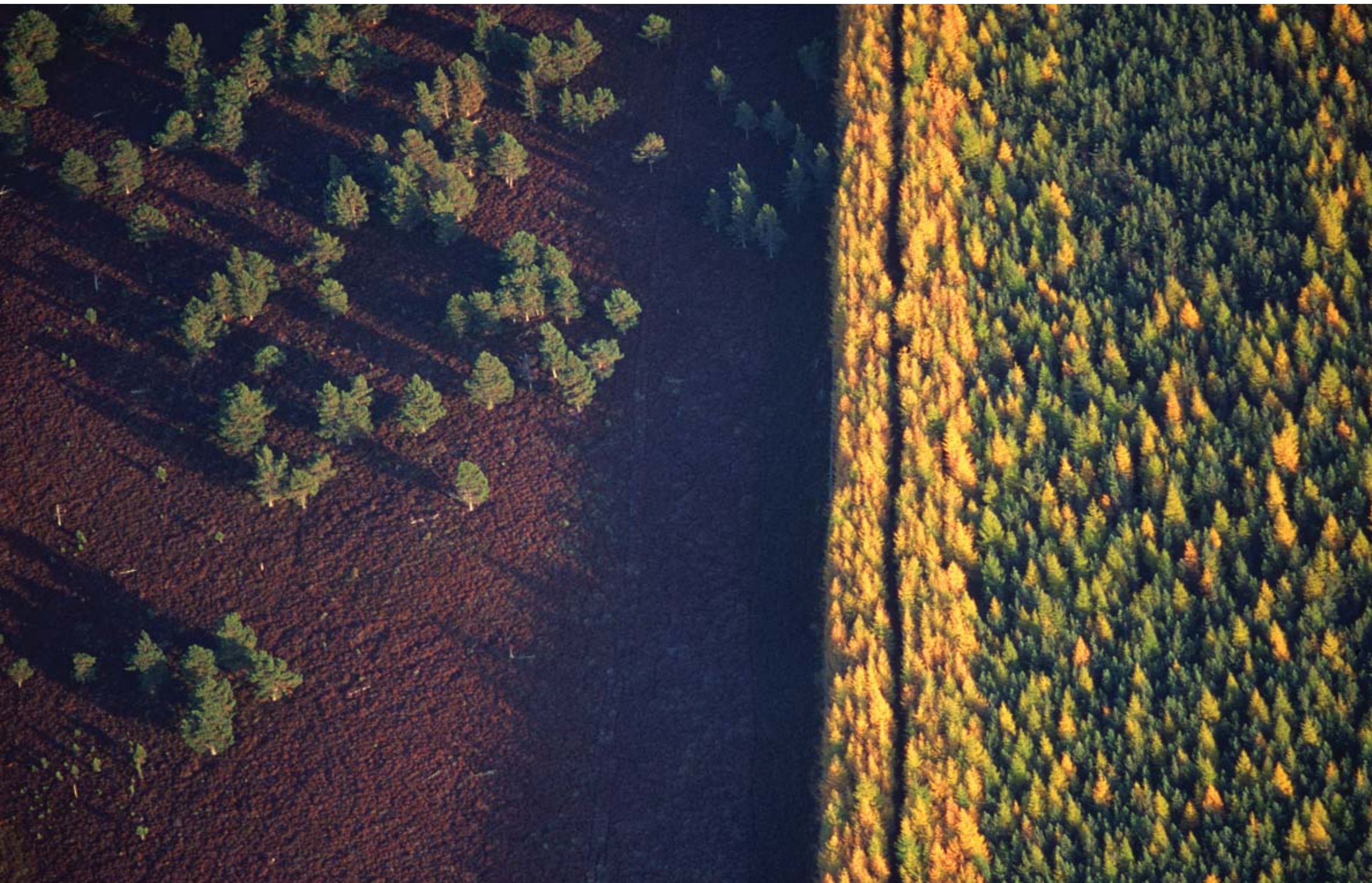
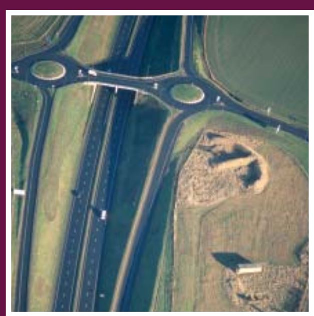
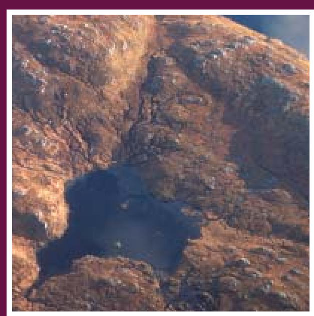
Policy futures series No 1/2009

Living Landscapes
towards ecosystem-based conservation in Scotland







SCOTTISH WILDLIFE TRUST

About Scottish Wildlife Trust

The Scottish Wildlife Trust (SWT) was founded in 1964 to take all appropriate measures to conserve the fauna, flora, and all objects of natural history in trust throughout Scotland. With over 33,000 members, several hundred of whom are actively involved in conservation activities locally, we are proud to say we are now the largest voluntary body working for all the wildlife of Scotland. The Trust owns or manages over 120 wildlife reserves and campaigns at local and national levels to ensure wildlife is protected and enhanced for future generations to enjoy.

The Scottish Wildlife Trust is a company limited by guarantee, registered in Scotland (registered number SC040247) having its registered office at Cramond House, 3 Kirk Cramond, Edinburgh EH4 6HZ. It is also a Scottish registered charity (charity number SC005792).

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Introduction

Healthy ecosystems are the very foundation on which we build our society and economy. They provide us with the goods and services on which our quality of life depends. Caring for the health of ecosystems and ensuring they continue to deliver benefits for future generations must therefore be a central purpose for Government and wider society. The conservation of biodiversity is the key to ensuring ecosystem health; quite simply, without thriving biodiversity, ecosystems begin to malfunction and lose significant value.

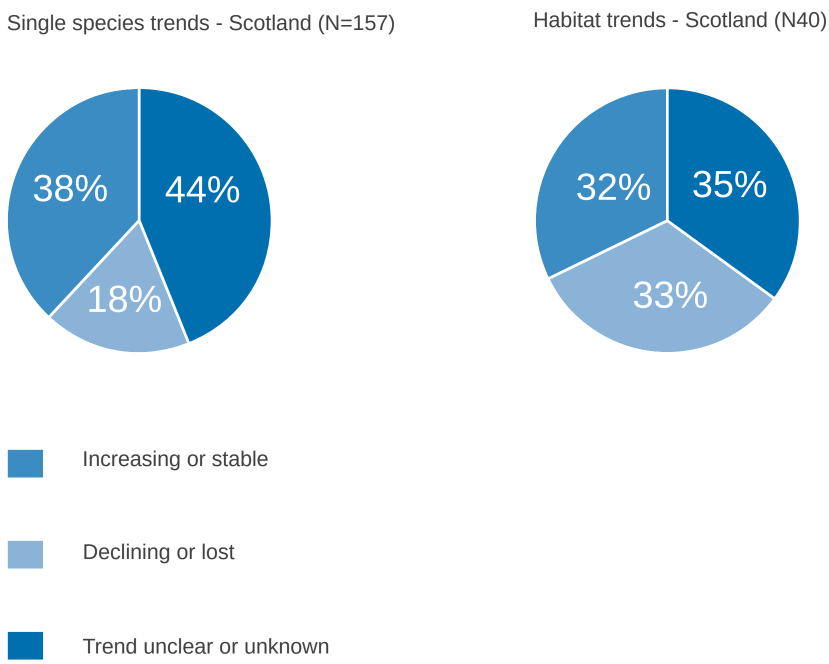
In recent years, both Government and voluntary sector organisations involved with biodiversity conservation have increasingly realised that to reverse continuing declines in biodiversity (see Figure 1) we need to take action not just in specially protected areas for wildlife, but also throughout the wider countryside, at the ecosystem or landscape, scale. There is also growing concern that the speed of climate change will exacerbate the effects of habitat fragmentation as species become marooned in unsuitable climate space, unable to adapt or migrate under rapid environmental change.[1] Coupled with this is a move towards a holistic approach to environmental policy making, moving away from 'silo' working to consider whole systems rather than individual elements of the system (e.g. forests, water, biodiversity, agriculture and so on).[2]

Photo 1 Fragmentation Severe habitat fragmentation in the lowlands; here caused by transport infrastructure, intensive agriculture and loss of hedgerows and small scale habitats.

Working at an ecosystem scale does not mean abandoning more established methods of conservation such as designating and managing protected areas, or targeting management at priority species and habitats. The Scottish Wildlife Trust (SWT) sees ecosystem-based conservation a means of delivering a coherent package of measures at multiple scales. At one end of the scale this might include micro-scale measures, such as the management of a veteran tree or the provision of a green roof; at the other end of the scale it will include better spatial planning to maximise environmental, social and economic benefits at regional and national levels.
The multiple-level nature of the ecosystem-based approach is the key to its success. No one component of the system (whether that be genetic diversity, species, community, habitat or system interactions) is treated in isolation from any other component. By taking such a joined up perspective, it will be possible to develop a much more strategic approach to tackling the systemic threats to biodiversity and prioritise the use of resources at the appropriate scale. It is also an approach which over time should encourage synergies rather than conflicts between social, economic and environmental objectives.

There is an ongoing debate on what an ecosystem-based approach means in practice and, whether by shifting emphasis towards such an approach, we will be making the best use of limited resources. The purpose of this publication is to try and demystify some of the theory behind the ecosystem-based approach (particularly in relation to biodiversity conservation) and advocate its adoption much more widely in Scotland. It will also suggest a range of actions which can be undertaken by Government, non-Governmental organisations, landowners and other stakeholders to practically apply an ecosystem-based approach. Furthermore, it will attempt to clarify some of the terms and concepts associated with ecosystem-based approaches and landscape scale action, many of which tend to be interpreted differently by different stakeholders.

Figure 1 UK Biodiversity Action Plan priority species and habitat trends in Scotland



Box 1 Some key concepts and terms in ecosystem ecology

Ecosystem
An ecosystem is defined by the Convention on Biological Diversity as a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. This definition suggests ecosystems have very diffuse boundaries and encompass very small systems (e.g. a garden pond or urban park) and very large systems or biomes (e.g. boreal forests or the north Atlantic ocean). For practical purposes, ecosystems are any expanse of land or sea where policy is planned and delivered. These areas may follow political boundaries (Local Authority area or the whole of Scotland) or areas with coherent biological and/or physical characteristics such as a river catchment, a landscape (see below), a regional sea or a cityscape. The key difference with planning for action in ecosystems is that the interactions of all the components of the system are not treated in isolation from one another.

Ecosystem function
The functionality of an ecosystem refers to the intactness of all the parts, both biotic and abiotic, relative to the known conditions of the ecosystem. Functional ecosystems are those which contain a largely complete suite of interacting components (including genetic diversity, species, communities and habitats) which are naturally characteristic of the ecosystem and are relatively stable in the long term. Larger, highly connected ecosystems tend to be more stable than smaller, more fragmented ones. In Scotland, upland areas with a high percentage of semi-natural habitat cover have relatively high functionality, whereas urban and lowland farmed landscapes have relatively low functionality.

Ecosystem services
Ecosystem services are defined by the Millennium Ecosystem Assessment[3] as “provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient recycling; and cultural services such as recreational spiritual, religious and other non-material benefits”.

Ecosystem resilience
The capacity of the ecosystem to absorb disturbance and reorganise while undergoing change so as to retain essentially the same function, structure, identity and feedbacks.[4]

Landscape
A landscape can be defined as a “mosaic of heterogenous landforms, vegetation types and land uses”.[5] As with ecosystems, the boundaries or ‘limits’ of the landscape depend on individual, subjective perception. A landscape could be anything from the whole of the country to a single hill or ‘view’. In biodiversity conservation, the term is most often used to refer to areas covering several square miles which often have a distinctive character, shaped by geology, geomorphology or land use. So for example, a range of hills (e.g. the Ochills or the high Cairngorms) constitute typical landscapes. One important distinction to make when using the term landscape is between the cultural landscape and the ecological landscape. From a cultural perspective the landscape encompasses people’s experience and perception of their physical surroundings. The ecological landscape refers to the relative functionality of the ecosystems contained within that landscape (see definition of functional ecosystems above), which may be inextricably linked to the cultural value of the landscape, for example as a perceived area of ‘wild land’.[6]

Island biogeography theory
This now experimentally proven theory simply states that ‘smaller and more isolated islands support fewer species in equilibrium than larger, less isolated islands’.[7] Fragments of semi-natural habitats within a matrix of more intensive land uses, such as developed land or intensively farmed land, behave in a similar way to islands. The relative effects of size and isolation will vary depending on the properties of the intervening landscape ‘matrix’. For example metapopulations – defined as a group of spatially separated populations of the same species which interact at some level - may be able to move more easily through a permeable matrix, such as permanent pasture, than through a relatively hostile one, such as arable land.[8]

The size effect
As the size of an area of semi-natural habitat increases, the number of species it can support also increases. This increase is not only due to an increase in the number of habitat niches available but also the ‘size effect’ per se. In other words, communities of species are more stable (less prone to local extinction) if they exist within large areas of contiguous semi-natural habitat.

