ‘fact’ that monospecific stands of species are more prone to disease, resulting in less stable ecosystems. From a sequestration perspective, its litter could play a valuable role in storing carbon, perhaps of the same order as woodland.

There seems to be no a priori reason why it should not be a climax vegetation type (or why natural systems should be diverse). Even under the canopy of native birch or oak woods it can be dominant, thriving in years of caterpillar defoliation of oak, and preventing tree regeneration. The presence of wild boar may have controlled it in the past, but again the carrying capacity of wild boar in the Highlands, much of which is of low fertility and productivity, is unknown. Even if boar did allow saplings to establish, these are still likely to have been eaten by herbivores. Bracken is a species which is likely to benefit from a warmer climate, particularly as late frosts are a controlling factor.

Bracken covered slopes in Argyll. In the short term at least, bracken in many locations can successfully outcompete young trees, resulting in long-lived colonies.

Native oak woodland at Taynish National Nature Reserve in Argyll showing a sudden transition to dense bracken, with no trees of any age. Such stands can colonise grassland at a rate of c.1-2 m/yr. Warmer winters will probably encourage its spread to higher altitudes as late frosts are a main controlling factor.

On richer soils at lower altitudes, such as some of the basalt soils of Mull, bracken can form a dense, almost impenetrable stands together with brambles and, occasionally, scrub. This can be a seral stage to woodland, e.g. on the Ross of Mull.
Concentrating action only on alien species that are seen to cause ‘damage’ misses the wider issue of the impact of colonisation of any alien species.

Imagine, for example, that Scotland’s biodiversity is characterised by species ABC, and a similar area of Norway by species ABCDE. Part of the biodiversity characteristics of Scotland are that it differs from Norway in being less species-diverse: the presence of areas with characteristics of both ABC and ABCDE contributes to the global biodiversity. Both Norway and Scotland are also characterised by the absence of species Y & Z.

If species D is introduced to Scotland, then it can be seen that the diversity of Scotland (now ABCD) and Norway (ABCDE) is converging, resulting in a loss of global biodiversity.

If further alien species Y & Z are introduced to both countries, Scotland is now ABCDYZ and Norway ABCDEYZ. Colonisation by some aliens, or climate change, may cause the loss of species, say species A. Hence, the diversity of Scotland will be BCDYZ, and Norway BCDEYZ. It can be seen that, in the long term, this will result in a general homogenisation of habitats across wide areas, particularly if Y & Z are opportunistic colonists throughout the region – and hence an overall loss of global biodiversity.
Commercial conifer plantations cover a large proportion of the upland landscape, and the offspring of the trees are seeding into the wider countryside. Although spruce trees are the commonest, other conifers are involved; for example, cypress colonising Kerrysdale in Wester Ross. The author has also seen a young larch tree at over 600m on scree on the north slopes of Liathach.

Similar to the situation with rhododendron, if not controlled, in time these non-native species will transform the Scottish upland landscape, causing a major loss of biodiversity.

Perhaps there should be a ‘polluter pays’ principle: the owner of the nearest seed source being responsible for removal of any self-seeded trees outwith the area of commercial plantation.

Self-sown commercial conifers are not just confined to within, and immediately adjacent to, plantations. They can generally be found in any locality where there are commercial plantations, including on far distant hills and cliffs. Here a Sitka spruce sapling is present in a native birch wood.

Extensive conifer plantations in the Galloway hills. With so many trees, the seed rain is enormous and, in a windy climate, seeds can be blown long distances. Remaining areas of open ground within plantations are particularly prone to alien conifer colonisation.
If the expansive moorlands and peatlands represent some of the most natural landscapes in Europe (in terms of vegetation pattern), then care needs to be taken in looking after them.

It is perhaps surprising that the construction of access tracks into tropical rainforest is seen as the first step in fragmentation and loss, but it is not recognised as an issue in the expansive, open moorland ecosystems of Scotland. See also page 42.

However, the sides of bulldozed tracks present a linear route into the heart of our upland ecosystems for invasive species. These include rosebay willowherb, gorse, broom, rushes, ragwort, foxgloves, grasses, willows, birch and conifers (see page 25). For example, some of the bulldozed tracks in the heart of the Caithness Flow Country (associated with 1980s forestry schemes) have birch and willow along their sides, introducing these species into the heart of a naturally treeless landscape.

Gorse is a particular fast invader, whose rate of advance may increase with warmer winters. In many parts of the Highlands it has been humans who have introduced it. This is yet another issue contributing to long-term biodiversity loss.
‘Rarity’ is seen as a key quality in assessing nature conservation importance. However, this may relate to a human propensity for ‘stamp collecting’, where the rarer the item, the more value we ascribe to it.

