SCOTTISH BIODIVERSITY FORUM

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Towards a strategy for Scotland's biodiversity:

Scotland's Biodiversity Resource and Trends

February 2003
Paper 2003/4

Scottish Executive Environment Group

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Towards a strategy for Scotland's biodiversity

THE RESOURCE AND TRENDS

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of the Scottish Biodiversity Forum
and
edited by Michael B Usher

February 2003

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PREFACE

In preparing for the draft Scottish Biodiversity Strategy, *Biodiversity Matters*, the Action Plan and Science Group (APSG) of the Scottish Biodiversity Forum felt it essential to collect together information that could be useful to many groups of people. The kind of questions that were initially asked were "What is important about Scotland's biodiversity?" and "What do you consider are the priorities?". When you think about these questions, other questions immediately start to occur, such as "How is Scotland's biodiversity changing?" and "What have been the successes and failures so far?"

In many ways these are scientific questions, and it is therefore correct that the APSG should have addressed them. There are many other questions about people, their knowledge of biodiversity, the impact of Scotland's biodiversity upon their lives and work, and the impact that Scotland has had, and is having, in relation to many other countries in the world. As members of the APSG thought more about the biodiversity strategy, the importance of a suite of indicators has become increasingly clear. This has raised a whole host of questions about data, what has been collected, what is being collected, what might need to be collected, and how such data can be used to compile indicators. The separate APSG paper, Developing Candidate Indicators of the State of Scotland's Biodiversity (Wilson *et al, 2003)* concentrates on the scientific issues associated with the development of indicators of the state of biodiversity in Scotland, whilst recognising that there are many other approaches to indicators that relate more closely to human pressures on, and responses to, biodiversity.

The APSG has developed two papers that are now edited into the chapters of this publication. The first chapter is a review of Scotland's biodiversity resource, and essentially focuses on its state at the start of the 21st century. The second chapter is a review of current trends in that resource. We offer these chapters in the knowledge that the contents rely on a far wider base of information, which is quoted, and also in the hope that this publication will bring together many concepts that will be helpful to anyone considering biodiversity in Scotland. Comments on the contents of these chapters would be welcomed by the APSG, who can be contacted via the Scottish Biodiversity Forum Secretariat based at the Scottish Executive.

The whole of this publication is essentially a collaborative exercise between many people. Chapter 1 was developed largely by James Curran with help from Ian Fozzard, Mary Gibby, Ed Mackey, Scot Mathieson, Ian Walker and Jeremy Wilson. Chapter 2 was developed by Alister Jones with a considerable input from Ed Mackey, Noranne Ellis and Joanna Drewitt. Although these people have been named as contributing to the chapters, and their input is acknowledged by all of the members of the APSG, thanks are also due to many other people who have assisted in many ways in providing detail, commenting on draft sections, and suggesting topics for inclusion.

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1. SCOTLAND'S BIODIVERSITY RESOURCE

James Curran, Ian Fozzard, Mary Gibby, Ed Mackey, Scot Mathieson, Ian Walker and Jeremy Wilson

1.1 Introduction

In preparing a Scottish strategy for the protection and enhancement of biodiversity, it is essential first to determine the starting point and priorities for action. This chapter attempts to define the present status, according to the Convention on Biological Diversity (CBD) definition of biodiversity in terms of habitats, species and genetic resource.

1.2 Habitats

1.2.1 Diversity of habitats

For its size, Scotland possesses a mixture, diversity and close inter-relation of habitats that is particularly unusual and worthy of protection. These mosaics create high landscape value and are the essence of Scotland's natural beauty.

Significant hotspots for species richness occur in Scotland. The richest areas occur in Argyll, the Breadalbane Hills, the Central Highlands, Mull and Skye. Scotland contains 65 of the 169 habitats listed within the European Commission's Habitats Directive, including some for which Scotland is globally important. The rest of the UK adds only a further 15 such habitats (Miles *et al.*, 1997). Species richness is likely to reflect the local diversity of habitats which form complex mosaics in these areas with high spatial variability of geology, drift and soil materials, coastal features, topography, climate, and land management activities.

1.2.2 Terrestrial habitats

Around 40 per cent of Scotland has been classed as upland in character, and a further 33 per cent as marginal upland (McGowan *et al.*, 2001). Mountains therefore exert a considerable influence on Scotland's visual and ecological distinctiveness. On the higher mountain tops, the montane plant communities represent southern and oceanic outliers of arctic-alpine fellfield and mountain tundra. Prostrate *Calluna vulgaris* heath above the natural tree-line, with a varying abundance of lichens, mosses and liverworts, is rare elsewhere. *Racomitrium* heath on the summit plateaux and erosion surfaces are absent from the continental European mountains (Ratcliffe & Thompson, 1988).

Blanket bog cloaks much of the Scottish uplands, accounting for a quarter of the overall land area (Haines-Young *et al.*, 2000). This habitat is more extensive and varied in Scotland and Ireland than elsewhere in Europe (Lindsay *et al.*, 1988). In the lowlands, Scotland also retains one of the richest surviving European concentrations of raised bog. Bogs support an especially rich diversity of invertebrates and dense populations of breeding waders, particularly dunlin (*Calidris alpina*) and golden plover (*Pluvialis apricaria*).

Many highly valued Scottish landscapes and habitats have evolved through low intensity farming activities, for example crofting and extensive sheep rearing (Beaufoy *et al.*, 1994). The mosaic of habitats thus created sustains a diversity of plants, invertebrates and birds, especially on the botanically-rich machair coastal grasslands. The densities of breeding wading birds - mainly redshank (*Tringa totanus*), snipe (*Gallinago gallinago*), dunlin (*Calidris alpina*), ringed plover (*Charadrius hiaticula*) and oystercatcher (*Haematopus ostralegus*) - on the machairs of the Uists and Tiree are unsurpassed in Europe. The breeding wildfowl of the machair lochs includes large numbers of native greylag geese (*Anser anser*). Acid grasslands, which predominate towards the wetter west, and dwarf shrub heath on drier, freely drained soils to the east, have been sustained by grazing and burning since the natural forest was cleared from Neolithic times onwards. Together, they cover about a fifth of the land area (Haines-Young *et al.*, 2000).

Heather moorlands are distinctive and remarkable for their beauty and economic value, wild plants and animals. Within Europe, they are now extensive only in the British Isles, and particularly in Scotland (Thompson *et al.*, 1995). Moorland is an important breeding or feeding habitat for 57 bird species, of which 12 are of European importance. Moorlands in the UK support exceptionally high densities of red grouse (*Lagopus lagopus scoticus*), a distinctive endemic race of the willow grouse, golden plover (*Pluvialis apricaria*) and hen harrier (*Circus cyaneus*).

At 17 per cent of the Scottish land area, forest and woodland cover is relatively, but not exceptionally, low by European standards. The Caledonian pine/birch-dominated forests, which have a smaller range of species than continental boreal forests, contain several plant and animal species which are rare or absent elsewhere in the UK (e.g. twin flower, *Linnaea borealis*, capercaillie *Tetrao urogallus*, and the shining guest ant, *Formicoxenus nitidullus*). The western oakwoods are also special with their epiphytic communities of non-vascular plants (mosses, liverworts and lichens).

Although built-up land accounts for only around 3 per cent of the total land area (Haines-Young *et al.,* 2000), some 80 to 90 per cent of the Scottish population encounters the natural world most frequently in and around settlements. Greenspace ranges in extent from around 10 to 40 per cent of the major Scottish towns and cities, but little is known about qualitative attributes such as composition, wildlife, connectivity, tranquillity and accessibility. Areas of semi-natural habitats can often survive within towns along rivers and burns, fragments of ancient woods, moors and wetlands. Where semi-natural habitats are conserved, or restored, a diversity of plants and animals can flourish. Environmental improvements have allowed the Atlantic salmon (*Salmo salar*) and otter (*Lutra lutra*) to re-colonise parts of the Forth and Clyde river systems that were grossly polluted in the recent past. The Central Scotland Woodland Initiative is improving the environment and landscape of the Central Lowlands, formerly degraded by mining and heavy engineering industries. The restored Lowland canal network has reinstated a corridor of waterway and greenspace, for recreation and wildlife, between towns across central Scotland.

1.2.3 Freshwater habitats

More than 2 per cent of the Scottish land surface is covered by fresh waters including some 28,000 standing waters, over 50,000 km of flowing waters, and 220 km of canals. The mountainous topography, hard, slow-weathering acidic geology, high rainfall and acidic soils of Scotland's large upland areas mean that much of Scotland's freshwater resource has clean, clear waters with low nutrient levels. Exceptions are to the south and east of the Highland boundary fault, and where isolated pockets of base-rich rocks are available for weathering, such as the Caithness limestone (Maitland *et al.*, 1994).

Scotland's river resource is dominated by high energy, gravel bed-rivers which are a global stronghold for the Atlantic salmon and the freshwater pearl mussel (*Margaritifera margaritifera*). Many other animals and plants associated with riverine habitats are identified as conservation priorities in the UK and in Europe including river jelly lichen (*Collema dichotomum*), otter, the lampreys (*Petromyzon marinus*, *Lampetra fulviatilis* and *L. planeri*), and several species of Diptera and Coleoptera.

The over-riding importance of Scotland's lochs in terms of biodiversity is their scale, their range of habitats and species, and their high quality. They contain over 90 per cent of the UK's standing water resource, including 14 of the UK's 15 largest standing waters. Scotland's loch resource is dominated by low-nutrient Highland lochs and lochans, which support high quality macrophyte and invertebrate assemblages, unique populations of Arctic charr (*Salvelinus alpinus*), whitefish such as powan (*Coregonus lavaretus*), and many bird species, including divers (*Gavia* spp.). Scottish lochs also support other rare plant species, such as American pondweed (*Potamogeton epihydrus*), and nationally scarce plants such as six-stamened waterwort (*Elatine hexandra*).