Minimum dynamic area
Different species require different habitat or ‘patch’ sizes to sustain viable population levels - so called minimum dynamic areas. For example, capercaillie have been estimated to require at least 500ha of open pine forest[9] whereas the persistence of many ancient woodland plant in small fragments of ancient woodland suggests their minimum dynamic areas are relatively small.[10] The quality of the habitat can be equally or more important than the patch size. Taken together, the spatial and qualitative requirements of a species are referred to as an ‘ecoprofile’. The species most at risk to extinction are those with an ecoprofile of low dispersal capability and larger area habitat requirements (see Figure 2).

Core area
Smaller, isolated habitats or patches also contain less core area, defined here in a Scottish context as the area within the patch not significantly affected by edge effects from the surrounding land. Core area is usually lower in linear shaped patches as there is more edge exposed to the potentially detrimental effects of surrounding land uses. Generally speaking larger core areas correlate positively with species richness but there can often be significant biodiversity associated with habitat edges and transition zones between different habitats.

Habitat networks
The term habitat networks relates to connected systems of land and water managed primarily for the purpose of conserving biodiversity. Habitat networks might include land that is used for other purposes, like recreation agriculture, or forestry, as long as biodiversity value is given special consideration, and the overall design of the network accommodates the needs of communities of native species. Habitat networks are of greatest value when they have a high degree of functional (as opposed to merely physical) connectivity. The relative functional capability of a habitat network depends not only on the properties and relative 'connectedness' of the landscape elements (habitats and any intervening matrix), but also the ecology of individual species (particularly their dispersal ability) and the community interactions between species, such as predation and competition.

Wildlife corridors and linkages
The term corridor is usually used to describe a physical connection between habitat patches. They include features like rivers, hedgerows, green lanes, roadside verges, riparian zones and urban greenspace networks. Some species may use corridors to move between patches but the functional value of corridors is often limited because larger scale 'functional linkages' are required to enable a full range of ecosystem processes to continue.[11] The relative value of the corridor will depend on a range of factors including the size and width of the corridor itself, the quality and size of the habitat patches it links, the species assemblage present in the source habitats and the nature of the landscape matrix surrounding the corridor. Corridors are certainly important conservation features in that they help increase physical, and to a lesser extent functional, connectivity within ecosystems. However, their value for rebuilding ecosystem functioning and climate change adaptation is more limited, and should not be overestimated.

Biodiversity and ecosystem functioning
The diversity and type of species present within an ecosystem can affect its functionality to a greater or lesser extent. As a general rule, the more biodiverse a system is, the greater resilience it has. Certain native keystone species (for example red deer, birch, Scots pine in the Scottish uplands) can have significant influence on both the structure and functioning of ecosystems. The presence of non-native, invasive species can disrupt the natural functioning of ecosystems making them more unstable and prone to species losses. The absence of formerly native keystone species from Scotland's ecosystems (for example beaver and lynx) has already led to widespread functional imbalances in the Scottish Highlands.

Natural processes
In the context of ecosystem ecology, natural processes are defined here as the cyclical successions and internal interactions which occur within ecosystems. The degree of 'naturalness' within a system will vary and affect the relative functionality and nature conservation value of the whole ecosystem. How much we intervene to manage natural processes is a key question in nature conservation. The cultural perceptions and values of key stakeholders and communities will often override any scientific justification for allowing natural processes to take their course.

Keystone species
Species which affect ecosystem function in a significant manner through their activities; the effect normally being disproportionate to their numerical abundance. Their removal initiates changes in ecosystem structure and often loss of diversity. These keystones may be habitat modifiers (e.g. invasive *Rhododendron ponticum*), keystone predators (e.g. lynx or wolf) or keystone herbivores (e.g. beaver or wild deer). At a site or discrete habitat level, certain organisms can be key in shaping the abundance and composition of the particular groups of flora and/or fauna. For example, wood ants can modify the invertebrate community composition of woodlands, or the dominance of a certain tree species can shape the composition of the whole forest ecological community.

Ecological profile
A term which refers to the spatial and qualitative requirements of a real, or surrogate, species (see Figure 2). Species with different ecological profiles (or 'ecoprofiles') differ in their sensitivity to habitat patch size and degree of isolation.

Foundation sites
A term used by SWT which refers to the role of designated, non-designated sites and other biodiversity features (Natura 2000 sites, Sites of Special Scientific Interest, Local Nature Conservation Sites and Ancient Woodlands) as the loci, or sources, from which healthy ecosystems can be re-built.

Biodiversity trends and threats

Biodiversity loss and associated loss of ecosystem health is continuing apace on global, European, UK, Scotland, regional and local scales. Between 2001 and 2005, the Millennium Ecosystem Assessment (MEA) assessed the consequences of ecosystem change for human well-being.[12] The headline findings of the MEA make stark reading; humans have made unprecedented changes to ecosystems in recent decades to meet growing demands for food, freshwater, fibre and energy. Human activities have taken the planet to the edge of a massive wave of species extinctions which is projected to be 10 times the current rate which itself is 1,000 times the background rate as evidenced by the pollen record. The consequences of this unravelling of ecosystem function across the world are already becoming clear: collapsing fish stocks, lack of drinking water, sharp increases in flooding and 'natural' disasters. Ecosystem breakdown is catastrophic for biodiversity which in turn impacts on our economy and the quality of our lives. In the words of the MEA: "the degradation of ecosystem services often causes significant harm to human well-being and represents a loss of a natural asset or wealth of a country".[12]

In Europe the trend is no better. A recent report by the European Environment Agency concluded that EU Member States are falling well short of addressing biodiversity decline in many ecosystems, particularly farmland, seas and coasts, mountains and wetlands.[13] There has been some progress in freshwater and forest systems but even here invasive alien species, fragmentation, dams and canalization remain significant threats. These conclusions are backed by hard evidence of declines in the land cover of all semi-natural habitats apart from forests, and net declines in species diversity. Between 1980 and 2002, wetland butterfly diversity in Europe declined by 37% and farmland bird diversity by 23%.

At the Scotland level, trends in biodiversity have been established from an analysis of the 2005 UK BAP reporting round.[14] The picture is a confusing one but suggests a continuing downward trend in both habitat extent and quality, and in species population sizes and ranges. The trends reported for priority species (total 157) and habitats (total 40) in Scotland are summarised below (see also Figure 1).

- A total of 29 species (18%) and 13 habitats (33%) were reported to be declining or fluctuating (probably declining) or were species that had been lost before publication of the BAP report.
- Of the declining species, about half were slowing in their decline and half were continuing or accelerating. All 12 declining habitats were reported as slowing in their decline.
- 65 species (41%) and 14 habitats (35%) showed a trend that was unclear or unknown.
- 11 species (7%) and 5 habitats (13%) were thought to be increasing or to be fluctuating (probably increasing).
- 49 species (31%) and 8 habitats (20%) were thought to be stable or to be fluctuating (probably stable).

Aside from UK BAP trends, there is also data from other status and pressure indicators which suggests the threats to both terrestrial and marine ecosystems are increasing. The Changing Flora of the UK report[15] was a milestone publication which showed a significant rise in non-native species together with a decline in species intolerant of high soil fertility. This shift in the composition of many vegetation communities has been driven by increased nitrogen and phosphorous inputs into agricultural soils which also affect soil faunal biodiversity, soil structure and the composition of above ground ecological communities. In 2005 alone, an estimated 206,000 tonnes of nitrogen and 30,000 tonnes of phosphorous were applied to farmland in Scotland from inorganic fertilizer. In addition, 178,000 tonnes of nitrogen were applied in the form of manure and in 2004, an estimated 900,000 tonnes of soil were lost to erosion, of which 88% was from agricultural land.[16]

Some of the biggest impacts on Scotland's wildlife, be they in the marine or terrestrial environment, are not yet monitored in a way which enables evidenced based objectives and targets to be drawn up. For example, unsustainable grazing by both wild deer and sheep and habitat fragmentation are two of the most significant impacts on biodiversity, yet we still have no agreed method of assessing diffuse deer impacts in the wider countryside, or any measures of relative habitat connectivity. There are similar data gaps for marine biodiversity where we urgently need better information on sea bed habitat extent, composition and quality to inform marine spatial planning and the identification of marine protected areas.

Climate change is also an increasing threat to biodiversity and the functioning of ecosystems. In a recent global review of phenological and range shift studies, Root et al reported that 87% of 1,700 species showed significant shifts towards higher latitudes/altitudes and earlier spring events.[17] Relative species abundance and habitat preferences can also shift rapidly in response to climate change causing disruption and potential regime shifts in ecosystems.

Clearly there are a number of complex drivers causing declines in biodiversity and ecosystem health. Many of these act in combination to cause even greater impacts. SWT has identified eight systemic threats which we believe are causing biodiversity decline in Scotland. These systemic threats operate at an ecosystem scale and need to be tackled at that scale. See Box 2 for a summary.

Photo 2 Overgrazing Whilst some areas of the uplands are now seeing collapses in sheep numbers, in other areas overgrazing by both deer and sheep continue to have profound impacts on ecosystem structure and function. In contrast, sustainable grazing levels are a vital conservation tool.

Box 2 Systemic threats to biodiversity in Scotland

Climate change
Climate change is likely to have profound influences of the structure and function of ecosystems at global and local scales. Some of the patterns already being observed include:
- Phenological shifts causing lack of synchronisation between interdependent species
- Range shifts to more northern latitudes and higher altitudes
- Population explosions and crashes causing ecosystem imbalance and further species diversity decline
- Changes in ecosystem productivity (e.g. tree biomass, peatland decomposition) with unpredictable effects
- Impacts arising from climate change mitigation measures e.g. agricultural and energy policy changes such as biofuel planting on semi-natural habitats and windfarms on important peatland sites
- Increase in severe weather events leading to soil erosion, loss of soil organic matter, drought with knock-on impacts to biodiversity

Habitat fragmentation
The small, isolated fragments of semi-natural habitat characteristic of much of lowland Scotland can support only small populations of plants and animals. These small populations are very vulnerable and it may take only minor fluctuations in climate, land use or other factors to cause species loss in such small fragments. Our current landscapes have been undergoing fragmentation for many centuries and this continues today with transport infrastructure construction, development pressures and the compartmentalisation of land uses.

Unsustainable grazing and browsing
This is particular problem in parts of the uplands where overgrazing by deer and/or sheep has modified the ecosystem to the extent it bears little reference to any natural vegetation and associated faunal communities which existed in the past, or indeed would develop in the future if grazing pressure were relaxed. Overgrazing on peatlands is likely to become an increasing threat as the intensity of rainfall and droughts increase with climate change. This could lead to severe erosion of peat soils and loss of soil organic matter.

Montane scrub communities have all but disappeared from Scotland and the compartmentalisation of forestry and upland agriculture has seen the loss of highly valuable, multi-purpose wood pasture systems.

Diffuse pollution
Three quarters of nitrogen inputs into surface and ground waters in Scotland come from agricultural sources.[18] The ecological impact of this pollution varies from region to region but is a particular problem in the lowlands and the east of the country. Eutrophication can disrupt freshwater ecosystems making them unsuitable for many species and creating imbalances in the food chain. Polluted waterbodies can become too low in oxygen for some species to tolerate, such as fish and shellfish. In very severe cases diffuse pollution can lead to the growth of toxic algal blooms which directly poison fish and other organisms. Diffuse pollution from fertilizers and pesticides also impact directly on the terrestrial environment by modifying plant communities and soil quality.

Diffuse pollution from air sources (mainly nitrogen oxides and ammonia) is a decreasing problem but over 16,322 hectares of land in Scotland remains at risk from damage. The most vulnerable areas are in the uplands where higher deposition rates impact on sensitive habitats.[19]

Poorly located and designed developments
Built development can lead to direct loss of semi-natural habitat. The problem is often exacerbated by developments which cause greater fragmentation than necessary and by poor design which fails to integrate biodiversity into the fabric of the development.

Invasive non-native species
Certain non-native species can cause significant damage to ecosystem composition and functioning through displacing keystone native species. Left unchecked, many species such as *Rhododendron ponticum* in woodlands, New Zealand pygmyweed (*Crassula helmsii*) in sheltered waters and North American signal crayfish (*Pacifastacus leniusculus*) in freshwater systems could have devastating impacts.