Species can be rare for a variety of natural reasons:
– Relict populations, more suited to a different climatic period;
– Previous climatic fluctuations;
– Long-term successional change such that ecological or soil conditions have changed to become unsuitable;
– Lack of suitable habitat;
– Competition from other species;
– Chance (e.g. through late colonisation of an area);
– Reproduction difficulties, e.g. arising from a small gene pool through a small founder population; a lack of suitable substrate for seedling establishment; absence of associated species for seed distribution, etc.

Rarity is often the rationale for attempts to make a species more common: if there is proven anthropogenic loss, then this a reasonable course of action. If not, there is a danger action could reduce the biodiversity value of the area.

Trees are more likely to persist in the landscape if there are ‘core areas’ – small areas, inaccessible to grazing, often of high nutrient status, where trees can regenerate continuously.

Isolated trees or woods, as shown here, are a key biodiversity characteristic of the area.

Drooping saxifrage (Saxifraga cernua) growing along a roadside in Longyearbyen, Svalbard; it is a common species in the Low to Mid Arctic. This species is only found in three locations in Scotland and at one, Ben Lawers, the population has been heavily depleted by plant collecting. The appeal of rare plants to collectors illustrates how we tend to ascribe value based on rarity.

Yellow saxifrage (Saxifraga aizoides) growing in a nutrient-rich, stony flush. It is restricted to such habitat at low and mid altitudes, but occurs in most, even if widely separated. Being locally rare is a key feature of this species, but it seems well able to distribute itself. There tends to be an assumption that rare plants need our help.
There is a scale issue here: we value habitats and species that are rare to us, *i.e.* rare in our locality, even though they may be globally common. We miss the point that ‘rarity in Scotland’ may be a key biodiversity feature of our landscape, whether applying to habitats such as Scots pine wood or species such as juniper and aspen.

We also miss the bigger picture, of the need to value the locally common but globally rare, *e.g.* *Calluna*-dominant heathland. The biodiversity priority for Scotland should be to conserve species for which Scotland represents the core of their range, whether red grouse, breeding waders, *Calluna* moorland, hepatic-rich heathland, lichen- and bryophyte-rich coastal woods, cross-leaved heath or bog asphodel. 

If rarity is attributable to human action, then there is as strong case for species or habitat restoration. If rarity is a natural feature, then there is no case for action (unless the area is a last stronghold, with loss of its core area).

Native pinewood at Glas Leitir. Because native pinewood is rare across Scotland as a whole, it is seen as being of key nature conservation importance. However, although locally rare, Scots pinewood in general is a common habitat in northern Europe and Asia. There is often an implicit assumption that ‘if some is good’, then ‘more is better’.

In contrast to Scots pine woodland, temperate wet heath with cross-leaved heath (*Erica tetralix*), for example, is a globally rare habitat type. Scotland is the global centre for *Erica tetralix* and *bog asphodel* (*Narthecium ossifragum*).

Juniper (*Juniperus communis*) is a common species in the northern hemisphere with a circumpolar distribution. Its relative rarity in much Scottish moorland and woodland could be a defining biodiversity characteristic of Scottish vegetation.
Some Conclusions from the Previous Pages

1. In many localities, woodland has been an episode in a long vegetation history.

2. Long-term successional trends point to a largely open landscape, except perhaps along certain coastal slopes.

3. Isolated woods in a largely open moorland landscape are a key biodiversity feature.

4. ‘Rarity’ as a key biodiversity feature can result in action that damages the area’s biodiversity: the concept has to be used with caution, with both an understanding of why something is rare and at what scale.

5. The moorland itself is the key biodiversity feature.

6. Vehicle tracks can fragment moorland and introduce invasive species.

7. Norway can present a misleading model of what Scotland ‘should be like’.

8. Woodland can be mobile in the landscape, in many places declining to extinction.

9. Old growth heather moorland can successfully resist colonisation by trees, even if grazing is low.

10. Areas of truly ancient woodland are often small in area, on cliffs and gullies.

11. Most anthropogenic woodland loss has probably been on coastal slopes, where conditions for regeneration are optimal. It is perhaps more common that human action has contributed to persistence of woodland?

12. Tree-line scrub has probably always been naturally rare.

13. The concept of a climatically-determined tree-line is probably not applicable.

14. Dynamism of the different plant communities means that the concept of ‘favourable condition’ for a given plant community can be somewhat meaningless.

15. Relatively high grazing levels are probably a natural feature.

16. Peat bogs go through a long-term cycle and it becomes arbitrary to ascribe conservation value to a particular stage.

17. Eroding peat is a natural feature.

18. Human activity is facilitating the spread of gorse.

19. Bracken stands are probably a natural feature.

20. A suite of invasive species continue to colonise the whole area. Their mere presence reduces the biodiversity value.

The previous pages look at the ecological dynamics related to the natural vegetation pattern of northern and western Scotland. A conclusion that must be drawn from these observations is that the mainstream model of how the vegetation has developed needs to be adjusted to reflect a new paradigm – see page 4.