Scotland is also the principal location in the UK for mesotrophic lochs, moderately nutrient-rich lochs which are the most botanically diverse standing waters, with around 275 sites identified to date. Scottish mesotrophic lochs hold all of the UK populations of the rare water plants slender naiad (*Najas flexilis*), Shetland pondweed (*Potamogeton rutilis*) and various stonewort species (e.g. *Chara* and *Nitella* spp.).

Ponds support a diverse and abundant biodiversity, beyond what might be expected for their small size. The shallow waters of Scotland's ponds and pools are home to a wide variety of species including a number of rare invertebrates such as the medicinal leech (*Hirudo medicinalis*). This species is found only in a few shallow weedy nutrient-rich lochs. Another rare invertebrate, the northern blue damselfly (*Coenagrion hastulatum*) is confined to the shallow waters of a few weeded pools in three small areas of Scotland. The great crested newt (*Triturus cristatus*) is also found in discrete areas of Scotland, with perhaps the largest concentrations of breeding ponds in Dumfries and Galloway and in the Central Lowlands.

Wetland habitats associated with fresh waters are principally fens, reedbeds, and some remnants of wet woodland forming natural transition zones between the open waters and grassland or woodland habitats. Apart from the Insh Marshes on the Spey (the UK's largest continuous area of base-poor fen) and the reedbeds fringing the lower reaches of the River Tay, they are generally relatively small remnant habitats compared with Scotland's rivers and lochs.

1.2.4 Coastal habitats

Scotland's large firths and estuaries are of international significance as habitats for wading birds and waterfowl, such as wigeon (*Anas penelope*), teal (*A. crecca*), dunlin and knot (*Calidris canutus*). The extensive mudflats contain remarkably high densities of worms, molluscs and crustaceans, all of which provide food for birds and fish. Eelgrasses (*Zostera* spp.) are unusual flowering plants with adaptations to salt water. Two species (one with two distinct varieties) are found in Scotland on shallow sand or muddy sand sediments. The Cromarty Firth hosts the largest known stand of dwarf eelgrass (*Zostera noltii*) in the UK. Saltmarsh dominates the Solway coastline, with 10 per cent of the total UK area of the habitat.

A number of important saltmarsh plants, such as rock sea lavender (*Limonium binervosum* aggregate), reach the northern limit of their distributional range in the Solway. Saltmarsh vegetation provides food for internationally important populations of wintering geese, particularly the barnacle goose (*Branta leucopsis*) and dark-bellied brent goose (*B. bernicla bernicla*), and breeding areas for wading birds such as redshank. Only relatively narrow areas of saltmarsh are found in east coast estuaries although the reed beds of the Tay Estuary are the largest continuous stand of this habitat in the UK. In Scotland, saltmarsh has special conservation significance wherever there is a complete transition in zonation from the saltmarsh to terrestrial habitats, such as woodland, grassland or dune. Complete ecological transitions are rare in other parts of the UK due to land use for development and agriculture and hence these transitions in Scotland are ecologically very important.

An essential feature of sand dunes is their dynamic nature and Scotland has a great variety of dune systems. Dune systems in the Western Isles include the best examples of the machair habitat, formed by coastal grasslands on wind-blown shell sand. Juniper (*Juniperus communis*) forms lichen-rich dune scrub at three sites in Scotland: Morrich More in the Moray Firth, Coul Links, just north of Dornoch, and Invernaver on the north coast. The natterjack toad (*Bufo calamita*), which has suffered a substantial decline in numbers and range during the 20th century due to habitat loss, lives in the sand-dune habitat on the Solway Coast, now the northern limit of its British range.

Saline lagoons are coastal water bodies with only limited connection to the sea and are internationally important priority habitats due to their rarity and unique species assemblages. Scotland has 139 lagoon sites, with most in the Outer Hebrides, Orkney and Shetland. Characteristic lagoon communities include priorities such as five species of stonewort and the lagoon sea slug (Martin *et al*., 2002).

The combination of offshore islands, indented sea lochs and tidal straits creates the conditions for the full range of rocky shore habitats, from extremely exposed Atlantic shores to extremely sheltered areas within sea lochs. As a result, Scotland has one of the most diverse rocky coastlines in the world. High coastal cliffs are a feature of the north and west of Scotland, particularly in the Outer Hebrides and Northern Isles. In close proximity to productive coastal waters, these provide the breeding sites for internationally significant concentrations of seabirds.

1.2.5 Marine habitats

The seas around Scotland support a varied and rich wildlife. The North Atlantic Drift brings warm waters to the west coast and cold sub-Arctic waters reach down to the Northern Isles, bringing together northern and southern marine species. The range of exposures to currents and wave action, and the varied geology, make Scotland's marine and coastal habitats among the most diverse in the world.

Underwater rock surfaces are frequently colonised by kelp *Laminaria* forests which fringe many parts of the Scottish coast. Kelp forests support a wide range of algal and faunal species, including sea anemones, sponges and sea squirts, as well as more mobile species like brittlestars, sea urchins, crabs and many fish species. Rock surfaces in current-swept areas also support large numbers of algal and invertebrate species, with faunal dominance increasing with depth as light levels decrease.

Sands and gravels in inshore areas are vital nursery grounds for commercially valuable fish and shellfish. Scotland is internationally important for maerl, a collective term for several species of red seaweed which form hard 'calcified' outer casings and grow as nodules on the sea bed. Over 1,700 animal and 300 seaweed species have been recorded from European maerl beds. A recent study of invertebrates inhabiting Scottish maerl beds found species previously unknown to science. Maerl beds are particularly well developed around the Scottish islands.

Serpula vermicularis is a marine worm which secretes a hard limy tube around itself and, exceptionally, aggregates into reefs covering areas up to 1 m across. This reef form appears to be very rare and, in the UK, only now exists in one Argyll sea loch. The Loch Creran populations are thought to form the best reefs of this type in the world and the three dimensional structure of the reef provides crevices in which a host of other animals can live.

Scotland's fjordic sea lochs, such as Loch Alsh and Kyle Rhea, have some of the strongest tidal streams in the UK. The marine life associated with tidal rapids typically includes a colourful mix of soft corals, sea firs (hydroids), sea mats (bryozoans), large sponges, anemones, mussels and, where the current slackens, dense beds of brittlestars.

In temperate oceanic seas, hard corals are usually solitary but the coral *Lophelia pertusa* is an exception. Small patches of *Lophelia* have been reported from waters to the west and north-west of Scotland and, although typically found in water depths between 200 and 400 m, it may grow as deep as 3,000 m. The Darwin Mounds are a series of unique large sand mounds in the Rockall Trough which are capped with reefs of *Lophelia pertusa*. Colonies of *Lophelia* can form substantial reefs growing several metres clear of the seabed, and perhaps taking hundreds of years to form. More than 800 different animal species have been recorded living amongst live and dead *Lophelia*. These reefs are as rich in biodiversity as some tropical coral reefs.

1.3 Species

Scotland's species richness is similar to Nordic countries at the same latitudes (Delbaere, 1998). Usher (1997) estimated that there may be 90,000 species in the terrestrial, freshwater and near-shore marine environments of Scotland, with approximately half of these being single-celled organisms, one quarter plants and fungi, and the remaining quarter animals. Scotland's species complement is relatively unremarkable in a European context since most of it is shared with other areas of the UK and Europe. Just 31 species are currently considered to be endemic to Scotland, and some of these may yet prove to have wider distributions elsewhere.

However, the diverse mix of Atlantic, Arctic, Arctic-alpine and boreal elements found within a limited geographical area is noteworthy, and includes many species on the edge of their global distributional range (Birks, 1997). Scotland's overall species resource is thus remarkable more for its unique assemblages of species than for either the sheer number or rarity of the individual species concerned. This, in part, results from the fact that Scotland has a wide spectrum of habitats rarely equalled in variety in a similar-sized area elsewhere in the world (Watling, 1997). For bryophytes, lichens, fungi, vascular plants and birds, boreal, arctic-alpine, oceanic and continental species co-occur within this diversity of habitats. Fifty-eight per cent of Europe's bryophyte species, 42 per cent of its birds and 37 per cent of its lichens are found within Scotland (Mackey *et al.*, 2001).

The unique attributes of Scotland's biodiversity resource are here characterised both geographically (i.e by reference to species endemic to Scotland or with their world range or population stronghold in Scotland), and functionally (by reference to 'keystone', 'umbrella' or 'flagship' species indicative of the wider conservation importance or state of ecosystems and habitats). Hill *et al.* (2002) provide a more complete inventory of Scotland's biodiversity from a similar perspective.

1.3.1 Endemic species

Scottish beard-moss (*Bryoerythrophyllum caledonicum*), *Halecania rhypodiza*, a lichen known only from the Ben Lawers range and Caenlochan in Angus, mountain scurvygrass (*Cochlearia micacea*), Scottish primrose (*Primula scotica*), *Ceratophyllus fionnus*, a flea found only on Manx shearwaters (*Puffinus puffinus*) breeding on Rum, and Scottish crossbill (*Loxia* *scotica*) are examples of the 31 species for which Scotland is responsible for the future of the entire global population. This list includes ten lichens, eleven vascular plants, five mosses, four insects and one bird; the species are listed in Fleming *et al*. (1997) and Hill *et al*. (2002).