Mismanagement of marine resources

The Scottish Biodiversity Strategy lists nine activities around the coasts and the seas which are currently causing losses in biodiversity.[20] Unsustainable fisheries can have severe impacts leading to ecosystem breakdown. This can have economic as well as environmental consequences as in 1992 when the devastating collapse of the cod stocks off the east coast of Newfoundland meant over 40,000 people lost their jobs. Other activities causing impacts are:

- Finfish and shellfish farming
- Shipping and ports
- Coastal development
- Pollution from diffuse and waste disposal sources
- Coastal defences and coastal erosion
- Military use
- Recreation and tourism

Unsustainable land management practices

This threat category covers a broad range of land use impacts which taken together cause significant impacts on biodiversity. Development pressures, diffuse pollution from agriculture and overgrazing are highlighted above. Other land use impacts include:

- Intensive farming practices leading to the loss in both the quality and extent of semi-natural features on farms
- An over-emphasis on some upland sporting estates on maximising grouse and deer numbers at the expense of wildlife rich habitat mosaics comprising wetland, moorland, grassland with scrub and woodland
- Inappropriate drainage of wetlands and canalisation and damming of water courses
- Unsustainable forestry practices including the planting of monocultures of non-native species and limited use of low impact silvicultural systems

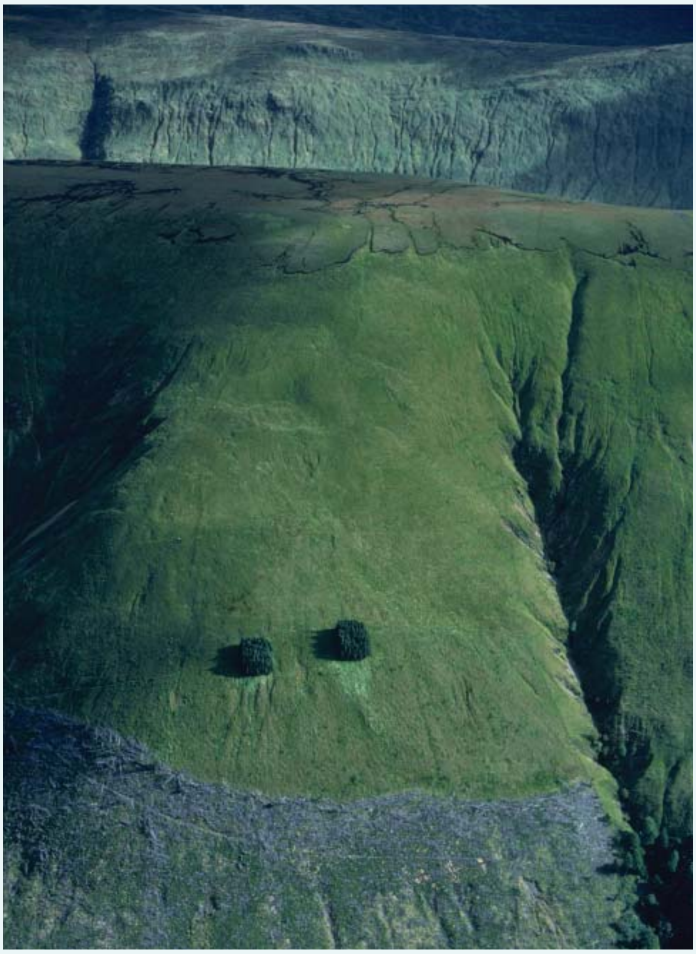


Photo 3 Multiple threats An upland landscape suffering from several systemic threats including erosion, unsustainable forest management and overgrazing. All are likely to be exacerbated by climate change.

The ‘ecosystem approach’

The idea that the complex interactions between climate, soils, plants and animals form ecological systems has been established for over 80 years. The concept was first developed by A. G Tansley in the 1930s, drawing partly on earlier work by F. E Clements on plant successions. In the late 1960s, R. H MacArthur and E. O Wilson developed the equilibrium theory of island biogeography which for the first time described the fundamental spatial factors which explain species diversity, namely island or patch size and the distance between patches (see Box 1 for explanation of some key terms).[21] Since the publication of the theory in the late 1960s there has been an explosion in the number of books and articles on ecosystem ecology.

The science of landscape ecology emerged partly as a response to this pioneering work on island biogeography. Landscape ecology considers the complex spatial relationships in the landscape - flows of nutrients, energy and species - and how these are affected by abiotic and biotic drivers. Landscapes are so often modified by human usage that much of landscape ecology is concerned with explaining the functionality of habitat patches within a matrix of dominant land use; usually either built development or agricultural land.

In the 1970s the concept of ecosystem resilience[22] was developed which can be defined as the relative capacity of the system to repair itself when damaged, disturbed or stressed.[23] Damage to ecosystems arises from a number of sources. The over-exploitation of a keystone species (e.g. a commercial fish species or a top predator) or the severe fragmentation of semi-natural patches are both examples which could lead to a regime shift to a less desirable and less productive state. Such regime shifts can be catastrophic not just in terms of biodiversity loss but also for the economy.[24]

In November 1995, the concepts underlying the science of ecosystems were translated into policy principles by the Convention on Biological Diversity (CBD).[25] The so called ‘ecosystem approach’ became the primary framework for action under the Convention. The ecosystem approach contains 12 core principles (see Box 4). It is clear from the broad scope of the principles that the ecosystem approach (at least as defined by the CBD) goes far beyond viewing ecosystems as biophysical systems. It encompasses social, cultural and economic parameters and their relationship to biodiversity and ecosystem functioning. Taken together, the principles promote an integrated approach to management which sets the conservation and sustainable use of biodiversity within a socio-economic context.

The ecosystem approach, when combined with spatial planning and habitat network modelling, could help resolve conflicting land use objectives. Indeed, it should even promote synergies between social, economic and environmental goals. Examples of such synergies flowing from the provision of ecologically functional green networks are given in Table 1. In urban and peri-urban areas where development pressures are usually highest, spatial approaches and habitat network modelling could be used to interweave functional green infrastructure into new developments. This could help in conflict resolution early in the planning process, particularly if plans are presented using landscape visualisation techniques. Perhaps more controversially, this approach could result in biodiversity being enhanced by development – assuming that existing natural heritage features are retained, and the functional connectivity of the area in and around the new development is increased by new habitat creation on formerly ecologically denuded land.

Box 3 Ecosystem approach and the marine environment

Applying the ecosystem approach in the marine environment entails considering the cumulative impacts of different pressures affecting the structure, functionality and key processes of the ecosystem, including human pressures.

The EU Marine Strategy Framework Directive takes an ecosystem approach with the ultimate aim of restoring the ecological health of Europe’s seas through achieving ‘Good Environmental Status’ by 2021. This integrated policy framework will aim to tackle all the pressures and threats to the marine environment and set clear actions to recover and sustain ecosystem integrity.

The outcomes of MSFD will also be delivered in the seas around Scotland through UK and Scotland Marine Acts.

Photo 4 Marine Pressures on marine ecosystems are likely to increase in the coming decades. It is therefore vital we secure robust legislation with the goal of securing ecosystem integrity at its heart.

Box 4 The 12 principles of the ecosystem approach as defined by the Convention on Biological Diversity

Principle 1
The objectives of management of land, water and living resources are a matter of societal choices. Different sectors of society view ecosystems in terms of their own economic, cultural and society needs. Indigenous peoples and other local communities living on the land are important stakeholders and their rights and interests should be recognized. Both cultural and biological diversity are central components of the ecosystem approach, and management should take this into account. Societal choices should be expressed as clearly as possible. Ecosystems should be managed for their intrinsic values and for the tangible or intangible benefits for humans, in a fair and equitable way.

Principle 2
Management should be decentralized to the lowest appropriate level.
Decentralized systems may lead to greater efficiency, effectiveness and equity. Management should involve all stakeholders and balance local interests with the wider public interest. The closer management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge.

Principle 3
Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.
Management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems; therefore, possible impacts need careful consideration and analysis. This may require new arrangements or ways of organization for institutions involved in decision-making to make, if necessary, appropriate compromises.

Principle 4
Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

a) Reduce those market distortions that adversely affect biological diversity;
b) Align incentives to promote biodiversity conservation and sustainable use;
c) Internalize costs and benefits in the given ecosystem to the extent feasible.

The greatest threat to biological diversity lies in its replacement by alternative systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favor the conversion of land to less diverse systems. Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (e.g. pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs will pay.

Principle 5
Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.
Ecosystem functioning and resilience depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

Principle 6
Ecosystem must be managed within the limits of their functioning.
In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning may be affected to different degrees by temporary, unpredictable of artificially maintained conditions and, accordingly, management should be appropriately cautious.

Principle 7
The ecosystem approach should be undertaken at the appropriate spatial and temporal scales. The approach should be bounded by spatial and temporal scales that are appropriate to the objectives. Boundaries for management will be defined operationally by users, managers, scientists and indigenous and local peoples. Connectivity between areas should be promoted where necessary. The ecosystem approach is based upon the hierarchical nature of biological diversity characterized by the interaction and integration of genes, species and ecosystems.

Principle 8
Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term. Ecosystem processes are characterized by varying temporal scales and lag-effects. This inherently conflicts with the tendency of humans to favour short-term gains and immediate benefits over future ones.

Principle 9
Management must recognize that change is inevitable. Ecosystems change, including species composition and population abundance. Hence, management should adapt to the changes. Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties and potential „surprises“ in the human, biological and environmental realms. Traditional disturbance regimes may be important for ecosystem structure and functioning, and may need to be maintained or restored. The ecosystem approach must utilize adaptive management in order to anticipate and cater for such changes and events and should be cautious in making any decision that may foreclose options, but, at the same time, consider mitigating actions to cope with long-term changes such as climate change.

Photo 5
People at the centre
The needs of communities is a key principle of the ecosystem approach.

Principle 10
The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity. Biological diversity is critical both for its intrinsic value and because of the key role it plays in providing the ecosystem and other services upon which we all ultimately depend. There has been a tendency in the past to manage components of biological diversity either as protected or non-protected. There is a need for a shift to more flexible situations, where conservation and use are seen in context and the full range of measures is applied in a continuum from strictly protected to human-made ecosystems.

Principle 11
The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
Information from all sources is critical to arriving at effective ecosystem management strategies. A much better knowledge of ecosystem functions and the impact of human use is desirable. All relevant information from any concerned area should be shared with all stakeholders and actors, taking into account, inter alia, any decision to be taken under Article 8(j) of the Convention on Biological Diversity. Assumptions behind proposed management decisions should be made explicit and checked against available knowledge and views of stakeholders.

Principle 12
The ecosystem approach should involve all relevant sectors of society and scientific disciplines. Most problems of biological-diversity management are complex, with many interactions, side-effects and implications, and therefore should involve the necessary expertise and stakeholders at the local, national, regional and international level, as appropriate.

Whilst the 12 principles are useful as a guiding 'management framework', they do not explicitly tell us how to achieve agreed objectives which, for the purposes of this paper, means 'halting biodiversity loss'. Principle 5 provides some clues in recommending that "restoration of interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species". This is in many ways a radical shift of emphasis which cuts to the heart of the debate between, on the one hand, ecosystem-based approaches to biodiversity conservation and, on the other, 'species and sites' based approaches. Since this principle was published in 1995 there has been alarmingly little progress in putting it into practice.

There are many other terms commonly used which are related to the CBD definition of the ecosystem approach, or at least some of its individual principles. When SWT uses the term 'ecosystem-based approach' we are referring primarily to the ecological aspects of ecosystems rather than the socio-economic ones, although clearly these are also important drivers affecting the ecology of the system. The term landscape scale action is also widely used but is rarely clearly defined. It is also most often used in an ecological sense, particularly in the context of rebuilding connectivity (e.g. through habitat networks) and also planning and delivering at larger scales (e.g. deer management groups, catchment management plans, multiple landowner projects). Landscape scale projects may also include social or economic parameters, for example the Woodland Trust's (2004) Space for People initiative which spatially analysed the location and extent of accessible woodland in relation to where people live.[26]

Table 1 Potential synergies arising from a well designed functional ecological networks

Economic	Social	Environmental
Attractive and quality local environment attracting inward investment	Opportunities for recreation and outdoor education	Enhanced biodiversity
People using local facilities more often	Improved physical health and well being linked to increased activity and air quality improvement	Species better able to adapt to climate change
Increase in tourism revenues	New green transport networks – cycling and walking	Reduced noise pollution
	Increased opportunities for direct involvement in greenspace management	Better air quality
	Social cohesion and a sense of community pride	Natural flood management
	Sense of place	Enhanced water quality

Photo 6 Protected areas Strict protection of Sites of Special Scientific Interest, such as this sand dune system at Menie Links in Aberdeenshire, is a vital pillar of the ecosystem-based approach. Such sites are repositories of important and increasingly vulnerable species and habitats. These are the foundation sites on which wider ecosystems can be rebuilt yet sadly some remain threatened by ambiguities in the planning system.

Ecosystem services

Since the publication of the Millennium Ecosystem Assessment (MEA), interest has grown in the concept of ecosystem goods and services.

There are various definitions of ecosystem goods and services. The MEA definition is given in Box 1 but a more comprehensive and definition is provided by a Defra led Ecosystem Services Project.[27] They divide ecosystem services into four categories:

- Supporting services: The services that are necessary for the production of all other ecosystem services including soil formation, photosynthesis, primary production, nutrient cycling and water cycling
- Provisioning services: The products obtained from ecosystems, including food, fibre, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources and fresh water
- Regulating services: The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination, natural hazard regulation
- Cultural services: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences – thereby taking account of landscape values

These services are found in both highly modified and semi-natural ecosystems and together provide a number of benefits to humans. The difference between services and benefits is not always obvious but it is nevertheless important to try and make a distinction between the two. For example, water as a service might provide a number of benefits such as drinking water supply, recreational benefits such as angling or boating and even less tangible benefits such as attractive landscapes and their relationship to health and well being.[28]

Ecosystem services are rarely valued as assets and therefore tend to have limited influence on political and business decisions. There are signs this may be changing. In May 2007, at a meeting of G8+5 in Potsdam, environment ministers launched a joint initiative on the global economic benefits of biodiversity and the costs of biodiversity loss and ecosystem degradation. Phase 1 of this initiative was completed in 2008 and the results published in an interim report entitled The Economics of Ecosystems and Biodiversity (the ‘TEEB report’).[29] The TEEB report is perhaps the start of a new approach to the valuation of ecosystem services whereby they are traded in a similar way as carbon is on carbon markets. The buyers and sellers would exchange ecosystem services with the result of no net loss in the quality or quantity of any key ecosystem components – biodiversity, soils, water and so on. TEEB recommends four broad policies to “repair society’s defective economic compass”:

- Pay for unrecognised ecosystem services and penalise uncaptured costs
- Rethink today’s, often perverse, subsidies to reflect tomorrows priorities
- Share the benefits of conservation
- Develop new measures of sustainability, which go ‘beyond GDP’.