Much nature conservation policy and associated action is predicated on the ‘old paradigm’. The following pages indicate areas where a rethink of current policy and action is needed to take account of the new paradigm, although many policy issues have also been raised in the previous pages.
Different parts of the planet have different combinations of species, and it is this variety of combinations that represents global biodiversity. Within this variety, some areas are species-poor and some are species-rich: conserving species-poor areas is part of global biodiversity conservation.

However, often the term ‘biodiversity’ is used synonymously with ‘diversity’, particularly to mean increasing the diversity of species within a defined area. However, if this increase of diversity is at the expense of the existing natural ecological characteristics of an area, then increasing the diversity of an area can result in a loss of its biodiversity value.

Human preferences often come into play here. For example, we have a natural predilection for trees and water, so we might add these to the landscape to make the area more visually pleasing, at the same time thinking we are ‘doing our bit for biodiversity’. Ironically, in the wrong place, this can actual damage Scotland’s biodiversity. It is hard to see the biodiversity gain from increasing the abundance of woodland species at the expense of moorland species. From a global perspective, Scotland’s moorlands have greater biodiversity value than the native woodlands, excepting the lichen- and bryophyte-rich western coastal woods (and there is plenty of coastal wood regeneration).
If one vegetation type is expanding at the expense of another, then it is impossible for both to be in favourable condition (see page 17). If woodland is expanding over moorland, then moorland condition will be unfavourable.

Additionally, it is often assumed that the low coverage of trees in many areas means that the woodland is in unfavourable condition, with computer programs developed to model what ‘woodland type should be there’. The biodiversity value of the existing habitats is implicitly assumed to be of lower value than any putative woodland.

In areas dominated by natural vegetation, preference given to certain habitats (see Compartamentalisation page 33) does not work, especially when some with conflicting needs occur in the same locality. Instead, action should targeted to ensure that the whole area is under the sway of natural processes – without concern whether a particular habitat is in favourable condition or not.

Instead of being applied to individual habitats and species, the term ‘favourable condition’ should be applied at the landscape-scale.
Scotland has the best network of temperate, oceanic open ground habitat in Europe. This rare ecosystem type has a globally restricted global distribution. It is becoming fragmented through the creation of woodland networks and new hill tracks.

The woodland networks are being created in the name of ‘habitat restoration’, arising from the mindset that woodland is the climax vegetation and that its loss has been largely human-caused.

However, if open moorland is the natural vegetation type at this stage of the post-glacial period, then the creation of woodland networks, and the encouragement of associated woodland species, is in fact damaging the biodiversity of Scotland.

Additionally, if a key biodiversity feature of Scotland is isolated woodland, each with its particular array of species, then this approach will also, in the long term, result in the homogenisation of woodlands.
Compartmentalisation of the uplands is one of the biggest issues. How did Scotland’s rich biodiversity survive the previous 10,000 years without fences, one might reasonably ask? The fact that it has survived perhaps shows that fences are not necessary! It’s just that in recent years we have focused on a few chosen habitats and compartmentalised them – isolating them from the surrounding vegetation.

Compartmentalisation can be on a large scale, for example roadside deer-fencing in effect isolates northwest Scotland in a line from Contin to Loch Maree. Or it can be on a small scale, whether isolated pockets of montane scrub or larger pockets of native woodland.

Where fencing has come about for nature conservation reasons, it is because of the currency of the concept of ‘overgrazing’ (or occasionally undergrazing on species-rich grassland). It is equivalent to micro-managing the landscape, and is often an attempt to countervail successional trends. The high mountains are littered with the remains of old fences from sheep-farming days – a management measure that rarely lasted beyond the life of the fence.

Fences such as this in Wester Ross, designed to remove grazing to allow for woodland regeneration, are now a common throughout the Highlands, parcelling-up the landscape.

Isolated woods such as this are often targeted as a particular habitat to be isolated from herbivory, to allow young trees to grow. Hence many now are enclosed by fences.

Grazing exclusion can be on a large scale, here north of Ullapool. A deer fence follows the right-hand shore of the loch visible here, enclosing a large proportion of this landscape into which native trees have been planted.
Fencing-off of riversides in the name of ‘habitat improvement’ is nowadays a common situation, but is another example of the ‘compartment approach’.

A prescriptive approach of fencing off riverbanks can be beneficial in lowland Britain, to reduce erosion rates of earth-based rivers, and to help absorb nutrient run-off from intensive agricultural practices.

However, in upland Scotland it goes against natural ecological processes as there would not be any natural barrier preventing herbivore access to the river. Hence it is introducing an unnatural element into many wild, free-ranging landscapes. It is argued that, by allowing tree growth, it reduces river erosion. Putting aside the question of why we should want to prevent the natural process of riverside erosion in upland rivers, it is also dubious as to whether it achieves this. Most erosion takes place during extreme flood events, and river banks, together with associated trees and roots, can often be seen to erode in these circumstances.