1.3.2 Stronghold species

There are many species where Scotland holds the majority of the world population; these include great skua (*Stercorarius skua*), gannet (*Morus bassanus*), Manx shearwater, grey seal (*Halichoerus grypus*), hay-scented buckler fern (*Dryopteris aemula*), and wintering populations of migratory pink-footed geese (*Anser brachyrhynchus*). Scotland is also the main stronghold of an important offshore commercial species, the Norway lobster (*Nephrops norwegicus*).

At a smaller geographical scale, there are also species with wider distributions whose UK or European range or population is concentrated in Scotland. For example, amongst vascular plants, several species restricted to western Europe achieve unusual dominance in Scottish vegetation (e.g. bluebell (*Hyacinthoides non-scriptus*), western gorse (*Ulex gallii*) and heather (*Calluna vulgaris*)), and 76 of the UK's species are found only in Scotland, 45 of these being species of montane habitats (Sydes, 1997).

Young & Rotheray (1997) suggested that 1,300 of 14,000 insect species in Britain may be unique to Scotland including dragonflies such as the azure hawker (*Aeshna caerulea*), and northern emerald (*Somatochlora arctica*), several moths and the chequered skipper butterfly (*Carterocephalus palaemon*) whose English populations are now extinct.

Over 30 annually breeding or wintering British bird species are also found exclusively, or with greater than 90 per cent of their British range or population, in Scotland. These include seabirds (e.g. great skua), raptors (e.g. golden eagle (*Aquila chrysaetos*)), rails and gamebirds (e.g. corncrake (*Crex crex*) and capercaillie (*Tetrao urogallus*)), waders and wildfowl (e.g. greenshank (*Tringa nebularia*)) and songbirds (e.g. crested tit (*Parus cristatus*)).

1.3.3 Keystone species

These are species whose loss from an ecosystem would have a disproportionately large effect on other species populations or ecological processes in that system. They include, for example, heather (*Calluna vulgaris*), a key dominant of heathland across Scotland. Intensive grazing and burning cause its decline in favour of grassland, yet the maintenance of heather and associated ericaceous shrubs in the upland vegetation mosaic may be critical to the maintenance of moorland biodiversity more generally. Similar key dominant plant species in other ecosystems include sessile oak (*Quercus petraea*), pedunculate oak (*Quercus robur*), Scots Pine (*Pinus sylvestris*) and the *Laminaria* kelp species.

Amongst invertebrates, the common earthworm (*Lumbricus terrestris*) provides a good example of a keystone species. It is one of the commonest and most widespread invertebrate species in Scotland and plays a major role in soil organic matter decomposition and nutrient cycles, influencing soil structure, fertility and productivity; it is also a key prey item for many birds and mammals.

In estuarine food webs, the majority of energy flows through the brown shrimp, *Crangon crangon,* which feeds on a wide range of invertebrates and is eaten by many species of bird, fish and crab. The sea urchin *Echinus esculentus* has a dramatic effect on the faunal and floral turf of subtidal rocks; heavy grazing can result in barren rocks covered only in pink encrusting algae with some *Laminaria*.

Amongst vertebrates, the meadow pipit (*Anthus pratensis*) might be considered a keystone species of upland habitats; it is abundant on grass or grass/heather moorland, depends for food on terrestrial invertebrates (mainly Diptera) within these habitats and is, in turn, an important prey species for raptors such as hen harrier (*Circus cyaneus*) and merlin (*Falco columbarius*). Red deer (*Cervus elaphus*) is a classic keystone species, strongly associated with Scotland, whose grazing and browsing affect forest regeneration and the development of tall herb communities over wide areas.

It is recognised that there is very little understanding of the importance of microbial or fungal species with equivalent keystone roles, particularly in soils and in marine waters.

1.3.4 Umbrella species

These are species requiring habitat or resource management on large spatial scales. If conservation management for these species is achieved, then many other species with smaller scale requirements within the same ecosystem will also be protected. For example, heathland dominated by bearberry (*Arctostaphylos uva-ursi*) in association with heather acts as an umbrella for a wider community of scarce herbaceous species (e.g. intermediate wintergreen (*Pyrola media*)), as well as a characteristic insect fauna not shared by other heathland types.

At much larger spatial scales, breeding populations of golden eagles require extensive, open upland an a good supply of prey. The species therefore serves as an umbrella for both its prey and for other species depending on open tracts of upland habitat. This species is clearly also a 'flagship' for the open, montane habitats of Scotland.

1.3.5 Flagship species

These comprise charismatic species serving as symbols and rallying points to stimulate conservation awareness and action. The freshwater pearl mussel (*Margaritifera margaritifera*) is a classic flagship species. A BAP priority species, listed under the Habitats Directive and on the World Red List, this long-lived species may be affected by siltation, poor water quality, river dredging and engineering, and exploitation for its pearls. The basking shark (*Cetorhinus maximus*), one of the world's largest fish, would also be a flagship species. It migrates north into Scottish waters each summer, where it feeds on the abundant supply of plankton.

A selection of other flagship species includes the Scottish primrose (*Primula scotica*, a beautiful plant dependent on unimproved coastal grassland with a light grazing regime), Atlantic salmon (*Salmo* salar, a fish with high public profile, serving as an emblem of pollution control and protection of stocks against excessive sea-fishing), puffin (*Fratercula arctica*, a charismatic species indicative of marine conditions for the fishes on which it preys), and otter (*Lutra lutra*, a species, at the top of the food chain, with high public profile and whose recovery reflects the effect of widescale reduction in aquatic pollution).

1.3.6 Postscript

Some species clearly fall into more than one of these categories. A classic example of a single species to represent Scotland is perhaps the Scots pine; a flagship emblem of the Scottish highlands whose natural populations have been reduced drastically in extent, as well as being a key dominant of native pinewoods and an umbrella species for a wide range of bryophytes, fungi, vascular plants and animals, all of which depend on the pinewood for their survival.

1.4 Genetic resources

Biodiversity includes not only habitats and species but also the genetic variation present within each species. Genetic variation comprises the variation within an individual population and the variation between different populations of the same species. This genetic variation influences the ecological amplitude of a species and its ability to evolve and adapt to changing environmental conditions, whether caused by natural or man-induced change. Knowledge of the genetic diversity of a species is desirable for its future management and conservation.

For many groups of organisms Scotland may appear to be relatively species-poor in comparison with countries from southern Europe, reflecting the effect of repeated glacial cycles in northern and western Europe. However, the species present today in Scotland are likely to have adapted to local conditions that include the rich mosaic of habitats here - woodlands, pastures, mountain tops, moors, offshore islands and open water. These local adaptations make the genetic component a significant element of Scotland's biodiversity resource (Ennos & Easton, 1997).

Populations growing at the edge of their range may show local adaptation. Experimental work has demonstrated that Scottish populations of Scots pine show greater growth in height than do continental European populations, when grown under Scottish conditions (Worrell, 1992). In trials in east Scotland, pine populations from this area show greater growth in height and resistance to local rust pathogens in comparison with populations from the west (Lines & Mitchell, 1964). This clearly demonstrates the importance of using local genetic material when undertaking any restoration or re-introduction work.

Fragmented landscapes and isolation on islands provide opportunities for adaptation through natural selection. In the Shetland Islands, adaptation in populations of field mice (*Apodemus sylvaticus*) has resulted in increased body size and change in body colour (Berry & Johnston, 1980). Similarly, Scotland hosts four forms of the wren (*Troglodytes troglodytes*), and one each of song thrush (*Turdus philomelos*), crested tit, starling (*Sturnus vulgaris*) and linnet (*Carduelis cannabina*) that are considered sufficiently distinctive to merit sub-specific status (Clugston *et al.*, 2001).

Scottish river systems support one of the largest and most diverse of the Atlantic salmon resources in Europe, with nearly 400 salmon rivers supporting many hundreds of populations, each with its own genetic distinctiveness (SERAD, 2000). Scotland is also a stronghold for Arctic charr (*Salvelinus alpinus*) with perhaps 200 separate loch populations. Research shows that, following post-glacial isolation, these have become genetically distinct between, even within, lochs (Hartley *et al.*, 1995). Each of these populations has evolved slightly differently in response to slightly different environments in each loch, with an explosion of forms and life histories which have formed in the 8,000 to 9,000 years since the glaciers retreated. The Arctic charr is an excellent example of the adaptation and development of a species. Within the species, many different morphs (or varieties) are seen. These morphs have different diets, and fit into the ecosystem at different points. They vary in colour from a tomato soup red to a drab camouflage colour. They also show different size characteristics and bone structure depending on their diet. As with Darwin's finches (*Geospiza* spp. in the Galapagos Islands), this is a single species adapting to inhabit different ecological niches to such an extent that many people now regard some populations as new species (Alexander & Adams, 2000).

Molecular tools are used to explore genetic variation. These provide information on dispersal and population genetic structure which, together with knowledge of reproductive biology and demography, can contribute to the development of appropriate strategies for conservation. Stewart *et al.* (1999) have demonstrated a metapopulation genetic structure in the water vole (*Arvicola terrestris*) in north east Scotland, with colonies showing genetic differentiation. A study of the otter across Scotland has revealed that isolation of the populations on Shetland and Orkney is associated with reduced levels of microsatellite diversity (Dallas *et al.*, 1999). Molecular markers also provide information on current and historical distribution patterns, and have proved valuable in studying post-glacial colonisation in tree species, including alder, birch, oak and pine (Ennos *et al.*, 1997, 2000).