Phase II of TEEB will take forward work on these four policy areas and aims to publish a “science and economics framework” which will help frame valuation exercises for most of Earth’s ecosystems, including in its scope all material values across the most significant biomes. Roll out of Phase II of TEEB should eventually help us put a true market value on biodiversity. It is partly this lack of valuation which is “an underlying cause for the observed degradation of ecosystems and the loss of biodiversity.”

Box 5 Potential barriers to delivery of the ecosystem-based approach

1. There is sometimes a lack of understanding and even suspicion surrounding ecosystem-based approaches. This is perhaps in part because the component parts of ecosystems (species and habitats) are far easier to understand and interpret, both scientifically and culturally, than the system itself. It is also in part due to defintions being unclear or variously interpreted.

2. Conservationists since the Victorian era have been fascinated by rarity rather than ecosystem related concepts such as keystone species or habitat integrity.

3. Delivering all the multiple objectives of the ecosystem approach (e.g. the 12 principles) simultaneously is very problematic. In reality, organisations implementing the approach rarely remain holistic and instead will tend to promote their own priorities above those of other stakeholders, thereby deprioritising certain principles.[30]

4. The conservation of charismatic and attractive species appeals to the public, many of whom help fund environmental bodies, so funds will often justifiably be diverted to single species conservation programmes.

5. The ecosystem-based approach requires landowners and other stakeholders to work together to common goals; not a strong tradition in some parts of Scotland.

6. Biodiversity conservation is still seen as secondary or tertiary objective in comparison to food production, housing, transport, industry and other land uses. This skewed balance of sustainability objectives means ecosystems are often over exploited rather than used wisely.

7. Cultural perceptions; for example the 'naturalness' characteristic of more functional ecosystems is sometimes perceived by the public as messy and uncared for.

8. Lack of spatial planning; the biodiversity conservation sector has traditionally been poor at integrating information into other planning mechanisms such as local development plans and sectoral strategies.

From a biodiversity perspective, one of the dangers in taking a purely ecosystem services approach is that it tends to ask the question - what can the ecosystem do for us, rather than what can we do for the ecosystem? In theory, taking an ecosystem to the very limits of its functioning, might provide substantial economic benefit for humans but could also see the erosion or loss of the less tangible benefits related to our quality of life. As Douglas McCauley said in an article in the journal Nature: "market based mechanisms for conservation are not a panacea for current conservation ills. If we mean to make significant and long lasting gains in conservation, we must strongly assert the primacy of ethics and aesthetics in conservation. We must act quickly to redirect much of the effort now being devoted to the commodification of nature towards instilling a love of nature in more people".[31]

The other assumption which is perhaps implicit in a purely ecosystem services approach is that nature is only worth conserving when it is, or can be made, profitable. There are numerous examples throughout history where ecosystem processes have been modified by man to make the ecosystem more economically productive whilst simultaneously destroying natural ecological functioning. Treating ecosystem services as a primarily economic resource could perpetuate this unsustainable approach to the management of natural resources, on both land and at sea.

It is clear that the ecosystem services approach is very different from the CBD definition of the ecosystem approach, which is different again from more ecologically focused ecosystem-based approach. These three perspectives on ecosystem working are all valid and it is particularly important that they incorporate not just environmental drivers but also socio-economic and cultural drivers. That said, SWT would advocate that a driving principle must be to safeguard and enhance the natural components of our ecosystems. The reason for this is as much for economic and social stability as it is for enhancement of natural heritage. Only by enhancing naturalness and connecting surviving fragments can we be sure that ecosystems will continue to function healthily and provide the multiplicity of goods and services we increasingly demand of them. In essence, this is an approach which is rooted in the inalieable principle that biodiversity is the foundation for maintaining life on earth.

So does this mean we need to treat initiatives such as TEEB with a healthy suspicion and maintain a clearer divide between economic activity and environmental protection? Ultimately, SWT feels that if conservationists fail to engage with market-based instruments to help achieve their environmental objectives, the very nature of the market will mean continued erosion of ‘natural capital’ and biodiversity loss. The current economic system has spectacularly failed to value and protect ecosystems and biodiversity. The future must lie in harnessing the power of the market to help deliver biodiversity conservation in a systemic, rather than piecemeal, way. This of course comes with a giant health warning and there will need to be robust guidelines developed before, for example, ‘biodiversity offsetting’ schemes are rolled out more widely (see Box 6). Perhaps most importantly there must be recognition that market mechanisms should be complementary to existing, often very successful, mechanisms such as regulation, incentive payments, protected area designations and the sizable effort of environment NGOs. There must also be a recognition that many places on the planet will simply be ‘off limits’.

SWT concurs with the World Business Council for Sustainable Development that future use of “mandatory market mechanisms will require complex partnerships involving business, governments and NGO’s, and usually new legal frameworks to assure that ecosystem services are being bought and sold at full cost, that there is clear ownership of and accountability for the ecosystem services that are to be traded, and that there is competition amongst buyers and sellers to increase efficiency”.[32]

Box 6

The World Business Council for Sustainable Development seven draft principles of biodiversity offsets[33]

1. **No net loss.** A biodiversity offset should achieve measurable conservation outcomes that can reasonably be expected to result in no net loss of biodiversity.

2. **Adherence to the mitigation hierarchy.** Biodiversity offsets are a commitment to compensate for significant residual adverse impacts on biodiversity identified after appropriate avoidance, minimisation and rehabilitation measures have been taken according to the mitigation hierarchy. Offsets cannot provide a justification for proceeding with projects for which the residual impacts on biodiversity are unacceptable.

3. **Landscape context.** Biodiversity offsets should be designed and implemented in a landscape context to achieve the best measurable conservation outcomes, taking into account available information on the full range of biological, social and cultural values of biodiversity and supporting an ecosystem approach.

4. **Stakeholder participation.** In areas affected by the project and by the offset, the full and effective participation of stakeholders should be ensured.

5. **Equity.** Biodiversity offsets should be designed and implemented in an equitable manner, which means the sharing of rights and responsibilities, risks and rewards associated with a project.

6. **Long-term success.** The design and implementation of biodiversity offsets should have as their objective sustained outcomes in terms of: a) the viability of key biodiversity components, b) the reliability and accountability of governance and financing, and c) social equity.

7. **Transparency.** The design and implementation of biodiversity offsets and communication of their results to the public, should be undertaken in a transparent manner.

Photo 7 Woodland network SWT's own reserve at Woodhall Dean forms part of a woodland network in East Lothian. Connected landscapes bring multiple benefits: climate change adaptation, walking and cycling routes, water regulation, landscape attractiveness and biodiversity conservation.

Ecosystem resilience and climate change

A recent report by the UK Biodiversity Partnership identified a number of direct key impacts of climate change on biodiversity based on evidence from observational data and models of future trends.[34] These include:

- changes in the timings of seasonal events, leading to loss of synchrony between species and the availability of food, and other resources upon which they depend
- shifts in suitable climate conditions for individual species leading to change in abundance and range changes in the habitats which species occupy
- changes to the composition of plant and animal communities
- changes to habitats and ecosystems, such as altered water regimes, increased rates of decomposition in bogs and higher growth rates in forests

Modelling how individual species will respond to climate change has been attempted for a range of species[35] but there remains a high degree of uncertainty as to how most species will respond. This uncertainty is due to a lack of adequate data on existing species distributions and their potential ecological responses to various climate change scenarios (including the interactions between species within ecosystems). There are also uncertainties over how climate change will lead to modified land usage (agriculture and forestry in particular) and how species will respond to these changes.

The 2007 UK Biodiversity Partnership report recommended six guiding principles for conservation action in the face climate change (See Box 7).

The UK Biodiversity Partnership report emphasises that all six of these principles need to be applied if biodiversity is to be adequately conserved as the climate changes. It concludes that there is an urgent need to "move away from management largely focused on selected species and habitats towards much greater emphasis on the underlying physical processes that are essential to the maintenance of biodiversity on site". At the same time, it emphasises the critical importance of protected area networks in helping nature adapt to a rapidly changing climate.

In many ways, these six guiding principles, when taken together, can be seen as an expression of the ecosystem-based approach. They focus on the need to develop resilience through increasing connectivity and variability in the landscape whilst stressing the need to be adaptive and evidence-based in our approach. Taking an ecosystem-based approach is therefore vital if we are to effectively adapt to the pressures which climate change will bring.

Photo 8 Peri-urban green network Connected habitats like those along Edinburgh's Water of Leith will help the post climate change city become more 'liveable' for both people and wildlife.

Box 7 Six principles for climate change conservation action

1. Conserve existing biodiversity

The richness of future biodiversity, in a changing world, will depend upon the diversity we conserve today.

- Conserve Protected Areas and other high quality habitats
- Such areas will remain vital as they have characteristics which will continue to favour high biodiversity; they will also act as reservoirs from which recolonisation of the landscape can take place
- Conserve range and ecological variability of habitats and species
- By conserving the current range and variability we will reduce the probability of all localities being lost, although some losses will be inevitable

2. Reduce sources of harm not linked to climate

Climate change is one of many threats to biodiversity and by reducing other sources of harm we will help natural systems maintain their biodiversity in the face of climate change.

3. Develop ecologically resilient and varied landscapes

By ensuring landscapes remain varied and allowing space for physical processes to take place, their ability to retain biodiversity will increase.

- Conserve and enhance local variation within sites and habitats
- Maintaining diversity in the landscape in terms of features such as vegetation structure, slope, aspect and water regime will increase the chances that species whose current habitat becomes inhospitable will be able to spread locally into newly favourable habitat
- Make space for the natural development of rivers and coasts
- Changing rainfall patterns and rising sea levels will affect our rivers and coasts; by allowing natural processes of erosion and deposition to take place we will increase the potential for wildlife to naturally adapt to these changes

4. Establish ecological networks through habitat protection, restoration and creation

Some species will need to move some distance from their current locality if they are to survive climate change; creating new habitat, restoring degraded habitat or reducing the intensity of management of some areas between existing habitat, will encourage this.

5. Make sound decisions based on analysis

Adopt an evidence-based approach which recognises that biodiversity is constantly changing.

- Thoroughly analyse causes of change
- Not all change will be due to climate change and by thoroughly analysing the causes of change we will identify those situations where climate change adaptation is needed
- Respond to changing conservation priorities
- Regularly review conservation targets to ensure resources are directed towards genuine conservation priorities as some species increase, others decline and habitats change in character

6. Integrate adaptation and mitigation measures into conservation management, planning and practice

When reviewing conservation management plans consider the impacts of climate change – for example more frequent summer fires and floods – and make changes as appropriate. Where they can be identified, reduce release of greenhouse gases to the atmosphere

Text adapted from Conserving biodiversity in a changing climate: building capacity to adapt. UK Biodiversity Partnership

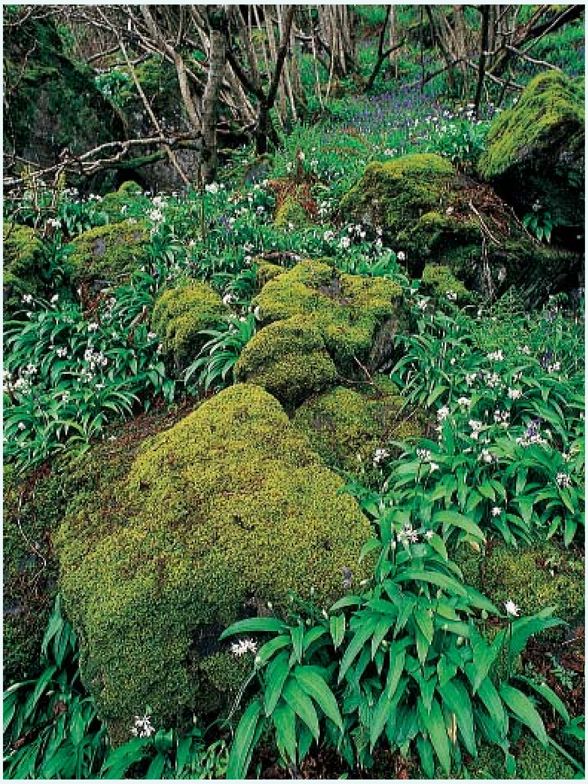


Photo 9 Woodland condition Restoring the biodiversity within degraded woodlands, including plantations on ancient woodland sites is as important as developing habitat networks.