Additionally, alder regeneration can take place on a massive scale after such events (e.g. at the bottom end of Glen Shiel).

A riverbank in Glen Esk, fenced off as part of a ‘habitat improvement’ scheme, with associated tree planting. Although such action may benefit fish (through increased input of insects/organic matter from future mature trees), it epitomises the ‘compartment approach’ to biodiversity.

The presence of riverside alders does not prevent erosion in fast-flowing upland rivers as can be seen here, because most erosion takes place in flood events. The presence of collapsed trees can exacerbate localised flooding by diverting held-back flood waters.

A treeless riverbank on Jura, perhaps the more normal and natural situation for many upland rivers in Scotland. See also picture 1 on page 13 which shows regenerating birch and alder in spite of the presence of deer and the absence of fences; this indicates that, in some localities, riverside woodland can persist without human intervention.
The action planning approach is allied to compartmentalisation. It is a perfectly reasonable approach to use in lowland, intensive landscapes, where action has to be targeted to prevent total loss of semi-natural habitats or native species.

However, when transferred to large-scale, natural landscapes, this fragmentation makes less sense. It is as if the ecosystem is taken apart and action for each part identified, and then ‘put together again’ by combining the action plans. However, it is quickly found that different components have contradictory needs, and the whole process tends to founder in its own complexity. Additionally, specialists with a particularly loud voice might lobby successfully for their (arbitrary) species of interest.

Action planning may be necessary to target truly endangered species, to assist with reintroductions, or to control alien species, but caution is needed in its use. See Approaches to Nature Conservation on page 45.
Grouse moor management can be likened to intensive farming, with heather burning, dosing, killing of predators, application of grit, digging of scrapes, reduction of red deer, killing of tick hosts (mountain hares) and use of dosed sheep as tick sweepers. In spite of this, and of red grouse being one of the most studied birds in the world, grouse numbers still fluctuate considerably.

It is likely that grouse moors in the north of Scotland have been *Calluna*-dominant heaths and bogs for hundreds, if not thousands, of years (see map on page 8) and represent a natural vegetation-type. Frequent burning affects the natural vegetation pattern, mainly through increasing vascular plant diversity. *Calluna* does not need burning to persist (see picture 2, page 9), and burning may open moorland up to subsequent tree colonisation.

Grouse shooting provides an economic incentive to maintain heather moors, but the intensity of management reduces much of their naturalness, and probably also contributes to global warming through preventing storage of carbon in the soils. Associated management reduces some wildlife, such as mountain hares, foxes and stoats, although it can increase the numbers of certain breeding waders through providing areas of shorter vegetation.

Strips of muirburn in the Cairngorms, carried out to increase red grouse numbers above the natural carrying capacity. By reducing litter input to the soil, increasing ash content and causing long-term reduction in water-holding capacity, muirburn tends also to reduce carbon storage potential.

Muirburn can introduce grass into the system, here visible near Mt Keen in the eastern Cairngorms. By doing this, muirburn is probably the biggest cause of *Calluna* loss on moorland in Scotland, particular on richer soils and where sheep grazing is also present. Muirburn also prevents development of internationally important hepatic-rich heath.

A recent scrape in blanket peat made to provide pools for grouse chicks (through increased insect abundance), and with grit put down on the turf. Breaking vegetation cover on peat is always a risky activity as it can instigate erosion. Current practice aims for a maximum, fixed, annual yield of grouse, something that appears not to be achievable.
Scotland has a Forestry Strategy, with the aim of creating 25% woodland cover in Scotland. One of the justifications given is that Scotland’s woodland cover is lower than the European average. This is a strange argument, though: should Switzerland increase its coverage of wet heath to meet the European average, Italy its raised bogs, or the Amazon Basin its savannah to meet the South American average?

One of the biodiversity characteristics of upland Scotland is extensive, open, oceanic ecosystems, with woodland being rare and disjunct in the landscape. This is a globally rare habitat pattern, very different, for example, from the temperate and boreal forests of Europe. Tree planting is obviously a valid activity to create a timber resource, but, at a gross scale, damages rather than benefits Scotland’s biodiversity.

However, in spite of the importance of moorland, both in biodiversity and economic terms, there is no Moorland Strategy to balance the Forestry Strategy. Likewise, although there is a dedicated Forestry Commission, there is no equivalent ‘Moorland Commission’ to develop and take forward a Moorland Strategy.

[See also Ecological Networks page 32: by definition, any new woodland network fragments the existing moorland network.]
Outline of the issue

Associated with the Highlands containing one of the largest area of relatively natural vegetation in Europe, is the large area of soils whose structure has not been affected by human activity (apart from areas of peat cutting). Such soils have developed over thousands of years, with processes of soil leaching, iron pan development and peat formation being slow.

However, in addition to 20th Century forestry ploughing, modern mounding methods associated with tree planting schemes is reducing the area of undisturbed soils. This is helping to reduce the overall naturalness (biodiversity value) of the area. Such damage cannot be reversed.