Many of the Scottish vascular plant species that are listed in the UK BAPs have complex taxonomies. The use of genetic markers has proved valuable in clarifying their taxonomic status, and has demonstrated the presence in Scotland of actively evolving groups that have given, or may be in the process of giving, rise to new species. Examples include Newman's lady fern (*Athyrium distentifolium* var. *flexile*) (McHaffie *et al.,* 2001), Young's helleborine (*Epipactis youngiana*) (Hollingsworth, 2001) and several Eyebrights (*Euphrasia* spp.) (G. French, pers. comm.)

1.5 Social resource

Scotland has a long history of interest in, and understanding of, its natural heritage, drawing its strength from the cultural importance of the landscape and seascape to its people over generations. Despite industrial development, urbanisation and demographic change, there remains a strong attachment to, and identification with, the natural heritage which defines the character of Scotland. This is a valuable resource which should support and facilitate delivery of biodiversity objectives. However, public understanding of biodiversity is poor with only 5 per cent of the population aware of the term (Cuthbert, 2002) and few having an understanding of the relevance of biodiversity or of the methods of protection. There are several obstacles to progress including perceived time and cost constraints (Cuthbert, 2002).

Scotland has a high reputation for its academic and research skills in relation to biodiversity, with particular strengths in conservation biology, marine biology and in population and ecological genetics. However, concerns have been raised about a serious loss of taxonomic expertise, due to a failure to train new recruits into professional positions (House of Lords, 2002). There have been calls for more attention to taxonomy, and to create an inventory of Scotland's biodiversity.

Scotland has invested in preparing and storing species collections, for example at the National Museums of Scotland and the Royal Botanic Garden Edinburgh, and for examining live marine species (with laboratories at Millport, Oban, Orkney, Aberdeen and St. Andrews), and all of these offer excellent opportunities to investigate and conserve Scotland's biodiversity and to assist in biodiversity conservation worldwide. For example, analysis of wildcat (*Felis silvestris*) specimens has helped in the development of techniques for distinguishing them from domestic cats and their hybrids, which is vital for the wildcat's effective legal protection. Specimen collections also offer the opportunity to extract DNA for taxonomic, population and genetic variability studies and there have been calls for the creation of a national DNA bank.

It has been estimated that there are over 8,000 jobs in activities related to the natural heritage. Approximately 60 per cent of these are in the public sector and 20 per cent each in the private and voluntary sectors (SNH, 2001). In addition, there is a wealth of voluntary effort marshalled by non-governmental organisations.

Statutory protection of conservation sites through designation of Sites of Special Scientific Interest, Special Areas of Conservation and Special Protection Areas, complemented by non-governmental initiatives, has created a network of protected sites across Scotland. Protection is provided for a long list of species. This approach has been criticised as being piecemeal and inflexible. The UK Biodiversity Action Plan and Local Biodiversity Action Plans are achieving a degree of co-ordinated action without additional specific funding.

1.6 Economic resource

Scotland's biodiversity can be valued in economic terms by various methods. The Costanza methodology (Costanza *et al.*, 1997) estimates that the total environmental services provided by Scotland's land, waters and sea out to a 12-mile limit amount to around £15 billion per year, compared to a gross domestic product of £60 billion (SEPA, pers. comm.).

Attempts have also been made to assess the value of various landscape features to the public by determining how much each individual might be willing to pay to prevent the loss of a specific feature. It has been estimated that the scales range between £6 per hectare for heather moorland and £36 per hectare for hay meadows (Hanley *et al.*, 2001). The natural heritage is also a key selling point for the majority of overseas tourists. For example, 74 per cent of Italian visitors say they associate nature and wildlife with a visit to Scotland (TEF, 2001). The chance to see species, perhaps common in Scotland but rare elsewhere, enhances the visitor experience.

Nearly 30,000 people are employed in wildlife tourism and there are 283 dedicated facilities and sites. Scotland's ospreys alone attract £1.7 million of business, while whale and dolphin watching generate £2.7 million and £0.7 million respectively (TEF, 2002). Angling on the River Tweed brings £12.5 million to the area (SERAD, 2000). Both fishing and shooting are highly dependent on Scotland's scenery and natural heritage. There is, therefore, no doubt that Scotland's biodiversity can be viewed not just as a scientific resource, but as a resource contributing both to Scotland's economy and to the environment in which its people live and work.

2. TRENDS IN BIODIVERSITY

Alister Jones, Ed Mackey, Noranne Ellis and Joanna Drewitt

2.1 Introduction

Trends reflect change and environmental change is continuous. Scotland's environment is the result of several thousands of years of change, with ecosystems developing under particular combinations of edaphic, topographic and climatic influences, and the activities of people. Directly or indirectly, human influence has come to be a dominant cause of change in recent times.

The aim of this chapter is to identify and explain some of the most prominent and relatively recent changes in biodiversity. It is often in the nature of biological sample data that confidence limits are wide, and surveys designed in the past do not entirely satisfy present day needs. Best use has, however, been made of available data, with an emphasis on those results that are statistically significant.

This chapter is divided into three parts, examining biodiversity trends, looking more closely at reported trends in BAP priority habitats and species, and considering the key influences that have an impact on biodiversity in Scotland.

2.2 Biodiversity trends

A description of biodiversity trends characterised by habitat settings is not ideal. It may appear to be compartmentalised, with insufficient regard being given to the natural processes upon which biodiversity depends, or to ecosystem functions and interactions within and between environmental media (for example between soil and water, the edge effect of ecotones, or the importance of habitat structure and connectivity). Nevertheless, trend data have for the most part been gathered in that way, and the convention adopted is to refer to the same settings that were used in *Action for Scotland's Biodiversity* (Usher, 2000), with an additional brief note on soils. Each section commences with an analysis of recent and current trends and concludes with a brief statement of predicted effects of climate change.

2.2.1 The seas, coasts and firths

Much of the Scottish coast is a naturally dynamic environment of erosion and accretion in which continuous processes of habitat creation and ecological succession are vital to maintaining species-richness (Usher, 1999). Yet it is on parts of the coast, and around the major Firths, that a host of social, economic and environmental pressures come together (Sankey, 1999). About 10 per cent of the Scottish coastline has been affected by intensive urban or industrial use (Ritchie, 1999); in the upper Forth estuary, for example, it has been estimated that 50 per cent of the intertidal mudflats have been claimed by various forms of land use and development.

The recent trend has been one of improving water quality in coastal waters, and severe pollution has, in general, become localised around sea outfalls, inappropriately sited fish farms or sludge and spoil dumping sites. A build-up of nitrates from diffuse pollution within the River Ythan catchment in north-east Scotland has enriched estuarine mudflats such that dense algal mats now affect invertebrate communities living in the mud. Land-based pollution from waste water and sewage is being brought under stricter control, and the input of nutrients and contaminants to the North Sea has been reduced since the dumping of sewage sludge stopped in 1998. Although much remains to be done to bring pollution under control, coastal water quality was assessed as predominantly excellent or good between 1996 and 1999, with little more than 3 per cent of the coastline classified as unsatisfactory or seriously polluted at any time.

Seriously polluted areas within Scottish estuaries were reduced by 40 per cent between 1996 and 1999. In the 1970s, the faunal composition of the upper Clyde estuary sediments was dominated by a few pollution-tolerant species. By the late 1990s it had begun to change in favour of a more diverse invertebrate community, and fish species richness increased from 25 to 40. Similarly in the Forth, returning fish populations, including smelt (*Osmerus eperlanus*) which is particularly sensitive to low oxygen levels, have been linked to increasing levels of dissolved oxygen and declining organic and metallic waste levels.

The population sizes of harbour or common seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*) have remained stable or increased (respectively) over the past decade. However, phocine distemper virus is now present again in British waters and is likely to impact especially upon harbour seals which are particularly susceptible. Between 1969-70 and 1985-87 four out of 18 seabird species, such as cormorant (*Phalacrocorax carbo*) and roseate tern (*Sterna dougalli*), showed marked declines. Conversely, 11 seabird species, including the Arctic skua (*Stercorarius parasiticus*), great skua (*Stercorarius skua*) and gannet (*Morus bassanus*), showed marked increases in breeding populations. In some cases, however, seabird populations have become sustained at artificially high numbers due to abundant feeding on fisheries discards.

Exploitation of fish in Scottish waters has a long history, with a wide range of species being taken from intertidal, coastal and offshore habitats. Intensive trawling disturbance may have affected the species composition of the seabed community in parts of the North Sea. Compared with conditions at the start of the 20th century, species composition in parts of the North Sea had changed by 1986. Scavenging crustaceans and seastars had displaced bivalve molluscs, long-lived species had declined and opportunistic and scavenging species had increased in abundance. Of the 12 commercially exploited fin-fish species for which Scottish data are available, nine are currently considered to be fished outside safe biological limits (based on spawning stock biomass, fishing mortality and recruitment), and some individual stocks, such as cod (*Gadus morhua*), have been brought to the point of collapse. The depletion of traditionally fished stocks has, in turn, stimulated the targeting of previously unexploited species and fish of deeper waters off the Continental Shelf. Current levels of exploitation of deep-water fish, such as orange roughy (*Hoplostethus atlanticus*), which grows and matures slowly, are thought to be unsustainable. Furthermore, the passage of trawl gear is especially destructive to species and habitats in deep-water environments that rarely experience changes, and damage to the deep-water reef structures constructed by the coral (*Lophelia pertusa*) is of international concern.