Implementing an ecosystem-based approach

In an attempt to simplify the 12 Ecosystem Approach principles, the IUCN have recommended five steps to implementation, namely:

Step A Determining the main stakeholders, defining ecosystem areas and developing the relationship between them.

Step B Characterising the structure and function of the ecosystem and setting in place mechanisms to mange and monitor it.

Step C Identifying the important economic issues that will affect the ecosystem and its inhabitants.

Step D Determining the likely impact of the ecosystem on adjacent ecosystems.

Step E Deciding on long term goals and flexible ways of reaching them.

Like the 12 principles, these five steps are a useful checklist of the kind of procedures that need to be thought through if ecosystem-based projects are to be realised on the ground. However, these steps are still somewhat theoretical and do not suggest more practical phases of project planning.

Broadly, around five phases of conservation planning can be identified.[36] It is a useful exercise to adapt these phases to the ecosystem-based approach. Although the phases suggested below are intended to be followed through in a step wise manner, in reality there will be considerable overlap and cross-informing between them.

- Data collection and ecosystem mapping
- Scenario mapping and outcome setting
- Projects and incentives
- On the ground delivery
- Measuring outcomes

We have not included stakeholder engagement here as a separate phase or exercise (as suggested in the 5 steps above). This is because we believe the involvement of the full range of stakeholders throughout all these phases of project planning and delivery is a prerequisite to success. For regional and sub-regional initiatives, local communities and landowners are particularly important partners and their active contribution will be vital. It is also essential to communicate the fact that scenario maps are in no way ‘master plans’ to be imposed on local communities and landowners, but evolving tools for identifying opportunities and constraints.

Successful delivery of ecosystem-based conservation will also depend on taking a spatial approach and using the most up to date datasets and digital mapping techniques.

Data collection and ecosystem mapping

The first step in the processes is to agree the parameters of the ecosystem being considered. Ecosystem-based planning can be at a national[37] or more typically a regional scale, for example a local[38] or national park authority area, or a discrete geographical region where local authorities are working collaboratively.[39] A regional scale area could also be based on more natural landscape boundaries, for example using an area of similar geology, a river catchment[40] or a sub-catchment. Whatever the size of the area being considered it is important it is not only ecologically relevant, but also socially and culturally acceptable.[41]

The second step is to map as many datasets as are relevant. Datasets should include species records, habitat boundaries and geographic boundaries[42] and need to be drawn from a wide range of providers (a list of key datasets is given in Table 2). The more comprehensive the datasets used, the more accurate the eventual targeting of action on the ground is likely to be.

Case Study 1

Delivering ecosystem health for people and nature in Wales: The Pumlumon Landscape Project

To address the challenge of unprecedented environmental change, Wildlife Trusts Wales helped forge new partnerships of local landholders, government and non-government agencies to find new and sustainable ways of managing change.

The Pumlumon area is the largest watershed in Wales and is the source of the rivers Wye, Severn and Rheidol. The project area (40,000 ha) holds a complex mosaic of locally, nationally and internationally important habitats and species, such as dry and wet dwarf-shrub heath, blanket bog, unimproved acid grassland and a number of oligotrophic lakes. Improved grassland, broadleaved woodlands and forestry plantations are also typical land uses in the area. Pumlumon is important for breeding and wintering birds particularly hen harrier, merlin, short eared owl, red and black grouse, and a number of Red Data Book and UK BAP invertebrate species.

Its landscapes also have great aesthetic appeal, for their natural beauty, their wide horizons and sense of space. However, like many areas of the Welsh uplands, intensive land use activities have resulted in a significant loss of biodiversity. Many upland habitats in Wales are being lost or are degraded. Over-grazing by sheep has induced soil compaction, which has resulted in diffuse pollution and increased flooding of the lowland areas.

The vision of the Pumlumon Landscape Project is to:
Enhance the natural capital of the project area to allow the production of key ecosystem services that will provide the local community with a sustainable economic future.

This is being achieved through:
- creating landscape solutions that address climate change, diffuse pollution, flooding, habitat loss and species decline by establishing an ecosystem-based approach to land use management
- enabling the farming community to have a sustainable future through the sympathetic management of ‘natural capital’
- encouraging economic activity through the promotion of enhanced natural assets
- empowering communities to address environmental issues through sustainable environmental management

To achieve the scale of change necessary, a Landscape Strategy is being employed, focused on delivery.
The project will support and provide payments for delivering ecosystem services including:
- climate change mitigation
- diffuse pollution management
- flood water management
- habitat and species management

Ecosystem goods and services will be enhanced by whole ecosystem management, including the management of carbon storage in soils (including peatlands), management of grazing levels, creation of ecological corridors and landscape scale hydrological management including the rewetting of damaged wetland habitats.

It is intended that the project provides a model for a top-tier agri-environment scheme. One that will pay for agreed capital and revenue works additional to current agricultural support. Prescriptions for action will be defined in partnership with the local community and land managers within the parameters of Landscape Strategy.

Social and economic outcomes
- more sustainable (less resource intensive) agriculture producing higher quality, high value-added products for local markets
- better ecosystem management, requiring greater inputs of labour, more research and planning, better delivery mechanisms, therefore creating a range of new, skilled jobs
- more opportunities to create new, higher value-added tourism and leisure products based on ecotourism
- the provision of environmental management services to farmers and landowners
- empowering and resourcing local communities to develop sustainable land-management, environmental or tourism projects of their own design

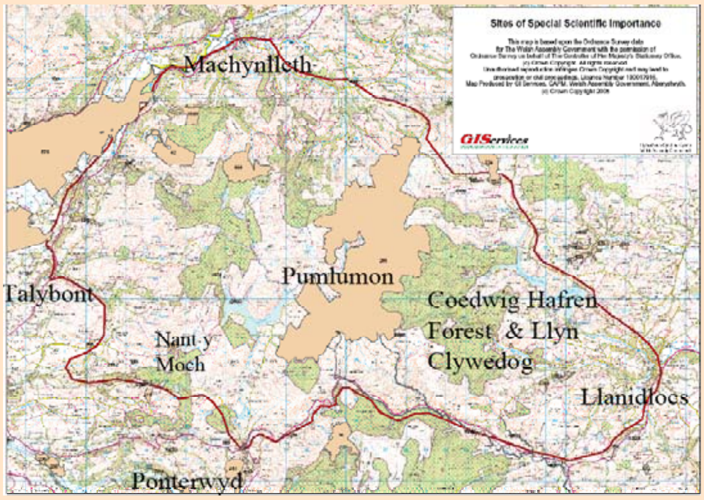


Table 2 Examples of spatial and other datasets available for network modelling (from Humphrey et al, 2005)[41]

Data	Description	Value
SAC, SPA, NNR and SSSI boundaries	Boundaries of protected areas / sites	Give indication of areas of high conservation value in general
Phase 1 Habitat Survey	Broad scale field mapping approach giving information on the extent and distribution of natural and semi-natural habitats	Ideal source of good quality habitat information, but limited in coverage to specific regions
Land Cover Map 2000 (LCM)	Satellite-derived remote-sensed datasets providing broad habitat definitions	Covers the whole of Scotland, but there are problems with accuracy in mapping some habitat types
Land Cover Scotland 1988 (LCS88)	Remote-sensed dataset derived from aerial photography taken in 1988; provides broad habitat definitions at 1:25000 scale	Covers whole of Scotland focusing on semi-natural habitats; is out of date, but currently being updated.
National Inventory of Woodlands and Trees (NIWT)	From LCS88 dataset plus updated to 1995 from FC sources; provides information on broadleaf / conifer woodland >2ha & small woods / trees (0.1-2ha)	Baseline data source on woodland for Scotland
Scottish Forestry Grant Scheme	Regularly updated records of new planting	Gives composition and extent of new woodland areas which can give indication of habitat value
Scottish Semi-Natural Woodland Inventory (SSNWI)	Constructed over the period 1995-2001 using interpretation of aerial photographs taken in 1988. Map of all woodlands >0.1ha classified according to degree of semi-natural character	Identifies all semi-natural woodland useful when combined with NIWT to locate sites of high conservation importance
Ancient Woodland Inventory (AWI)	Map of all ancient (existing since 1750) woodlands over 2ha in size	Identifies areas of key importance for woodland biodiversity
Scottish National Digital Soil Map (MLURI)	Broad-scale mapping of soil series at 1:250000 scale (1:50000 and 1:25000 soil maps occur for some lowland areas)	Of limited value in predicting soil type unless combined with other information (e.g. Digital Elevation Model; LCS88)
Ordnance Survey Pan-Government product portfolio	Products include: 1) for large scale mapping – OS MasterMap; Land-Line; 1:10000 Scale Raster; 2) for small scale mapping – 1:50000 Scale Colour Raster; 1:50000 Scale Gazetteer; 1:250000 Scale Colour Raster; Strategi; Meridian 2	MasterMap is the new, more definitive, large-scale digital map of Great Britain, containing information on roads, tracks, paths, etc. Gives accurate representation of woodland areas and boundaries and can identify linear features which can act as barriers to dispersal or as corridors
Ordnance Survey Digital Elevation Model (DEM)	Digital elevation data for whole of the country	Allows construction of elevation maps aiding in deriving ESC climatic and soil quality indices
British Geological Survey 1:625000 digital maps, (BGS)	Maps of geological series across Britain	Can help with predicting soil type and hence soil quality in ESC
SNH BAP priority habitat report and maps	Maps and description of UK BAP priority habitats; summary of all previous phase I and phase II survey information in Scotland	Provides information on location of key habitats in Scotland
Ecological Site Classification	A tool for predicting suitability of areas for creating/restoring woodland and open-ground habitats based on climate and soil variables	Allows construction of suitability maps for different habitat types across the whole of Scotland
National Vegetation Classification survey data	Various surveys covering SACs, SSSIs and other habitats of high conservation value in Scotland	Coverage is geographically limited and information is often too detailed to make meaningful links with species requirements
Scottish Integrated Agricultural Control System (SIACS)	Contains information on field sizes and crop types for every field in Scotland	Aggregated statistics available at parish level but data from individual land holdings are covered by the Data Protection Act

Photo 10 Jupiter Urban Wildlife Centre The ecosystem-based approach is about making connections – connections between fragmented nature, but also connections between people and nature.

Scenario mapping and outcome setting phase

At this stage, the ecosystem map is in effect a spatial plan for biodiversity which identifies where within the ecosystem the most appropriate areas are for protection, enhancement, restoration and expansion of biodiversity. But the map is not just about mapping opportunities for expansion and joining up of the natural components of the ecosystem. One of its most useful applications is that it can be overlaid onto other socio-economic spatial data sets, including development plan data, to help guide the location of new residential and commercial developments, transport infrastructure, energy and other industrial development. The ecosystem map is much more than a simply a GIS layer with designated areas mapped onto it – it will also show important ecological networks and potential future networks. Far from being a constraint on development, the map could enable development to be located and designed in such a way which potentially increases the ecological connectivity of the landscape and ultimately improves the health of the ecosystem.

There are four basic elements to biodiversity conservation; these also form the basis of UK Biodiversity Action Plan target setting:

- **Protection** – usually referring to protection from direct adverse impacts or from loss to development
- **Enhancement** – referring to the management of a feature or habitat to conserve its special value or increase the population of a priority species
- **Restoration** – the managed recovery of highly degraded former semi-natural features - usually habitats – to a more natural composition and structure
- **Expansion** – referring to habitat creation on land not currently managed with nature conservation as an objective. This includes establishing new habitat on formerly developed land, farmed land and also conversion of recent plantation forests to native composition or open ground habitat. Expansion is usually most valuable when it is adjacent to an existing semi-natural habitat but it is also a valid approach to ‘build towards’ existing habitats as part of implementing a longer term strategic habitat network.