Trees & albedo Additional note June 2016
If the oxidising effect of tree roots on soil carbon (see page 41) and the effect of trees on lowering the albedo are taken into account, it is possible that adding more trees to the landscape could accelerate climate change.

“The albedo of forested land is generally lower than that of open land because the greater leaf area of a forest canopy and multiple reflections within the canopy result in a higher fraction of incident radiation being absorbed ... Surface albedo change may therefore provide the dominant influence of mid- and high-latitude land cover change on climate.”


A native woodland ‘restoration’ scheme with mounding for tree planting on wet heath. Trees are planted on the turves. In this locality it is unlikely that woodland would naturally be present on this vegetation/soil type. The darker area at the top of the picture, dry heath, is more suited to trees, although this does not necessarily mean it would be wooded.

A wider view of the same scheme in Wester Ross which has pockmarked the soil. The natural vegetation type on this gentle slope would probably be blanket peat, although in this locality the top layers of peat have probably been removed by centuries of peat cutting.

Most of the landscape here in the near and middle distance has had a digger carrying out mounding similar to that above (although with a smaller bucket on the digger). In this instance the vast majority of trees have died since planting, owing to poor soil conditions. Even if subsequently beaten-up, there will be permanent pockmarking of the soil.
Timber is a valuable and necessary economic resource for Scotland. However, through its irreversible soil changes, commercial forestry is incompatible with biodiversity conservation (in the sense of maintaining the natural ecological characteristics of Scotland). It can, of course, have nature conservation value through hosting certain indigenous species.

The disturbed ground produced by forestry operations does provide an excellent seed bed for subsequent colonisation by native trees. However, this can give a misleading impression of the natural woodland cover as the substrate conditions before tree planting may well have unsuitable for tree colonisation. A successional trend on felled plantations on drier sites (for example on the Culloden battlefield site) can be dominance of wavy hair grass *Deschampsia flexuosa*, followed by dominance of *Calluna*. However if a seed source is nearby, birch and pine can seed into the heather, eventually becoming dominant and shading out the heather. Such new growth *Calluna* on disturbed soils appears much more susceptible to tree colonisation than old growth *Calluna* on undisturbed soils (see picture 2 on page 9).

Any expansion of commercial forestry on natural and semi-natural habitats can only be at the expense of Scotland’s biodiversity.

Modern forestry practice creates permanent effects on the soil, through the establishment process, the drying effect of roots, the oxidation of peat/humus, killing of native vegetation (through shading), ground disturbance during extraction, brash heaping and scarification.

Vegetation colonisation following felling results in a very different vegetation type than that which existed before planting – foxgloves may have been unknown, for example. It also results in a vegetation/soil type much more suitable to tree regeneration than the original type. In effect, it ‘rejuvenates’ the soil.

A high level experimental forestry plot in the Cairngorms, which has recently been clear-felled, apart from a few areas of Scots pine. This soil will be more amenable to tree regeneration, and this, combined with the rejuvenated soil, will cause this area to remain an unnatural pocket within natural vegetation, possibly for hundreds of years.
TOPIC
Outline of the issue

It is often stated that tree planting on Scottish hill slopes will help prevent erosion. Surprisingly, though, there is little, if any, research into whether it will actually achieve this. If major landscape change is to be carried out in the name of erosion (or water) control, then it is imperative that this should be evidence-based.

Certainly in arid climes, where ground flora can be sparse, tree roots will help bind soils and the canopy break heavy rainfall. But it is not apparent that this would also be the case in upland Scotland, especially on grassy slopes with tightly-bound ground vegetation, or where an iron-pan is present. Slope failures through native woodlands are visible in some areas, and the large landslides on the east shore of Loch Lomond in the 1980s took place through commercial plantations. In the latter case, the lack of ground flora under the conifers appeared to have increased the erosion potential.

Additionally, in Scotland’s windy climate, mineral soils exposed by wind-blown trees may actually exacerbate erosion.

Ancient gullies, a common sight in the Highlands. Palaeoecological research shows that the erosion rate has varied over time. Here the current grass-dominated vegetation is tightly bound to the soil and relatively resistant to erosion.

A major peat slide on Shetland in 2003 following torrential rain. It shows how the slip zone at c. 1.5m depth, is at a greater depth than tree roots would reach. Hence it is unlikely that the presence of trees would prevent such slips as these in areas where tree planting was possible.

A pine plantation showing wind-blown trees. In such a windy climate as Scotland with often waterlogged soils leading to shallow rooting, windthrow is common. On steep slopes, the exposed mineral soil below the roots increases the risk of erosion in storm events.
Peatland Conservation and Carbon Storage

Outline of the issue

The long-term cycling of peat is shown in the diagram on page 21, which also demonstrates the carbon storage potential of each phase.