Sea temperatures increased by 0.5°C, on average, between 1871and 2000. By 2100 they may be as much as 2 to 3°C higher than now (Hulme *et al.*, 2002), with the east coast warming at a greater rate. Increasing air and seawater temperatures are likely to result in an increased diversity of marine life, with species such as pink sea-fan (*Eunicella verrucosa*), a red alga (*Anotrichium barbatum*) and the honeycomb worm (*Sabellaria alveolata*), probably extending their ranges northwards into Scottish waters. On the other hand, species such as northern sea-pen (*Swiftia pallida*) and green sea urchin (*Strongylocentrotis droebachiensis*) may retreat and ultimately disappear from our coasts (Hiscock *et al.*, 2001).

Sea level is predicted to rise by varying amounts relative to the land, depending on the assumptions and the models used, but it is not expected to exceed 69 cm by 2080; contrast Hulme *et al.* (2002) and Dawson *et al*. (2001). The Northern and Western Isles are expected to experience the greatest rise, indicating a need for a 'managed retreat' along some areas of the coast and within the firths. Climate models are poor at simulating high intensity wind speeds and predictions for occurrences of storm events are uncertain, but when they occur they are expected have a major adverse effect on the coast. However, westerlies are expected to be the prevailing wind direction (Hulme *et al*., 2002).

2.2.2 Lochs, rivers and marshes

Scotland has at least 30,000 lochs and lochans, and over 10,000 burns and rivers. In 1997, sites surveyed for river habitat included some that were categorised as obviously modified (15 per cent), extensively modified (12 per cent) or heavily modified (1 per cent), reflecting the impacts of agriculture and urban development. By 1999, some 4,000 km of classified river length (about 10 per cent of the total) and 30 out of 150 classified lochs were polluted (SEPA, 1999). Nevertheless, the general trend in recent decades has been of improving water quality. Levels of contamination implicated in the former decline of the otter (*Lutra lutra*) have gradually been reduced. Water quality in central Scotland has improved since the decline of heavy industry and the introduction of better sewage treatment facilities, such that the restoration of fish stocks has allowed the otter to re-occupy much of its former range in lowland Scotland (Green & Green, 1997).

Eutrophication, particularly from phosphorus-rich discharges, has degraded the ecological status of Loch Leven, with knock-on effects on its value as a trout fishery. Pollution of the only Scottish lochs in which the vendace (*Coregonus albula*) was known led to its extinction, although it was subsequently re-introduced from English populations into two other lochs. By 2000, some 50 per cent of the native freshwater fish species were thought to have declined throughout Scotland, while non-native fish species had generally expanded. About half of the world's functional populations of freshwater pearl mussel (*Margaritifera margaritifera*) are found in Scotland, but by the late 1990s, only 7 per cent of mussel beds were classified as being in a near-natural state and 65 per cent had no juveniles (Cosgrove *et al*., 2000). An increasing number of heavy rainfall events have also been associated with uprooting pearl mussel beds and transporting them downstream (Hastie *et al*., in press).

The acidification of Scotland's fresh waters, notably in upland parts of south-western Scotland, has been linked to declines in the distribution of the dipper (*Cinclus cinclus*). Acidification has also been related to reductions in otter distribution and abundance, with otters absent from 61 per cent of km squares where acid deposition exceeded critical loads in 1997 (Fowler *et al*., 2002). However, many previously acidified freshwater systems in upland and south-west Scotland have recovered to the point that a number of acid-sensitive diatom species have returned (Harriman *et al*., 1995; Soulsby *et al*., 1997). Given further reduction in acidifying pollutants such improvements should continue, but it may take decades to realise the full ecological effects (Battarbee *et al*., 1988).

Ponds are an important habitat for wildlife, especially aquatic plants, invertebrates and amphibians. The National Amphibian Survey in Scotland (1983-1992) indicated a median percentage loss per survey of 7 per cent since the 1950s, mainly due to agricultural practices, mismanagement and in-filling. The largest decreases were in Fife (57 per cent) and the former Lothian Region area (42 per cent). Estimates from the Countryside Survey reported no significant change in Scotland for the period 1990 to 1998. By 1996, the number of sites where the great crested newt (*Triturus cristatus*) had been recorded since 1876 had fallen by 55 per cent.

The Atlantic salmon (*Salmo salar*) is locally extinct in some rivers in the West of Scotland but is becoming re-established in formerly polluted rivers of the Clyde and Forth catchments. Its status is a matter of current conservation concern. On the basis of catch records, including those from net fisheries that have now been mostly closed, salmon in Scotland declined by 82 per cent between the 1960s and the late 1990s. The genetic diversity of distinct populations within Scottish rivers is threatened by declines in the number of salmon returning to their natal rivers and by hybridisation with escaped farmed fish.

Of the breeding bird species dependent on fresh waters, five species expanded their range in Scotland between 1970 and 1990. These included the kingfisher (*Alcedo atthis*) and the grey heron (*Ardea cinerea*), both of which may have benefited from milder winters as well as improved water quality. At the same time the range of nine species reduced. In most cases the reasons are unclear, though the decline of the moorhen (*Gallinula chloropus*) is possibly linked to land drainage.

The non-native American mink (*Mustela vison*) was introduced for fur farming in 1938 and subsequently escaped. Mink can now be found throughout much of Scotland, except in some Hebridean Isles and the Northern Isles. The impact of mink on ground nesting birds, waterfowl and water voles has been serious (Craik, 1997).

Winters are expected to continue to become wetter and summers to become drier over Scotland as a whole (as has happened over the last century), although retaining the west-to-east gradient in the annual total rainfall. However, the models indicate that the far north of Scotland may experience an increase in summer precipitation variability (Hulme *et al.*, 2002). Lower flow rates in small water bodies and upland streams during the summer may exacerbate the degree of warming, with potentially greater adverse effects on freshwater species. However, heavy rainfall events will lead to a greater frequency of flooding and possible damage to spawning gravels.

2.2.3 Farmland and lowland grassland

Intensification and specialisation of Scottish farming have transformed the appearance and structure of lowland farmland. Over recent decades, the west has become more dominantly pastoral and the east more dominantly arable. According to the agricultural census, hay production declined by 34 per cent and silage production increased by 8 per cent between 1991 and 2000 (FPD Savills, 2001). In north-west Scotland there was a reduction in the number of crofters between 1960 and 1985, a reduction in tillage and the replacement of cattle grazing by sheep (RSPB & Scottish Crofters Union, 1992).

Mixed farming declined by 23 per cent between 1987 and 1999. Many hedgerows, despite their importance for biodiversity, became redundant as stock barriers, and were removed – the overall length reducing by half between 1947 and 1988 (Mackey *et al.*, 1998). The effect was noticeable in western pastoral areas, and most evident in the eastern grain-growing areas, as it coincided with the ongoing trend towards larger field units to facilitate the use of modern farming equipment. No further reduction was detected between 1990 and 1998 (Haines-Young *et al.*, 2000). Farm woodland recorded in the June Agricultural Census doubled between 1991 and 2000.

These are all symptomatic of significant changes in the mosaic of habitats that have been sustained by mixed farming systems. Between around 1970 and 1990, 12 species of farmland bird, such as the barn owl (*Tyto alba*), contracted in range by more than 10 per cent. Similarly between 1994 and 1999, the abundance of three out of 13 widespread farmland species, the skylark (*Alauda arvensis*), lapwing (*Vanellus vanellus*) and kestrel (*Falco tinninculus*), showed a statistically significant decrease.

Environmentally friendly farming practices have been shown to enable wildlife such as the corncrake (*Crex crex*) to recover or re-establish in its core areas (Green & Riley, 1999). By contrast seed banks of native flora on agricultural land are now depleted due to intensive agricultural practices and the return of arable flora is unlikely to occur naturally (Ford, 1997). The creation or re-establishment of habitats such as wildflower meadows from seed carries a potential risk of the genetic structure of native species being affected by the use of non-native provenances, either by displacing plants of local origin or through hybridisation (Welch *et al*., 2001). An example is the non-native variety of bird's-foot trefoil (*Lotus corniculatus* var. *sativus*) which is more vigorous in growth and out-competes native varieties.

Cereal farming since the 1950s has seen a steady decline in the use of oats as a crop (down to less than 10 per cent of the total cereal area), whilst the area of barley has expanded. Recent studies on the genetics of the current varieties of barley show that they can be traced back to only 17 foundation cultivars, indicating a declining extent of genetic diversity in modern spring barley.

Climatic changes are not expected to increase biodiversity on farmland because, although warmer average temperatures may encourage some species of butterflies and birds to extend their ranges northwards, not all species will have the ability to shift northwards at the same rate. For those that do there may be a lack of suitable habitat(s). New crops and cropping patterns will undoubtedly need to be considered to take advantage of warmer, drier summers and the constraints of wetter autumns. Altitudinal limits of managed land could move further up the hill, reducing the extent of upland semi-natural habitats.

2.2.4 Forests and woodland

Woodlands are the climatic climax vegetation over most of Scotland, but had been reduced to less than 5 per cent of Scotland's land area by the early 1900s. Forest and woodland cover in Scotland expanded to around 17 per cent by 2001 (FC, 2002), with the steepest rise being in Dumfriesshire, Argyll and parts of the Scottish Borders. This afforestation (which was strongly driven by government policy) occurred largely between the 1940s and the late 1980s. Most of it consisted of plantations of non-native conifers, and was achieved by displacing rough grassland, blanket mire and heather moorland, as well as by conversion of former broadleaved woodland – the extent of the latter declining by 26 per cent during this period.