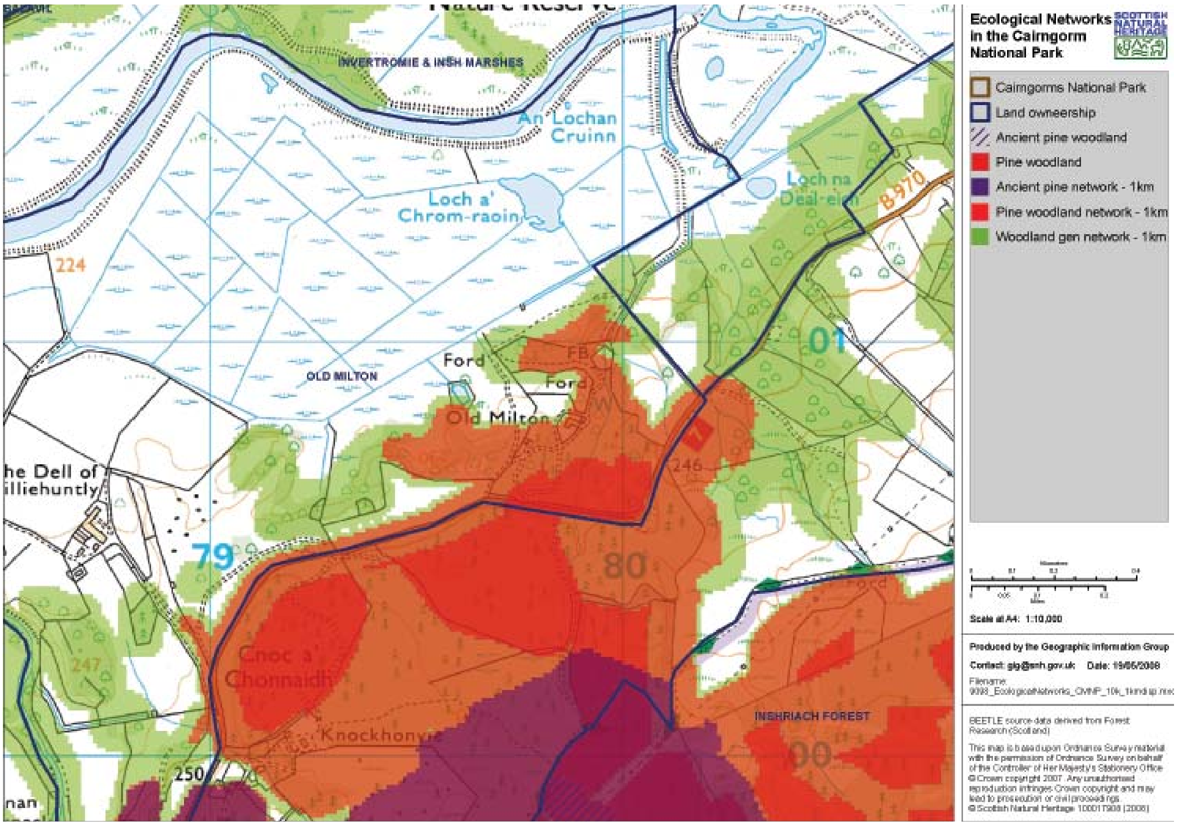
Photo 11 Towards agricultural ecosystems? Ongoing Common Agricultural Policy reform may present both economic and ecological opportunities for Scotland’s farms.

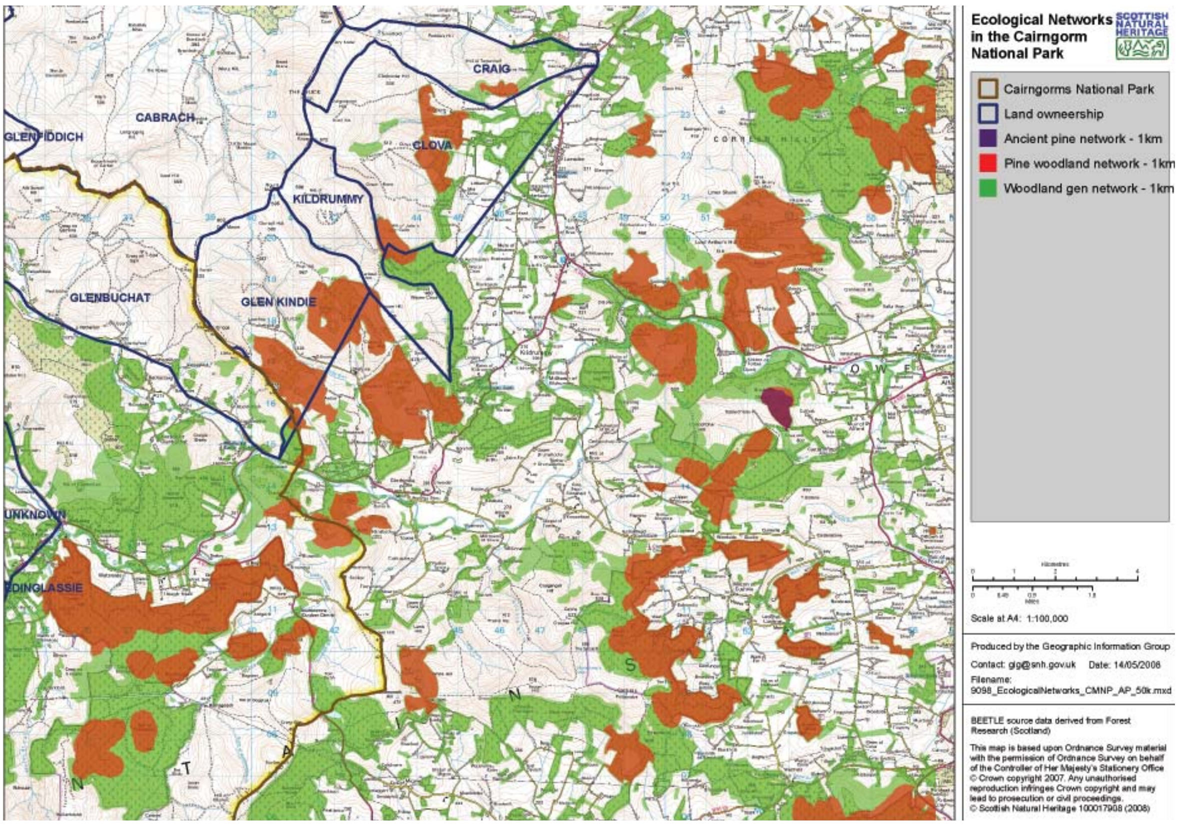
As a bottom line, international and national statutorily designated sites, local nature conservation sites, Local Nature Reserves and ancient woodland should be prioritised for both protection and enhancement. These areas will be the vital foundation sites from which to build a more ecologically resilient habitat network and improve ecosystem health. Quantitative targets for enhancing and maintaining ecological condition across a range of existing sites can be drawn up at this stage in line with UK BAP targets.

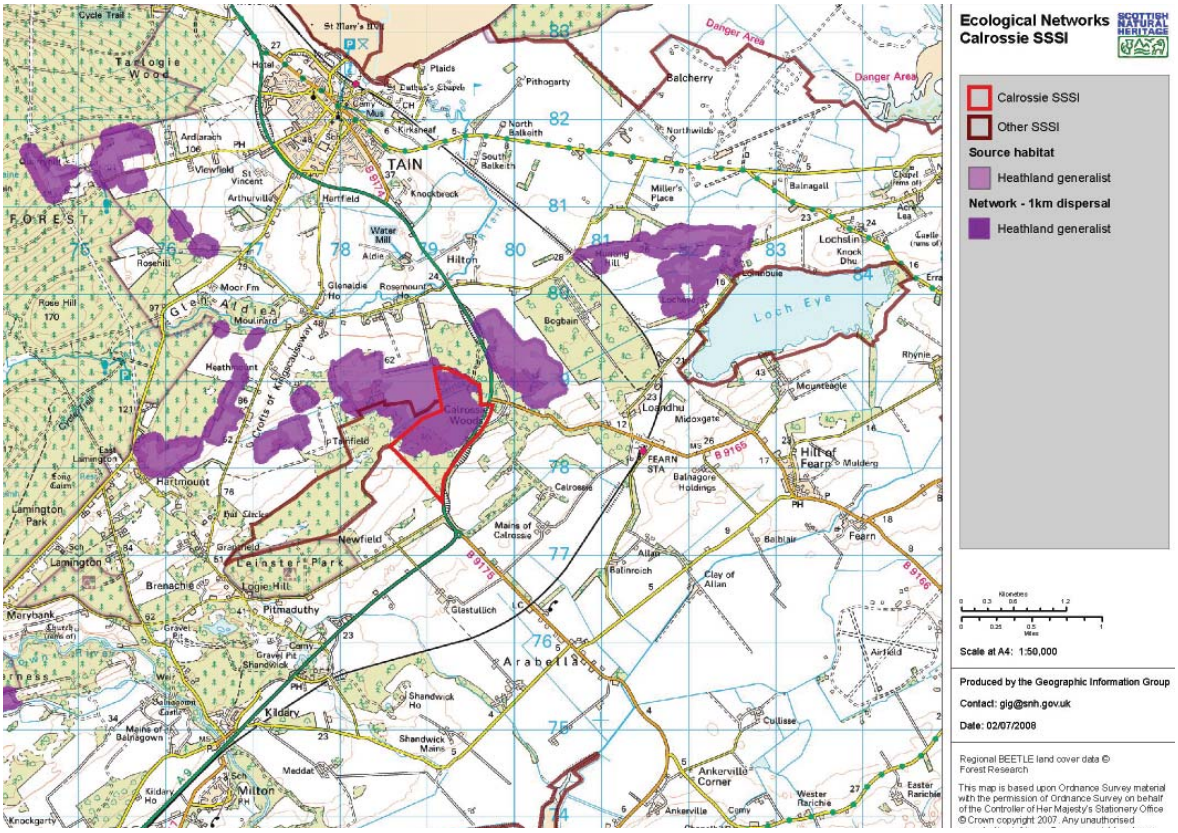
The science behind selecting areas for restoration and expansion is more complex, and ideally should be guided by an evaluation of the distribution of habitat patches in the landscape (landscape metrics) combined with predictions as to how species will respond to modelled future landscape patterns (species-based modelling). Box 6 compares the advantages and disadvantages of the various approaches to landscape evaluation. Such detailed evaluations allow the creation of scenario maps for a range of different species or, perhaps more usefully, for theoretical ‘focal species’ which act as surrogates for a range of different species with different ecoprofiles i.e. their dispersal capability and habitat patch size requirements (see Figure 3).

Photo 12 Species
The ultimate beneficiaries of restored ecosystems will be the species which are the building blocks of those ecosystems. Species such as this common blue butterfly habitat ‘patchworks’ as well as networks.

Maps 1-4 Some examples of ecological network






Ecological Networks
Calrossie SSSI
Calrossie SSSI
Other SSSI
Source habitat
Heathland generalist
Network - 1km dispersal
Heathland generalist
Scale at A4: 1:50,000
Produced by the Geographic Information Group
Contact: gig@snh.gov.uk
Date: 02/07/2008
Regional BEETLE land cover data © Forest Research
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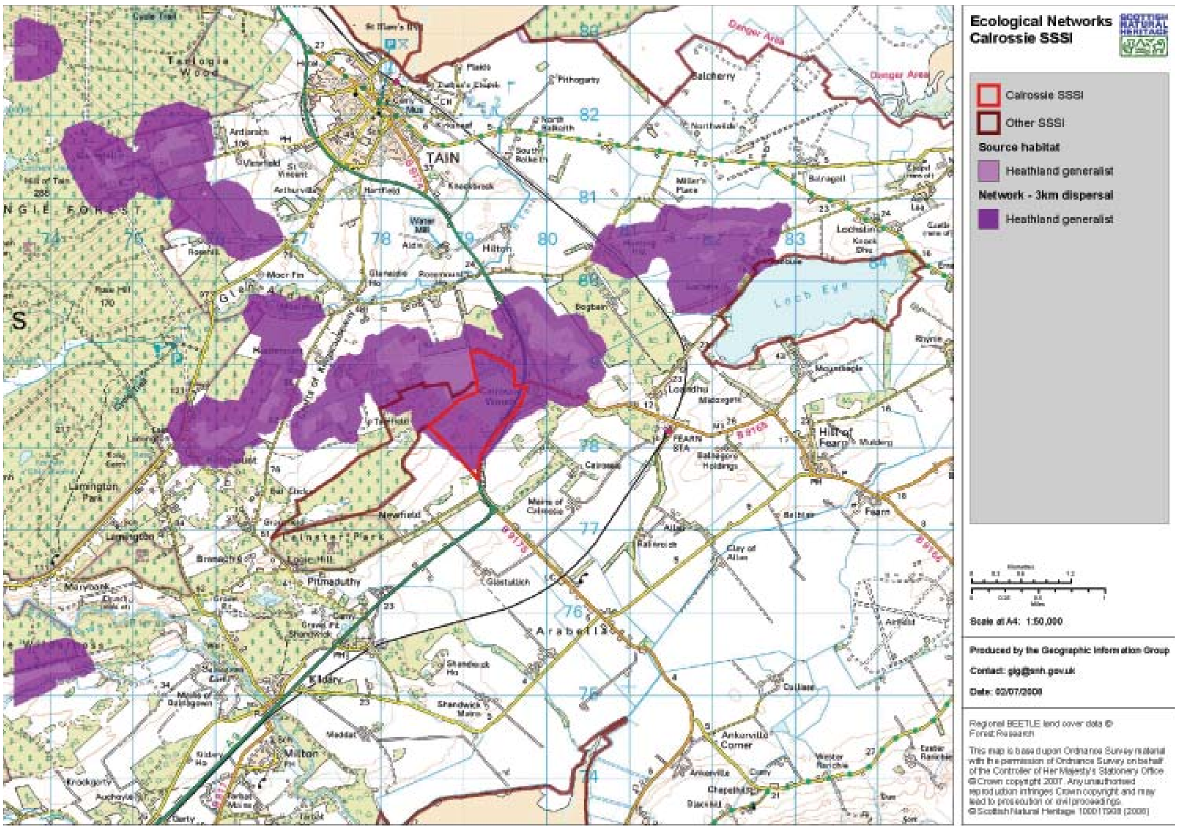
Ecological Networks
Calrossie SSSI
Calrossie SSSI
Other SSSI
Source habitat
Heathland generalist
Network - 3km dispersal
Heathland generalist
Scale at A4: 1:50,000
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Figure 2 Ecological profiles in relation to dispersal ability and patch size requirements

Dispersal capacity / Required area	Restricted	Moderate	Extensive
Small patch	Medium vulnerability to fragmentation (dog's mercury, great crested newt)	Low vulnerability to fragmentation	Low vulnerability to fragmentation (many invasive non-natives, common passerines)
Medium sized patch	High vulnerability to fragmentation (wood ants)	Medium vulnerability to fragmentation (roe reer, badger)	Low vulnerability to fragmentation (barn owl)
Large patch	High vulnerability to fragmentation (capercaillie)	High vulnerability to fragmentation (beaver, red squirrel)	Medium vulnerability to fragmentation (golden eagle)

As a general principle, creating wildlife corridors and larger functional linkages in the landscape is usually most valuable where there is already a high percentage of connected semi-natural habitat. At 30% semi-natural habitat cover in a landscape, it becomes difficult to add new habitat which is not linked to an existing patch and at higher percentages (50% +), habitat becomes largely contiguous.[43] In such landscapes, metapopulations can move more easily between habitat patches and are therefore likely to be more stable. Simplistic targets might therefore be set which increase semi-natural habitat cover from say 15% to 30% or 50%.