The patterned bog in picture 1. contains deep peat, so will be storing a lot of carbon. However its potential to continue as a carbon sink is probably limited, particularly as it could soon enter an erosive phase (if the pool system drains or the pools continue to expand in size).

The developing shallow peat bog in picture 2. has the greatest long-term potential to be a carbon sink, i.e. actively storing carbon, although the current amount of carbon stored is still relatively low (albeit of the same order of magnitude as a woodland would be on the same site). Picture 3. shows how tree planting on peat, by oxidising the peat, can contribute to carbon release to the atmosphere.

There sometimes seems to be an arbitrary definition of peat as being ‘greater than 50cm depth’, which would rule out that in picture 2. However, shallow peats of less than 50cm depth have the greatest long-term potential as carbon sinks. Because such peats are often deemed as floristically uninteresting, they do not necessarily correspond to designated sites. There is a case for a new ‘carbon sink’ designation to cover those areas with most carbon sink potential.
Remote, untrammelled land, where the imprint of human activity is minimal, is becoming increasingly rare on a global scale. Neither does there appear to be any slow down in its rate of attrition in the Highlands; in fact, with continual construction of tracks by sporting estates and those associated with renewal energy developments, the rate of decline of wild land is, if anything, increasing.

These tracks are also laying-up potential problems for the future as corridors for invasive plants – see page 26.

Do we want development everywhere? Do we really want future generations not to be able to experience places where naturalness is dominant? Do we want to share this planet with other species, or appropriate every square inch for ourselves?

A recent extension to an older bulldozed track in the Monadhliaths, created for shooting access. Note the drainage ditch to the left of a design that will be liable to gully erosion. There has also been use of imported hardcore on the track base. The disturbed ground on the edge and to the right provides suitable soil conditions for colonisation by invasive

An old Victorian stalking footpath in the hills north of Loch Cluanie bulldozed into a vehicle track within the past three years.

A new bulldozed track through blanket peat in the northern Monadhliaths (visible from Inverness) created in 2008 to provide access for shooting.
Re-wilding is about letting natural processes determine the direction of ecological change and, before the evolution of humans, was the only option available to the planet! It is the antithesis of the prescriptive ‘compartment approach’ to landscape management. Ecological outcomes are left undefined (dependent on the whims of nature). What happens, happens! [See page 45]

Owing to the perception that the Highlands are an anthropogenically damaged landscape, and ‘should be wooded’, it is also used in many quarters to mean ‘putting back trees in the landscape’. However, if trees would not naturally be part of the landscape, then adding trees, together with associated woodland species, is not re-wilding. If woodland declined naturally, then so would the associated obligate woodland species (e.g. red squirrels, capercailzie) – some to extinction – a natural process.

Re-wilding is about ensuring that all the naturally occurring species are present, so reintroduction of species lost through human action is a key part of the concept. Without doubt wolves died out in Scotland through persecution, so reintroduction of these is a key part of re-wilding (but only where they would naturally be present, which is not everywhere, e.g. islands). See the Appendix page 47.

Wolves were present throughout the Holocene, apart from the last 250 years. It is often said that bringing wolves back into the landscape will cause woodland expansion through controlling red deer numbers. However, several thousand years of woodland loss in the presence of wolves suggests otherwise. See also the Appendix p.47.

This fence has been erected to encourage regeneration of a small area of woodland in the Monadhliaths. An area with fences cannot be wild, as fences create highly artificial barriers to herbivore movement (as well as killing grouse species).

A typical, open, free-ranging landscape in Wester Ross, the result of over 10,000 years of natural processes. A landscape that is wild already, and does not need ‘re-wilding’. Wildness has been reduced in the foreground through draw-down zone of the hydro-electric scheme, the planting of larches c. 100 years ago, and a modern woodland ‘restoration’ scheme.
Climate change has not been singled out as a separate issue because the climate of Scotland has always been changing. It has been colder during phases such as the little Ice Age, and possibly up to $2.5^\circ C$ warmer during the Holocene climatic optimum. It is also impossible to state with certainty what any detailed climate changes will be at a given locality. The only difference with anthropogenic climate change is that it is likely to be permanent, or at least significant in geological timescales, and may eventually result in temperatures above that seen before in this interglacial. Indeed, it may make the interglacial permanent. However, the following observations are put forward:

1. All species currently present have survived a previous warm period, possibly up to $2.5^\circ C$ warmer.

2. Because of continual climate change in the past, the ecosystems that have evolved are those that are most buffered against change: e.g. high soil organic content helps mitigate periods of drought; vegetation types are resistant to varying grazing levels arising from the secondary impact of climate on herbivore numbers.

3. Some vegetation changes are reasonably predictable, e.g. increase of bracken, gorse and broom at higher altitude through less late frost; fewer snow-dependent habitats and species.