The area of woodland with native species increased by one-third between 1984 and 1999. This included a 9 per cent expansion of broadleaved woodland between 1990 and 1998, mainly on grasslands, and the restoration of native woodlands tree cover in plantations on ancient woodland sites. There was also a significant expansion in new woodlands of Scots pine (*Pinus sylvestris*), formed by the incremental enlargement of existing native pinewoods by natural regeneration, or by planting of other suitable sites using plants raised from seed of the appropriate biochemical origin for the locality (FC, 1999).

Native woodland species, and those of previously open habitats will have been affected by the loss and fragmentation of their habitat, the change to conifer plantations or changes in traditional management (e.g. the demise of coppicing). However, given the intensification of management of adjacent (non-woodland) areas, remnant woodlands have become relatively more important for species like the pearl bordered fritillary (*Boloria euphrosyne*).

Perversely, for a short time, threatened butterflies were doing better in native woodlands that had been partially cleared and planted with conifers than they were in unmanaged woods (Warren & Key, 1991).

Between around 1970 and 1990, ten woodland species, including the woodcock (*Scolopax rusticola*), contracted in range by more than 10 per cent. Eleven others, such as the wood warbler (*Phylloscopus sibilatrix*), expanded. Between 1994 and 1999, five out of 14 widespread woodland species, e.g. the great tit (*Parus major*), showed a statistically significant increase in abundance. The geographical range of the capercaillie (*Tetrao urogallus*), the largest of the native grouse, contracted by 64 per cent between around 1970 and 1990. More targeted surveys have shown that the number of individuals declined by 51 per cent between around 1992 and 1999, from an estimated 2,200 to 1,070 birds. Several factors have been implicated – the main ones being habitat fragmentation and management, deer fencing, disturbance, and adverse weather conditions particularly during the chick-rearing period.

Fluctuations in species abundance and composition can be a feature of any woodland's development. This is very evident in plantations where, as they mature, they attract a higher proportion of species that are the same as, or similar to, the characteristic species of semi-natural woodlands, particularly fungi and invertebrates (Humphrey *et al.*, 2002). Since the early 1990s there has been more emphasis on restructuring conifer plantations. This is usually carried out as they approach the end of their optimum economic life cycle, and is coupled with more appropriate management of the non-wooded areas within forest boundaries, and the replanting (after felling) of a wider range of tree species.

With mean annual temperatures expected to rise by 1 to 3.5°C by the end of the century (Hulme *et al.*, 2002) some southerly species are expected to extend their ranges into Scotland. For example, the nuthatch (*Sitta europa*) has already been observed within woodlands in the Borders. Species composition within woodland habitats may alter, initially with the addition of species with good dispersal capability from the south (particularly birds and invertebrates), and then over a much longer period as the relative dominance of the tree species within individual woods changes. For example, birch (*Betula* spp.), which is already a constituent species of many pinewoods, may become a bigger component; similarly, but probably to a lesser extent, oak (*Quercus* spp.) may increase around the margins of pinewoods where soil conditions are favourable. There is likely also to be an upward shift in the treeline from the 650 m altitude today.

2.2.5 Mountains, heaths and bogs

Montane environments are among the least altered in Scotland. Their arctic-alpine communities of plants and animals echo Scotland's post-glacial past. Nevertheless, they are vulnerable to disturbance by, for example, excessive trampling, climate change and air pollution. Nitrogen enrichment, together with grazing pressure, have been implicated in declines in the extent and quality of montane heaths dominated by the moss *Racomitrium lanuginosum* (Baddeley *et al.*, 1994). Increased tissue nitrogen, associated with air pollution during the twentieth century, also poses a threat to snowbed bryophyte communities (Woolgrove & Woodin, 1996a,b).

Moorlands, peatland and rough grassland form a mosaic of semi-natural habitats covering more than 50 per cent of Scotland's land area. Apart from the places where tree cover is naturally limited due to severe wetness, cold or exposure, the condition of other semi-natural habitats and woodland regeneration is governed mainly by the grazing of sheep and/or deer. Overgrazing has become evident in parts of the uplands due to the number of sheep increasing by 32 per cent between 1950 and 1990, and the red deer (*Cervus elaphus*) population allegedly doubling between 1959 and 1989. As a consequence the natural regeneration of trees has been arrested and the condition of heather moorland has deteriorated.

Between the late 1940s and the late 1980s, the overall area of blanket bogs and the less extensive lowland bogs were reduced by 21 per cent and 44 per cent respectively (Mackey *et al*., 1998). In each case the main cause was afforestation, and to a lesser extent agricultural improvement; commercial peat extraction was an additional factor on lowland bogs. Between 1990 and 1998, no change was detected in their extent (Haines-Young *et al*., 2000).

Conditions are optimal for the development of heather moorland in Scotland (Thompson *et al*., 1995). Sporting estates flourished from the 1870s onwards, but their economic value has declined since the 1930s. Fewer gamekeepers to manage the sporting interest, rising sheep numbers, and falling standards of muirburn have contributed to a decline in the heather cover upon which grouse rely (Watson & Lance, 1984). Between the 1940s and 1980s, heather moorland was reduced by about 23 per cent through afforestation and conversion to rough grassland. Weaker evidence suggests that a further decline of 5 per cent between 1990 and 1998 was associated mainly with forest cover (or canopy closure) and conversion to grassland. Also within dwarf shrub heaths, the number of species characteristic of low-nutrient soils declined, and those typical of more fertile conditions increased (McGowan *et al.*, 2002).

Rough grassland decreased by 10 per cent between 1947 and 1988, due mainly to afforestation and grassland improvement. An estimated reduction of 16 per cent in the extent of calcareous grassland in the marginal uplands between 1990 and 1998 was due mainly to its conversion to more intensively managed grassland. However, a 19 per cent expansion of fen, marsh and swamp is partly attributed to reduced or abandoned grassland drainage in wetter areas (McGowan *et al.*, 2002).

The number and distribution of recent cases suggests that the illegal persecution of raptors is widespread in Scotland, severely limiting the breeding success and distribution of hen harriers (*Circus cyaneus*) and suppressing golden eagle (*Aquila chrysaetos*) recruitment (RSPB, 2001). Incidents of alleged raptor persecution are associated geographically with parts of the country where game shooting is practised and, compared with the rest of the UK, they are disproportionately common in Scotland (RSPB, 1999).

The area affected by potentially harmful levels of nitrogen deposition on peatland ecosystems is expected to decline by 28 per cent by 2010 (Mackey *et al.*, 2001). Global ozone concentrations are, however, expected to continue to rise over the next decade, and will be more persistent in upland areas. High levels of ozone exposure reduce the productivity of crops, although it is not yet known which species are most sensitive it.

With a rise in mean annual temperature, vegetation zones will shift by between 250 and 1,400 km northwards, and uphill by between 200 and 960 m. The extent of the arctic-alpine habitat will therefore decrease by 93 per cent on a best case scenario and, at worst, will disappear completely. However, with the expectation that the high wind speeds already experienced across many areas of Scotland will continue, then there is some hope that pockets of suitable micro-climate may continue for some arctic-alpine species. The arctic-alpine species expected to be adversely affected include lichens, such as alpine sulphur-tresses (*Alectoria ochroleuca*) and snow caloplaca (*Caloplaca nivalis*), vascular plants such as the tufted saxifrage (*Saxifraga caespitosa*) and drooping saxifrage (*Saxifraga cernua*), snow-patch moss (*Kiareria starkei*), and montane birds, such as snow bunting (*Plectrophenax nivalis*), ptarmigan (*Lagopus mutus*) and dotterel (*Charadrius morinellus*). Heavy rain events in autumn and winter may cause physical and chemical alterations in ecosystems, such as greater erosion of upland peatlands and extreme flows in upland streams.

2.2.6 Soil

The productivity of soil, the largely unseen foundation of much of Scotland's biodiversity, is often an inheritance of reclamation, cultivation and manuring over the last 400 years (Davidson & Smout, 1996). Land use change and pollution can have large impacts on soil biota and species richness (Usher, 1996). In recent decades, more intensive farming and forestry practices, together with urban and industrial development, have in places damaged soil and water processes (Bullock & Thompson, 1996). Soils may be polluted and contaminated, eroded, compacted, truncated and lose their ecosystem functions; as a terrestrial carbon reservoir, soil properties can be affected by the drainage of wetlands, afforestation, peat extraction, cultivation and climate change (Taylor, 1995; Puri *et al.*, 1999). It has been concluded, nevertheless, that the lack of data on trends in soil properties makes it impossible to assess whether current land use practices and pollutant inputs to soil are sustainable (SEPA, 2001).

Warmer temperatures have been related to a 65 per cent increase in the concentration of dissolved organic carbon in freshwaters across the UK between 1988 and 2000 (Freeman *et al.*, 2001). With increasing soil temperatures in the future, concurrent with drier soils in summer, the rate of decomposition may increase. The concern is that the soil carbon store is released to the freshwater environment, and thereby relocated to the oceans.

2.3 Reported trends in BAP priority habitats and species

The most recently assessed trends in the status of all UK BAP priority species is to be found in the analysis of the BAP Lead Partner reports in 1999 (Kerr *et al.*, 2000; Jones *et al.*, 2001). It is recognised that the size and distribution of species populations was only one of the criteria used to determine BAP status, and that the validity of some of the assessments made in 1999 were questionable, due to insufficient information. The results are summarised in Table 2.1 and given in full in Annex 2.1. Though the BAP implementation process was then at an early stage, the figures are broadly encouraging, indicating that the habitats and species for which Scotland has a dominant share (i.e. over 50 per cent of the habitat area or over 50 per cent of the species population) were performing slightly better than the other BAPs.

Table 2.1. Comparison of biological status of BAP habitats and species in Scotland. All data are percentages. The 'lost/extinct' category includes only species that had disappeared from Scotland before the SAPs were published.