One of the limitations to setting simple percentage cover targets is that habitat can be created anywhere in the landscape and still contribute to the overall target. To increase functionality, habitat creation may be better targeted where it increases the cumulative core area of semi-natural habitats in the landscape i.e. creating fewer, larger patches instead of many, smaller patches. However, there are still implicit assumptions in taking this approach. It assumes that improving the overall connectivity and patch size in a landscape makes that landscape more ecologically functional. This may be theoretically true but is best supported by results from focal species modelling (see Box 6) and, in the longer term, feedback from monitoring programmes. It may be the case in certain landscapes that creating a patchwork of habitats rather than a network will better increase functionality through, for example, enhancing metapopulations of certain species.[44]

In any given landscape, there will, of course, be numerous constraints to realising an ideal scenario, ranging from permanent ecological barriers (roads and other built infrastructure, intensively farmed land) to local stakeholder and landowner opposition to habitat expansion on cultural, social or economic grounds. Although models are useful in showing where the ideal locations for habitat expansion and restoration are likely to be, in the end the optimum scenario for biodiversity conservation may not be achievable and the decision for locating new habitat, or restoring degraded habitat, may have to be a pragmatic one, based on opportunity and guided by the general principles of landscape ecology.

Photo 13 Private versus public benefits
What functions should Scotland's upland landscapes be providing?

Box 8 Comparison of landscape evaluation techniques comparisons

Landscape structure approaches	Advantages	Disadvantages
Landscape metrics i.e. evaluating the arrangement of semi-natural habitat patches in a landscape	Provide simple surrogate measures for ecological function. Useful for broad scale regional-based evaluations.	Landscape structure is not always correlated with function so evaluations are rather crude and based on assumption.
Spatial targeting & landscape thresholds	Develops landscape metrics by setting simple thresholds (amount, patch size etc.) for habitat patches within a landscape. Can be used to help prioritise areas for habitat expansion.	Landscape structure is not always correlated with function so evaluations tend to be crude and based on assumption.
Ecological networks	Potentially increases connectivity of the landscape by focusing on physically 'joining up' habitat patches. Has additional socio-economic benefits such as development of sustainable access networks.	As for other structural approaches this approach is largely based on assumptions that 'functionality follows structure'. Unlikely that the creation of physically connected networks, however well designed, will have 'optimal' benefit for wildlife communities.

Species-based modelling approaches	Advantages	Disadvantages
Habitat suitability	Relates species occurrence with habitat size and other variables. Provides quick estimates of landscape suitability for a range of species over large areas.	Only as good as the variables which are included in the model to start with. Takes no account of species dispersal or population dynamics.
Metapopulation modelling	Useful in evaluating the dynamics and requirements of fragmented species populations	Tends to lead to a narrow focus on a few species rather than whole communities.
Focal species modelling	Focal species represent the requirements of a range of species selected to represent a range of habitat types, processes and sensitivities to fragmentation. Considers the effect of the type of intervening matrix. Very useful tool for prioritising the location of habitat expansion and restoration.	Assumes that a theoretical 'umbrella species' can represent a range of real species. Difficult to test model outputs as focal species do not exist in reality.
Spatially-explicit population modelling	Combines population dynamics with dispersal ecology and landscape parameters so closer to reality than other species-based modelling approaches.	Complex and requiring large amounts of detailed data on species and habitats which is rarely available. Limited to single species analyses and not practicable over larger areas.

Note: Approaches to landscape evaluation have been reviewed by Humphrey et al (2005)[45] who differentiate two broad categories: landscape structure approaches and species-based modelling approaches. Each approach has its advantages and limitations although the authors conclude that overall, combining structure and species-modelling approaches strikes the right balance between evaluating the ecological 'reality' of landscapes, whilst also being relatively straightforward to use as a practical conservation tool.

Projects and incentives

Once the scenario map / spatial plan is completed, stakeholders will then be able to draw up project proposals for delivering conservation action in those areas identified and agreed as priorities. Projects will vary in size and scope depending on the funding available, the number of partners involved and the area being considered. What is different about the ecosystem-based approach is that the portfolio of individual projects will contribute to the delivery of a coherent spatial plan for biodiversity. The sum total outcome of all the projects should be enhanced ecosystem functioning and more viable species populations in the longer term.

The design and targeting of Government incentive schemes and other funding sources will be pivotal to the successful delivery of the spatial plan. There are already some examples where Government incentives, particularly forestry grants, have been spatially targeted using ecosystem maps and ecological modelling to improve connectivity and increase the extent and connectivity of priority woodland habitats.[46] Incentives for encouraging landowners to work across ownership boundaries, such as collaborative agri-environment applications, will also help facilitate ecosystem-based delivery.

On the ground delivery

There are a number of practical land management measures which can deliver ecosystem-based action on the ground if delivered in a strategic way as part of a spatial plan for biodiversity. The targeting of measures can be based on broad principles of landscape ecology (the structure or 'metrics' of the landscape) or through modeling the dispersal profiles and habitat requirements of focal species, or a combination of the two. Many of the individual measures listed below are well established approaches whilst others, usually larger in scale, are currently less extensively practiced. Some can be viewed as primarily spatial measures (expand X ha of habitat to increase connectivity between existing habitat patches), whilst others are more about whole ecosystem processes (e.g. collaborative deer management, diffuse pollution control).

Conserving genetic diversity and integrity.
Often difficult to quantify, but usually achieved through diversifying small inbred populations by introducing stock from other more viable populations of similar provenance. Conversely, protecting the integrity of existing populations can be achieved through the eradication or control of invasive non-local provenance genetic strains.

Targeted priority species management.
These are usually management prescriptions specifically designed to enhance a particular species. This also includes mitigation measures where more generic land management (e.g. timber harvesting) is designed in a way which does not cause damage to priority and protected species.

Habitat buffering. Essentially the expansion of an existing patch of semi-natural habitat through habitat creation but most often used in reference to 'buffer strips', margins and 'headlands' between the habitat patch and other more intensive land uses.

Habitat expansion. This usually refers to more significant expansion of a habitat patch, for example, establishing new native woodland adjacent (patchwork) or contiguous to (network) an existing woodland. Conversions from forestry plantation to native woodland or open ground habitats such as peatland or heathland fall under the 'restoration' category.

Habitat linking. Connecting habitat patches through habitat corridors or larger functional linkages.

Habitat restoration. This includes conversion of inappropriately located land uses (such as plantations on bogs, ancient woodlands or heathland) back to the original semi-natural habitat. Also refers to restoration of severely degraded habitats such as hydrological restoration for wetlands.

Increasing matrix permeability. This involves managing non semi-natural habitats to make them less hostile to wildlife through a range of measures. This category includes a number of agri-environment prescriptions such as the timing of farming operations, enhanced wild bird seed plots, fodder crop management, low input spring cereal to retain arable mosaics, maintenance of species rich grasslands and extensive grazing systems.

Sustainable land management practices. This is a general term referring to land management practices which help enhance ecological condition, or at the very least mitigate against damage to key biodiversity features. Many practices now have associated certification schemes e.g. sustainable forest management[47], organic farming practices[48] or wildlife friendly farming practices[49]. In the Highlands of Scotland, both over and under grazing are significant conservation issues.

Utilising natural processes. In many cases, particularly where land is not being actively managed for economic reasons, encouraging natural cycles of succession is a cost effective way of enhancing ecosystem functioning.

Utilising natural disturbance events. Where ecosystems have a high degree of naturalness and relatively high functionality, natural disturbance events can be of valuable tool in creating new niches and fresh successional cycles on which whole communities of species might be dependant. Examples include, storm events, fires and flooding which create new habitats, deadwood and canopy gaps for tree regeneration.

Keystone species re-introductions. A keystone species is one which can significantly affect other species in the ecosystem by its presence or absence. Thus the absence in Scotland of a species such as the beaver means the forest niches associated with the natural disturbances created by the beaver are largely absent. Re-introductions and translocations can be an effective and cost-saving nature conservation management tool.

Invasive and problem species control. Invasive species disrupt the normal functioning of ecosystems by radically altering the 'normal' interactions between species in the system. They also displace native species and if left unchecked can cause localized extinctions. A strategic, ecosystem-based approach to the control, or eradication, of significant-threat non-native invasive species is preferable.

Pollution control. Pollution from industrial, domestic and agricultural sources is a significant threat to terrestrial and freshwater biodiversity. Like invasive species, pollution needs to be tackled strategically at an ecosystem scale. The Nitrate Vulnerable Zone initiative[50] which followed the EU Nitrates Directive is an example of an attempt to control diffuse pollution at a regional scale.

Photo 14 Recovery Ecosystems will respond when given a chance, but only large scale ecological restoration is likely to restore the health of our ecosystems. Such restoration efforts are happening and have been shown to be entirely compatible with social, economic and cultural objectives.

Case Study 2

Setting the pace for the ecosystem-based approach in Scotland:

Glasgow and Clyde Valley integrated habitat networks.

The Glasgow and Clyde Valley (GCV) Green Network Partnership is a catalyst for the creation of a transformational, high quality Green Network across the Glasgow metropolitan area. The role of the Partnership is to act strategically to stimulate and facilitate the planning, delivery and sustainable long term management of the Green Network. The aim is to create a step change in the scale and quality of the Green Network to improve the region's competitiveness for investment, enhance quality of life, promote biodiversity and more sustainable use of natural resources, and encourage healthy lifestyles.

The GCV Green Network Partnership brings together the eight local authorities which comprise the Glasgow metropolitan region with five major government agencies that promote and deliver on the environmental, social, health and economic agendas throughout the GCV area, namely Scottish Government Housing and Regeneration Directorate, Scottish Enterprise, Glasgow Centre for Population Health, Forestry Commission Scotland and Scottish Natural Heritage.

The role of the Partnership in promoting a regional scale perspective and analysis which also support local decision making is exemplified by our work on Integrated Habitat Modelling. Habitat networks are a configuration of habitats that allows species to move and disperse through the landscape. The GCV catchment contains a wide range of diverse habitat and landscape types. A long history of intensive land-use throughout the GCV has resulted in the loss and fragmentation of semi-natural habitats and a subsequent reduction in biodiversity. Conservation policy and practice now seek to reverse the effects of fragmentation by combining site protection and rehabilitation measures with landscape-scale approaches that improve connectivity and landscape quality.

Integrated Habitat Network Modelling

The Integrated Habitat Network (IHN) modelling approach will provide a strategic framework for functioning habitat networks across the GCV, focusing on three key habitat types. This is the first time such a complex modelling exercise has been undertaken both in terms of geographical scale and the number of habitats modelled.

The study spanned the eight local authority areas which constitute the GCV and the analysis covered three habitat types selected through stakeholder workshops: woodland, grassland and wetland. The modelling utilised a landscape ecology model from the 'BEETLE' (Biological and Environmental Evaluation Tools for Landscape Ecology) suite of tools, developed by Forest Research, to assess the spatial position and extent of functional habitat networks.

The BEETLE least-cost focal species approach was chosen to map and analyse the IHNs. Different species have different dispersal abilities and habitat requirements and a limited number of species are selected and used to represent key functions of selected habitats and the array of other species that use them. This approach negates the need to carry out a vast number of individual species analyses, which is particularly important as data regarding species habitat requirements and dispersal through the landscape is lacking. The model outputs were GIS datasets and maps that can be used to assess habitats and how connected they are within their associated networks and within the wider landscape.

Applying the GCV IHN Model as a Planning Tool

The GCV IHN model will be developed into a Decision Support Tool that will identify areas that are ecologically connected and will be used to target and justify planning gain and conservation effort in relation to policy drivers.

Habitat network modelling has the potential to support and guide the planning process and to target conservation effort by highlighting areas that prioritise the greatest development potential of habitat protection and enhancement. An analysis of the habitat networks was undertaken on a GCV wide basis to identify potential Priority Enhancement Areas. These are key areas for habitat restoration chosen on the basis that they are:

a) the largest encompassing networks
b) the greatest area of habitat within these networks
c) the largest number of the contained habitat networks

The identification of Priority Enhancement Areas will help target effort towards the development of networks for woodlands, wetlands and grasslands in these areas and will also help link the GCV IHN to neighbouring habitat networks in Falkirk, Loch Lomond and the Trossachs National Park, and Edinburgh and the Lothians, further highlighting the importance of ecological connectivity throughout Scotland's central belt.