4. Some are more unpredictable, e.g. effect on peat growth. Study of palaeoecological analogues may help in predictions.

5. Vegetation on the infertile, acid soils (most of upland Scotland) is unlikely to change much, because, being a specialised habitat, there are few indigenous species capable of colonising that have not done so yet. Most change will be through colonisation by species introduced from other parts of the world, and not necessarily climate-related.

6. Many habitats are found far distant in warmer climes, e.g. on Dartmoor or the Scilly Islands, and look much the same as those in upland Scotland. In other words, temperature is not the limiting factor.

7. Lack of habitat linkage may prevent colonisation by southern species, e.g. dwarf gorse *Ulex gallii*, although will depend on dispersal mechanisms (see page 27).

8. Warmer winters may encourage higher herbivore numbers, through increasing plant productivity – although, conversely, wetter winters could cause higher mortality.

8. The current ‘compartment’ and ‘action planning’ approaches [see pages 33 & 35] are the least suitable for dealing with climate change [Approaches 2 & 3, page 45].

9. The re-wilding approach, i.e. not having predetermined ecological outcomes, is most suited to dealing climate change: we cannot prevent a warming climate in the short-term, and will have to accept what happens [Approach 1, page 45].

10. In conclusion, anthropogenic climate change will probably not significantly change the physiognomy of Scottish ‘upland’ vegetation, at least in the short term.
Approaches to Nature Conservation

1. THE WILDERNESS APPROACH – Wild Nature: the Ideal?

The concept:
- UNDEFINED OUTCOMES (with respect to habitat/species composition)
- Minimal human intervention (except control of alien species & reintroductions)
- Letting nature ‘do its own thing’, manage itself (it has managed itself for the past 4000 million years)
- Acceptance of natural dynamics (immigrations/extinctions)
- Letting plants and animals characteristic of each part of the planet follow their natural progressions

Applicable to:
- Large areas of land (but not necessarily so, e.g. offshore islands, underwater in pond): site-based approach less meaningful
- Land where there are few economic or social constraints

2. THE NATURE RESERVE APPROACH – ‘Wildlife Gardening’

The concept:
- DEFINED OUTCOMES (with respect to habitat/species composition)
- Managing nature
- Varies from minimal intervention to full-scale habitat & species manipulation
- Intolerance of ecological succession

Applicable to:
- Areas where specified habitats/species or cultural landscape conservation is the primary objective: site-based approach essential
- Islands of semi-natural habitat in an intensively managed landscape
- Conservation of species now rare through human activity

3. FITTING-IN

The concept:
- Fitting as much wildlife (indigenous species) as possible around economic activities, e.g. farming, forestry
- Examples: conservation headlands, farm ponds, 10% native trees in commercial forests, wildflower verges

Applicable to:
- Any area of land where conservation is secondary to other land uses

Different approaches to nature conservation are valid in different localities, and in conservation planning the relevant approach should be identified at the start.

A problem with current approaches in northern Scotland appears to be that the ‘Nature Reserve Approach’, which is perfectly reasonable, indeed essential, in much of lowland Britain, is unthinkingly transferred to our free-ranging northern landscapes.

In effect, large tracts of northern and western Scotland are being managed when, from a biodiversity perspective, there is no need.

Applied to this area, the ‘Nature Reserve Approach’ tends to lead to compartmentalised thinking, rather than seeing the system as a whole. It leads to concentration on what could be seen as arbitrary species and habitats, often identified as ‘priority’; and also to concentration on only a sample of the landscape (albeit, a good one – i.e. designated sites).

Biodiversity targets

The EU had an ambitious target to halt biodiversity loss by 2010. In Scotland, the 2004 document Scotland’s Biodiversity: It’s in Your Hands has in its vision: “To halt the loss of biodiversity.”

If much of northern and western Scotland consists of natural vegetation, together with the associated natural processes which define its pattern, then, looked at logically, any loss in its extent or its pattern will result in a loss of biodiversity (as defined on page 4).

In order to halt the loss of terrestrial biodiversity, the relevant issues raised in this paper will have to be tackled – for ‘biodiversity’ applies to all the natural vegetation, not just that deemed priority or within designated sites (although a large proportion of this ‘wider landscape’ does consist of habitats recognised in Annex 1 of the EU Habitats Directive). Halting the loss presents a daunting and challenging task, and will need a review of policy all the way up to the EU level.

A ‘whole landscape’ approach will be needed, as, for example, exemplified in ‘High Nature Value Farmland’ (which includes most of the area), and the associated The Environmental Impact Assessment (Agriculture) (Scotland) Regulations 2006 – which apply to all unimproved land.
How can it be that much nature conservation action in the northern and western Scotland has, in the author’s view, become so divorced from ecological reality?

We have many systems in place designed to look after our plants and animals: European Directives, a designated sites system, action plans, numerous organisations: are these helping or hindering our understanding of our ecology? Perhaps the approach of focusing on priority species, habitats and sites is getting in the way of seeing the ecosystem as a whole – missing the bigger picture?