Status	Habitats		Species	
	>50% of habitat area in Scotland	<50% of habitat area in Scotland	>50% of population in Scotland	<50% of population in Scotland
Recovered	0	0	3	1
Showing signs of recovery	14	9	5	4
No change	57	47	59	31
In decline	29	9	25	26
Lost/extinct	0	0	1	15
Unknown	0	35	8	23

2.4 Key influences

Many of the positive and negative trends are directly or indirectly attributable to key influences affecting our environment, such as those listed in Table 2.2. The examples are drawn from the National Prospectuses of Natural Heritage Futures (SNH, 2002), but have been grouped and 'scored' for their relative impacts on biodiversity. The list may not be exhaustive, and there will not be complete agreement on the scale, severity or cross-boundary effects of some impacts. The list, however, provides a framework for examining key influences in a semi-systematic way. For example, one may quickly identify those mechanisms that could be directed towards more positive outcomes, such as the EU Common Agricultural and Fisheries Policies. It can also flag up anomalies, where what is beneficial in one sector may have an adverse effect in another sector, such as the ending of sewage dumping at sea.

The BAP Lead Partners reports (Kerr *et al.*, 2000; Jones *et al.*, 2001) also included an analysis of specific 'constraints' to BAP implementation, now summarised in Table 2.3. Certain aspects had been referred to in the BAPs themselves as 'threats' to specific habitat or species, and the similarity between them and the key influences identified in Table 2.2 suggests that many of the issues have been evident for a long time.

Table 2.2. Key Influences on Scottish biodiversity. The following symbols have been used: ++++ for a strong positive impact, + for a low positive impact, **C** to be viewed in context, — for a low negative impact, ---- for a strong negative impact, and a dot (·) for possible neutrality.

Factors influencing biodiversity	Examples	Seas coasts firths	Lochs rivers marshes	Farms (& low grass)	Forests woods	Hills heaths bogs	Settlement
Statutory protection and regulation	National/international laws/directives	++++	++++	++++	++++	++++	++++
	Conservation management of protected areas, inc. SPAs & SACs	++++	++++	++++	++++	++++	++++
	Environmental (management & compliance) Standards	++++	++++	++++	++++	+	·
	Integrated Coastal Zone Management (6 Firths & 3 other areas)	++++	·	·	·	·	·
	Combined sewer overflows - EC Urban Waste Water Treatment Directive	++++	++++	·	·	·	++++
	Integrated Catchment Management - WFD	++++	++++	·	·	·	·
	Pollution - point-source discharges (being brought under control)	++++	++++	·	·	·	·
	Inshore (6 nm) policy - UK Regulating Orders / integrated approaches	++++	·	·	·	·	·
Direct (positive) conservation action	Habitat Networks - expansion, diversification, balance (all land uses)	·	++++	++++	++++	++++	++++
	Habitat restoration – e.g. native woodlands, riparian vegetation	·	++++	++++	++++	++++	·
	Habitat creation – e.g. wetlands, ponds, farm woodlands	·	++++	++++	++++	·	·
	Species introduction & translocation (as conservation measures)	·	++++	++++	++++	++++	·
Sectoral policies	European Agricultural policy - CAP	·	·	------	**C**	------	·
	Scottish Sectoral Strategies for Agriculture, Forestry etc.	·	+	++++	++++	+	+
	European Offshore fisheries policy – CFP	------	·	·	·	·	·
	European Coastal Strategy (in prep.)	++++	·	·	·	·	·
	Sustainable integrated travel and transport policies	·	·	·	·	·	++++
Public sector incentives and associated guidelines	Natural Care	·	+	++++	++++	++++	·

	Rural Stewardship Scheme	.	++++	++++	+	++++	.
	Farmland - agri-environmental schemes	.	.	++++	+	+	.
	Farmland - management schemes for geese refuges	.	.	++++	.	.	.
	Farmland - set-aside	.	.	+	.	.	.
	Woodland Grant Scheme (Scottish Forestry Grant Scheme from 2003)	.	+	++++	++++	+	+
New technologies/solutions	Improved forest design and operational management	.	++++	.	++++	.	.
	TIBRE - Targeted Inputs for a Better Rural Environment	.	.	++++	.	.	.
	Sewage sludge incineration/use on land (not dumping at sea)	++++	.	–	.	.	.
	Short rotation coppicing (wood fuel)	.	.	+	+	.	.
Community factors	Environmental and sustainable development education	+	+	+	+	+	+
	Membership/support for environmental NGOs	+	+	+	+	+	+
	Community involvement and voluntary action	.	+	.	+	.	+
	(Responsible) access - urban and rural	C	C	C	C	C	C
	Public/consumer preferences, demand for sustainable products (incl. organic foods)	C	C	C	C	.	C
	Locational choice - environmental enhancement/greenspace land take	.	.	------	.	.	++++
	Public health - active lifestyles	.	.	.	.	.	C
	Litter - effects on wildlife and amenity	–	–	–	–	–	–
	Vandalism & wildlife crime	.	------	------	–	------	–
Socio-economic issues	Demographics - contracting, ageing - increased housing demand	.	.	C	.	.	C
	Increased recreation and tourism	C	C	C	C	C	C
	Marketing conditions - resulting changes in traditional industries & practices	C	C	C	C	.	C
	Globalisation and trade liberalisation	.	.	C	C	.	.
	International maritime laws and conventions (governing trade)	C	.	.	.	.	.
	Increased shipping - hence risk of accidents and pollution	C	.	.	.	.	.
	Farm economics – e.g. farm amalgamation, reduced employment	.	.	C	.	C	.

Factors influencing biodiversity	Examples	Seas coasts firths	Lochs rivers marshes	Farms (& low grass)	Forests woods	Hills heaths bogs	Settlement
Socio-economic issues (cont'd)	Biotechnology and biosecurity	.	.	C	.	.	.
	Knowledge economy, use of Information Technology	.	.	.	.	.	C
Natural processes	Species evolution & dispersal	C	C	C	C	C	.
	Carbon sequestration	.	.	.	C	C	.
	Water quality - paralytic, amnesic, diarrhoetic shellfish poisoning, toxic algal blooms	------	.	.	.	.	.
Public utilities and development	Renewable energy provision of facilities	C	C	.	.	C	.
	Reservoirs and dams; water extraction	.	—	.	.	.	.
	Coastal developments - energy, industry, defences due to increased storminess	—	.	.	.	.	—
	Flood defence works	.	—	—	.	.	—
	Quarrying and aggregate extraction; opencast mining	—	—	—	.	—	.
	Development - urban, industrial and infrastructure	.	.	------	—	.	C
	Land claim/land fill	------	------	------	.	.	.
Global atmospheric conditions	Exposure to increasing ground level ozone	.	.	—	—	------	.
	Climate change - species responses to sea and air temperature	—	—	.	—	------	.
	Climate change - sea level rise	------	.	.	.	.	.
	Climate change - increased storminess and flooding	------	------	—	—	.	—
Activities with adverse effects	Ballast water - non-native marine species and pathogens	—	.	.	.	.	.
	Trawl damage and mechanical harvesting of shellfish	------	.	.	.	.	.
	Commercial fisheries - fish stocks reduction, by-catch, discards	------	.	.	.	.	.
	Deep water fisheries - outside safe biological limits	------	.	.	.	.	.
	Salmon farming - feed, chemical treatments, nutrients, lice, escapes	------	------	.	.	.	.
	Aquaculture in fresh waters	.	—	.	.	.	.
	Pollution - nutrient, chemical, pharmaceutical run-off	------	------	.	.	.	.

Pollution - spills, leakage, mine drainage, contaminated land	.	----- -	.	.	.	.
River dredging, straightening, bank reprofiling, poor culvert design	.	----- -	.	.	.	.
Impermeable surfaces - drainage of contaminated water	.	----- -	.	.	.	----- -
Acidification and eutrophication of soils - air pollution and agriculture	.	----- -	—	—	----- -	.
Farmland - use of agri-chemicals (herbicides, pesticides, anti-parasitic drugs)	.	----- -	----- -	.	.	.
Soil - tillage and compaction - soil erosion	.	----- -	—	.	.	.
Farmland - increased mechanisation, intensification, specialisation	.	----- -	----- -	.	—	.
Crofting - decline in cattle rearing and associated cropping	.	.	----- -	.	—	.
Overgrazing (by sheep and deer); use of deer fences	.	----- -	.	----- -	----- -	.
Uncontrolled spread of invasive non-native species	----- -	----- -	.	----- -	----- -	----- -

Table 2.3. Analysis of 'constraints' to the implementation of the Scottish BAPs (from Jones *et al*., 2001). These are data based on Lead Partner reports for 21 HAPs and 150 SAPs relevant to Scotland.

Top 20 changes identified by Lead Partners to aid action plan implementation	Percentage of plans		
	Habitats	Species	Total
Additional research and survey	90	82	83
Extra resources (funding and staff time)	95	51	57
Improved access to information (e.g. a national database)	86	51	55
Improved habitat and species management	90	43	49
Communication/publicity to achieve increased involvement and awareness among land-owners, managers and the general public	76	45	49
Changes to agri-environment schemes	95	26	34
Habitat enhancement (increasing habitat area and/or quality)	67	26	31
Increased protection on statutory sites (including designation of additional sites)	71	22	28
A need for ex-situ conservation and reintroduction programmes	n/a	32	28
Changes in farming practice	62	23	28
Legislation and policy changes	86	19	27
Changes to the Common Agricultural Policy	67	9	16
Improved conservation outside protected areas	38	12	15
Reducing the impact of tourism and human recreational activities	14	12	12
Improved species-specific management (reducing the effects of competition, non-native species, hybridisation or disease)	19	11	12
Improved management of fresh water systems	29	9	11
Changes to forestry (including application of Forest Design Plans and increased funding of Woodland Grant Scheme)	29	5	8
Reducing the impact of building works and other human development	14	6	7
Reducing pollution	19	5	6
Ameliorating the effects of climate change	10	4	5

2.5 Concluding remarks

Although the best available data have been used, they were not necessarily designed or captured for the present purpose. They give a partial and approximate view of some of the more obvious trends in Scottish biodiversity. More thought needs to be given to biodiversity data needs in Scotland, and it should be done in ways that facilitate meaningful comparisons with the rest of the UK and Europe.