In addition to the GCV wide analysis the model was applied to individual sites to demonstrate how optimal solutions can be found which do not negatively affect proposed developments, but which can incorporate strategically located habitats to provide connectivity and enhance the network. This type of analysis will be extremely useful in informing master planning or the development of Community Growth Areas or Corridors.

However, the potential benefits of the GCV IHN model will be realised only if its use can be mainstreamed into everyday decision making, particularly within local authorities. To this end the Green Network Partnership has embarked on an extensive programme of dissemination and promotion of the model as a decision support tool. By early 2009 each of the eight GCV local authorities and interested agencies will have had the model demonstrated in their own work places on locally relevant scenarios. A DVD tutorial on the model's application has also been developed and will be distributed to support the dissemination.

An evaluation of the success of the first round of dissemination will assess what still requires to be done to make the model an accessible, relevant and valued tool for those involved in decision making in the planning process and the allocation of resources.

Applying the GCV IHN model as an environmental indicator

As part of the Concordat between national and local government, local authorities have, over the last year, been developing criteria and targets for Single Outcome Agreements (SOAs). SOAs are effectively contracts between councils and the Scottish Government for the delivery and improvement of services.

The first round of SOAs was generally disappointing in terms of the inclusion of specific measures for biodiversity enhancement but also for the lack of reference to, and aspiration for, the conservation, enhancement and creation of functional habitats.

A process of SOA revision is currently underway (to be completed early in 2009) and the Green Network Partnership has been actively promoting the inclusion of targets which aim to conserve and expand functional habitat networks and the use of measures which utilise the integrated habitat model. As future rounds of SOAs are drafted, the Partnership will continue to advocate the habitat network approach informed and measured by the IHN model.

Photo 15 Part of the Glasgow and Clyde Valley Green Network

Measuring outcomes: ecosystem health indicators

The long-term conservation outcome for working at an ecosystem-scale is to restore the natural structure and functioning - sometimes called 'health' - of ecosystems. Economic, social and cultural constraints will almost always mean that restoring a fully functional ecosystem is not possible, so a pragmatic interim outcome might be to increase functionality to levels where biodiversity within the ecosystem is more resilient and stable in the longer term.

Accurately measuring resilience, stability and the degree to which functionality has changed in response to action on the ground is problematic. In the future it may be possible to compare species datasets before and after the implementation of a spatial plan, but until then it is probably more practicable to use surrogate measures based on some of the concepts explored above.

Simple surrogate measures include the amount and connectedness of the semi-natural patches in the landscape, though, as outlined above, this will only ever be a crude surrogate of the health of the ecosystem as the functional connectedness and ecological quality each of the patches are not considered. That said, mapping and measuring the extent and connectedness of the semi-natural components of a landscape (landscape metrics) is a very simple and powerful way of presenting information on the degree of habitat fragmentation at a regional level. Combining measures of the amount of the habitat and their connectedness with measures of habitat condition will provide a more accurate measure and may be possible in the future for certain habitat types as more data is collected e.g. for native woodlands in Scotland.[51]

Indicators of ecosystem health (EHIs) have been developed for ecosystems in many parts of the world. Approaches vary, but most tend to combine data collected on a range of ecosystem components, arriving at a 'score' which indicates the relative health of the ecosystem concerned. So, for example, the EHIs developed for the ecosystem of Lake Michigan[52] combine dozens of datasets on state, pressure and response indicators. These include zooplankton and phytoplankton populations, phosphorous concentrations, benthos diversity and so on, but they also include catchment land use indicators such as habitat fragmentation, sustainable agricultural practices and land conversion. The resulting EHI in this case is backed by detailed scientific data which is not always available.

A very simple and cost effective method of calculating an EHI is to take the main attributes of the ecosystem and assign these a score depending on their condition. These scores can then be combined to produce the cumulative EHI. Key attributes linked to functionality might include:

- landscape integrity from highly modified to near natural
- extent of habitat fragmentation
- proportion of non-native invasive species present
- habitat complexity
- presence or absence of functional groups

Assigning scores to each of these might be very difficult in the absence of good scientific data and is, of course, rather subjective. However, such an exercise is useful in that it considers the system as a whole, and, if used as a first step on the way to developing more robust EHIs could still be a useful technique.

In Queensland, Australia, an Ecosystem Health Monitoring Program (EHMP) produces annual Ecosystem Health Report Card (see http://www.ehmp.org/annual_report_cards.html) which an provides easy-to-understand snapshot of the health of South East Queensland's aquatic ecosystems. It provides 'A' to 'F' ratings for 18 catchments,18 estuaries and Moreton Bay. The report card is a powerful communication tool which has raised awareness of the changes in the condition of Queensland's aquatic ecosystem with the general public. It also serves to direct management effort to failing areas and to protect environmental values identified by the local community. Furthermore, it provides an insight into the effectiveness of investments in catchment management. The main failing of the Queensland EHI is that it does not yet fully consider the terrestrial elements of the ecosystem, and therefore the health of the ecosystem as a whole.

In Scotland, the Government produces 'Key Environment Statistics'[53] annually which track trends in 38 indicators in categories including public attitudes, atmospheric pollution, water quality, land use and biodiversity. If we are to move towards developing regional EHIs, for example for a local authority area or river basin, then datasets such as these will be invaluable. Ultimately, EHI report cards at a regional level will not only help target resources to those areas where ecosystem health is failing but, as importantly, they will clearly and simply help people understand what is going on in their local environment - and what they might do to help.

Photo 16 Patterns in the landscape Vast swathes of the Scottish uplands are intensively managed for sporting interests in a way which dictates the composition of the ecosystem. SWT understands the importance of these traditional enterprises but strongly supports a shift towards management which also allows for the recovery of areas of woodland and scrub, and strictly avoids the burning and drainage of peatlands.

Future policy directions

Delivering an ecosystem-based approach will mean developing and implementing policies across a range of sectors. Listed below are a number of broad policy actions which SWT believes will take forward the delivery of ecosystem-based conservation in Scotland. This list is not exhaustive and does not explore the detail behind each of the policy suggestions. It is intended as a catalyst for bringing the approach into the mainstream.

Cross sectoral action

- Government and civil society in Scotland to work in partnership with the EU and other governments worldwide to develop market-based mechanisms for valuing and trading ecosystem goods and services in a sustainable way
- Environmental agencies to prepare biodiversity opportunity and ecological network maps to be formally incorporated into local authority development plans
- Replicate the Glasgow and Clyde Valley Green Network initiative in other local authority areas across Scotland
- Develop a dedicated ‘climate change adaptation unit’ based within central Government to oversee a suite of land use initiatives designed to protect ecosystem health in the face of climate change

Marine policy

- Ensure timely and appropriate transposition of the EU Marine Strategy Framework Directive
- Ensure the Scottish marine bill includes targets for marine ecosystem health with the purpose of delivering a healthy marine environment and conserving biodiversity
- Ensure the Scottish marine bill delivers a marine planning system based on natural regional seas boundaries
- Ensure the Scottish marine bill places a duty on Scottish Ministers to create an ecologically-coherent network of Marine Protected Areas covering the full range of types of site, from representative habitats to critical sites for mobile species

Water and soils policy

- Encourage River Basin Management Plans to adopt an ecosystem-based approach by integrating objectives for the terrestrial elements of catchments, including those for biodiversity and soils
- Develop sustainable flood management policies based on natural systems approaches linking into less intensive management of land under agriculture and forestry, particularly in the riparian zones
- Deliver an ambitious landscape-scale programme of wetland creation and peatland restoration which demonstrates the economic and environmental benefits of restoring natural hydrological systems
- Develop market-based mechanisms which give greater protection and provide funding for Scotland’s peatlands and forests to ensure they retain their carbon stocks (climate change mitigation) and their biodiversity value

Biodiversity policy

- Make the biodiversity duty work for Scotland by developing measurable high-level outcomes to be implemented by public and local authorities; these could be linked to single outcome agreements (SOAs) and regional Ecosystem Health Indicators (EHIs)
- Re-vamp the role of local biodiversity partnerships by providing them with a key role in the preparation of regional biodiversity opportunity and ecological network maps
- Increase levels of project funding targeted at initiatives which contribute directly to ecological networks or wider ecosystem health e.g. by holistically tackling systemic threats
- Sustain funding for the delivery of Scottish Natural Heritage Species Framework, particularly for those species with keystone roles in ecosystems or which are indicators of ecosystem health

Agriculture policy

- In the medium term, support fundamental reform of the Common Agricultural Policy which should be replaced by a Sustainable Land Use Policy (SLUP) which rewards land managers for good management of ecosystem services, including biodiversity, soils and water; the new SLUP should facilitate a fundamental shift towards ‘agricultural ecosystems’, productive in terms of both food *and* ecosystem services
- In the short term, agri-environment schemes under the Scottish Rural Development Programme (SRDP) should be designed to deliver spatial targeting of habitat restoration and creation (informed by biodiversity opportunity and ecological network maps) which contribute to the development of micro and macro scale ecological networks and patchworks
- In the short term, target funding to encourage extensive conservation grazing regimes (particularly for cattle) in upland fringe areas to create wildlife-rich vegetation mosaics and wood pasture habitat more resilient to climate change; this could be achieved, for example, through a new national envelope to support High Nature Value farming and will also support rural livelihoods
- Develop robust monitoring systems which assess and report on the effectiveness of agri-environment schemes on reversing biodiversity loss; tie these into national and regional Ecosystem Health Indicators

Planning policy

- National Planning Framework II to enable delivery of a National Ecological Network across Scotland through combining regional initiatives such as Glasgow Clyde Valley Green Network
- Through the biodiversity duty, embed biodiversity conservation into all relevant planning policies and ensure protection and enhancement of biodiversity in all new developments (at micro and ecological network scales)
- Introduce minimum biodiversity standards for all significant new developments linked to climate change adaptation and sustainable urban drainage systems
- Implement the Local Nature Conservation Guidelines with all Local Authorities, all of whom should aim to have LNCS systems in place by 2012
- Ensure protected areas are indeed strictly protected so they continue to form the foundation sites from which our ecosystems can be re-built

Climate change policy

- Include provisions in the Scottish Climate Change Bill that future policies for mitigation and adaptation must be developed in accordance with the principles of sustainable development, including the conservation and enhancement of biodiversity
- Include a requirement in the Scottish Climate Change Bill for Ministers to produce an adaptation strategy that includes ecosystem-based conservation measures as well as a statutory requirement to regularly report on progress with adaptation measures
- Develop a climate change land use strategy for Scotland which includes information on greenhouse gas emissions from land use and mechanisms by which these can be radically reduced

Forestry policy

- Significantly increase native woodland, and wood pasture creation targets in proportion to non-native conifer planting; new woodland should be targeted at locations which contribute to functional habitat networks.
- Direct substantially more SRDP funds into encouraging new and existing wood pasture systems as these tend to deliver multiple benefits in terms of cattle/sheep, timber products, rich biodiversity, landscape and access.

Education policy

- Enable teachers to provide every child with regular access to inspirational and challenging out of classroom learning where they can enjoy first hand experience of the natural world

Indicators

- Develop national and regional indicators of habitat connectivity based, for example, on cumulative core area of semi-natural habitat
- Develop national and regional Ecosystem Health Indices (EHIs) which present combinations of

indicators in a simple score card format; communicate these effectively to the public.

Deer policy

- Revise the Deer (Scotland) Act 1996 to enable Scottish Natural Heritage to more effectively protect biodiversity and ecosystem services, particularly upland peatland soils and vegetation.

Environmental liability

- Transpose the EU Environmental Liability Directive into Scottish legislation and include biodiversity damage thresholds which capture nationally protected biodiversity and damage SSSI site integrity.

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[47] See http://www.ukwas.org.uk/index.php

[48] See http://www.soilassociation.org/certification

[49] See http://www.jordans-cereals.co.uk/page.asp?partid=94 for more information

[50] http://www.scotland.gov.uk/Topics/Agriculture/Environment/NVZintro/NVZintr

[51] http://www.forestresearch.gov.uk/fr/INFD-6TRKCL

[52] Bertram, P., Forst, C. & Horvatin, P (2005) Developing ecosystem health indicators. State of Lake Michigan: Ecology, Health and Management, pp. 505-519. Edited by T Edsall & M. Munawar. Ecovision World Monograph Series. Aquatic Ecosystem Health and Management Society

[53] Scottish Government (2008) Key Scottish Environment Statistics

Box 8 Quick checklist of the 12 principles of the ecosystem approach

1. Recognise that objectives for land and seas are society's choice
2. Encourage decentralised decision making
3. Consider impacts on adjacent ecosystems
4. Ensure economic policies encourage biodiversity
5. Conserve ecosystem structure and function
6. Manage ecosystems within the limits of their functioning
7. Plan and deliver at appropriate scales
8. Set objectives for the long term (ecological timescales)
9. Accept and adapt to change
10. Balance the use, conservation and integration of biodiversity
11. Gather local as well as scientific knowledge
12. Involve all relevant stakeholders