Has action has become too formulaic, dogmatic, and office-led? Do we just unthinkingly accept and apply given priorities? How many people are actually out there in the field researching the ecology and palaeoecology of our plant and animal communities? And how much are we feeding new knowledge and our practical experience of nature back into policy review? Are we too attached to our current mental models of how the ecosystem functions that we are reluctant to delve too deeply into our preconceptions? Or is it because, as a species, we so predisposed towards trees that our objectivity is clouded?

How many people can tell a beak sedge from a bottle sedge, a soft rush from a hard rush, a sloe from a cotoneaster, a peat from a podsol? How many people know whether heather is common or rare in this world, the global distribution of Scots pine, or the grazing preferences of sheep and red deer?... Without such knowledge, how can we possibly look after our northern landscapes?

Too many questions; too much investment of both policy and resources in the current approaches; better to keep our heads down and carry-on as we are... instead of undertaking a full review of current rationale and practice.

The area possesses an increasingly rare type of landscape, where it is still possible to see how natural processes have shaped the vegetation pattern over large tracts of land. But for how much longer?

### An example of the mismatch between mental models and ecological reality

**The Vision:**

**A woodland network stretching from A to B**

*(based on the principle of allowing natural processes and on the ecological theory of networks)*

1. Deer numbers reduced to allow for natural regeneration between the existing woods of A and B
   ↓
2. Regeneration not sufficient for woodland expansion
   ↓
3. Deer numbers reduced further
   ↓
4. Still not enough regeneration: scarification carried out
   ↓
5. These areas homed-in on by deer – regeneration eaten
   ↓
6. Areas fenced off
   ↓
7. Mountain hares get in and eat regeneration
   ↓
8. Cull of mountain hares takes place + enhancement planting
   ↓
9. ‘Broadleaved element’ fails to arrive: planting of broadleaves
   ↓
10. Deer get into the exclosure via a snowdrift and eat the young trees
    ↓
11. Voles damage the replaced broadleaves: vole guards added to the saplings
    ↓
12. Broadleaves fail, superphosphate added...

*Nature is going to do it our way, like it or lump it!*  
*Nature is not allowed to be wild!*
APPENDIX Assessing herbivore carrying capacity using trophic levels

Fig. 1. Indicative theoretical trophic level diagram for 1 square kilometre of Scottish upland vegetation

<table>
<thead>
<tr>
<th>Carnivores 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary consumers (herbivores) 10%</td>
</tr>
<tr>
<td>Primary producers (plants) 100%</td>
</tr>
<tr>
<td>7 wolves = 10% red deer eaten</td>
</tr>
<tr>
<td>78 red deer = 10% plant production eaten</td>
</tr>
<tr>
<td>Plant production = 500 tonnes dry matter/sq km/yr</td>
</tr>
</tbody>
</table>

Fig. 2. Trophic level diagram for Scottish upland vegetation with 8 deer/sq km – the maximum indicative level for woodland regeneration

<table>
<thead>
<tr>
<th>Primary consumers (herbivores) 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary producers (plants) 100%</td>
</tr>
<tr>
<td>Plant production = 500 tonnes dry matter/sq km/yr</td>
</tr>
<tr>
<td>4-8 red deer = 0.5-1% plant production eaten</td>
</tr>
</tbody>
</table>

A standard model used in ecology is that of trophic levels. At the bottom level is the primary production, *i.e.* the biomass of plants produced through photosynthesis. 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 (biomass = chemical 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 northern Scotland as shown in Fig.1. The data comes from various sources (see references on the right).

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.

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. The same method indicates a carrying capacity of 131 blackface sheep, 23 Highland cows or 1,000 mountain hares. 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.

The wolf figures are added for interest, based an average daily meat consumption of 5.53 kg/day (references indicate a range 2.77-10.4) and 65% water content of the meat.

Fig.2 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.1 and Fig.2 is one reason why it is so difficult to keep deer numbers low; it also indicates that the presence of wolves amongst unmanaged red deer would not bring the density down to 4-8/sq km.

Data sources
Armstrong H, 1996. The grazing behaviour of large herbivores in the uplands. Scottish Natural Heritage Advisory Note 47.
After gaining an honours degree in botany from Durham University, James Fenton worked for five years as a research ecologist with the British Antarctic Survey studying Antarctic peat, gaining a PhD from London University in the process. Thereafter he tutored ecology in the Lake District before returning to Scotland to work as an ecological consultant. Subsequently he became the first ecologist for the National Trust for Scotland, remaining with them for 14 years. From 2005 to 2011 he worked on landscape policy for Scottish Natural Heritage before heading to the Falkland Islands to be chief executive officer of Falklands Conservation. In 1987 James launched the news digest SCENES: Scottish Environment News. In 2009 he published A Field Guide to Ice, a layman’s guide to the different types of land and sea ice (reprinted in 2011).