In the meantime, we should recognise the inherent dynamism and inevitable complexity of the environment given the cumulative effect of natural processes and human impacts upon it. The rate of change has been increasing due to the intensification of land use and other development pressures in both urban and rural areas (including water catchment and forestry). This has resulted in a reduction of 17 per cent in semi-natural land in the 40 years or so up to 1988 (Mackey *et al.*, 1998). In the subsequent decade, some declines, such as hedgerow loss, appear to have been arrested (McGowan *et al.*, 2002). Climate change is expected to become more evident in the future.

Restoration of coastal seabed life to some, mostly unknown, pristine condition that pertained prior to exploitation is unachievable. It is probable that these ecosystems can exist in multiple stable states. However, there is a need to develop marine policies and management measures that aim to restore sustainability to the exploitation of Scotland's seas.

As a consequence of the loss, fragmentation or degradation of semi-natural habitats, the populations of many species have declined to non-viable levels; others have been directly destroyed (e.g. by collecting or over-exploitation). Non-native species have also been introduced, with some becoming invasive and damaging to native biodiversity. This includes species such as the signal crayfish (*Pacifastacus leniusculus*), which carries the crayfish plague that is inimical to native white-clawed crayfish (*Austropotamobius pallipes*), and feral Sika deer (*Cervus nippon*), able to hybridise with the red deer (*Cervus elaphus*) and now occupying about one-third of the native red deer range. It also includes locally non-native species, such as the hedgehog (*Erinaceus europaeus*), which has proved highly destructive to ground nesting birds since its release within the Western Isles.

Many favourable trends in biodiversity have been brought about, or assisted, by political or other strategic level intervention, regulation and the promotion (and funding) of better land and water management practices. Biodiversity Action Plans have identified vulnerable habitats and native species for targeted action. A Scottish Biodiversity Strategy can build upon the environmental improvements that are evident, but it must also tackle the many problems that remain, recognising that new concerns will emerge through time.

Annex 2.1. The assessment of the status of BAP species described by Jones *et al.* (2001). The species are grouped by habitats, as in Usher (2000). The status column indicates that the species has recovered (1) or is showing signs of recovery (2), or that there is apparently no change (3). Species that have declined further are given status (4), whilst those that have become extinct in Scotland prior to the SAP publication are given status (5) – no species has become extinct since plan publication. The status of some species remains unknown (?). More recent information about BAP species is constantly becoming available; see www.ukbap.org.uk.

Habitat and species name	Scientific name	Status
Seas and coasts		
New Forest burnet	*Zygaena viciae argyllensis*	2
Corncrake	*Crex crex*	2
Otter	*Lutra lutra*	2
Slender Scotch burnet	*Zygaena loti scotica*	3
Egg (or knotted) wrack	*Ascophyllum nodosum ecad mackaii*	3
Rock sea-lavender	*Limonium binervosum* agg.	3
Eyebrights	*Euphrasia* spp.	3
Lesser bearded stonewort	*Chara curta*	3
Northern hatchet shell	*Thyasira gouldi*	3
Allis shad	*Alosa alosa*	?
Freshwater habitats		
Vendace	*Coregonus albula*	2
Otter	*Lutra lutra*	2
Scottish small-reed	*Calamagrostis scotica*	3
Slender naiad	*Najas flexilis*	3
Ear-lobed dog-lichen	*Peltigera lepidophora*	3
Scottish pohlia	*Pohlia scotica*	3
Shetland pondweed	*Potamogeton rutilus*	3
a stiletto-fly	*Spiriverpa lunulata*	3
a stonefly	*Brachyptera putata*	3
Common scoter	*Melanitta nigra*	4
Red-necked phalarope	*Phalaropus lobatus*	4
Marsh clubmoss	*Lycopodiella inundata*	4
a reed beetle	*Donacia aquatica*	4
Freshwater pearl mussel	*Margaritifera margaritifera*	4
Irish lady's-tresses	*Spiranthes romanzoffiana*	4
Mossy stonewort	*Chara muscosa*	?
Lowland grassland		
New Forest burnet	*Zygaena viciae argyllensis*	2
Corncrake	*Crex crex*	2
Slender Scotch burnet	*Zygaena loti scotica*	3
Elm's gyalecta	*Gyalecta ulmi*	3
Red-backed shrike	*Lanius collurio*	3
Great yellow bumblebee	*Bombus distinguendus*	4
Northern colletes	*Colletes floralis*	4
a leaf beetle	*Cryptocephalus primarius*	?
Forests and woods		
Wilson's pouchwort	*Acrobolus wilsonii*	3
a lichen	*Arthothelium dictyosporum*	3
a lichen	*Arthothelium macounii*	3

Habitat and species name	Scientific name	Status
Green shield-moss	*Buxbaumia viridis*	3
Chequered skipper	*Carterocephalus palaemon*	3
Stump lichen	*Cladonia botytes*	3
Scottish wood ant	*Formica aquilonia*	3
a hoverfly	*Hammerschmidtia ferrunginea*	3
Wryneck	*Jynx torquilla*	3
Scottish crossbill	*Loxia scotia*	3
Warty wax-lichen	*Thelenella modesta*	3
Scaly tooth fungus	*Sarcodan imbricatus*	3
Blunt-leaved bristle-moss	*Orthotrichum obtusifolium*	3
a lichen	*Peusocyphellaria norvegica*	3
a lichen	*Biatoridium monasteriense*	3
Narrow head ant	*Formica exsecta*	3
Elm's gyalecta	*Gyalecta ulmi*	3
an ascomycete	*Hypocreopsis rhododendri*	3
Pale bristle-moss	*Orthotrichum pallens*	3
Young's helleborine	*Epipactis youngiana*	3
a hoverfly	*Blera fallax*	4
Twinflower	*Linnaea borealis*	4
Small cow-wheat	*Melampyrum sylvaticum*	4
a mason bee	*Osmis uncinata*	4
Capercaillie	*Tetrao urogallus*	4
Red squirrel	*Sciurus vulgaris*	4
Juniper	*Juniperus communis*	4
Speckled script lichen	*Schimatomma graphidioides*	4
Black grouse	*Tetrao tetrix*	4
a weevil	*Procas granulicollis*	4
a jumping weevil	*Rhynchaenus testaceus*	5
a cranefly	*Lipsothrix ecucullata*	?
Dark bordered beauty	*Epione parallelaria*	?
Atlantic lejeunea	*Lejeunea mandonii*	?
Mountain, heath and bog		
Norweigan mugwort	*Artemisia norvegica*	1
Newman's lady fern	*Athyriun flexile*	1
Lindenberg's featherwort	*Adelanthus lindenbergianus*	3
a lichen	*Alectoria ochroleuca*	3
Scottish beard-moss	*Bryoeryrophyllum caledonicum*	3
Mountain scurvy-grass	*Cochlearia micacea*	3
Perthshire beard-moss	*Didymodon mamillosus*	3
a lichen	*Halecania rhypodiza*	3
Northern prongwort	*Herbertus borealis*	3
a mason bee	*Osmis inermis*	3
Wooly willow	*Salix lanata*	3
a gasteromycete fungus	*Tulostoma niveum*	3
Slender Scotch burnet	*Zygaena loti scotica*	3
Icy rock-moss	*Andreaea frigida*	3
a lichen	*Gyaliddeopis scotia*	3
Round-mouthed whorl snail	*Vertigo genesli*	3
Sword-grass	*Xylena exsoleta*	3
Shetland mouse-ear	*Cerastium nigrescens*	3

Habitat and species name	Scientific name	Status
Netted mountain moth	*Semiothisa carbonaria*	4
Juniper	*Juniperus communis*	4
Baltic bog-moss	*Sphagnum balticum*	4
Black grouse	*Tetrao tetrix*	4
Hawkweeds	*Hieracium* Sect. *Alpestria*	4

3. OVERVIEW AND CONCLUSIONS

The Convention on Biological Diversity (CBD) contains the following definition of 'biodiversity'.

> 'Biological diversity' means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'.

In essence, this means that biodiversity has to be considered at three levels - the habitat level (ecosystems), the species level (diversity between species) and the genetic level (diversity within species). It is essential that biodiversity is addressed at all three levels within the Scottish Biodiversity Strategy (SBS) if the aims of the CBD are to be achieved.

In Scotland we know a considerable amount about the biodiversity resource, more at the species and habitat levels than at the genetic level. We can be proud about the resource, on land, in fresh waters and in the seas surrounding Scotland. As chapter 1 says

> "For its size, Scotland possesses a mixture, diversity and close inter-relation of habitats that is particularly unusual and worthy of protection. These mosaics create high landscape value and are the essence of Scotland's natural beauty".

Although the chapters focus on the scientific aspects of biodiversity, chapter 1 also reminds us of the economic values of biodiversity, important in creating a prosperous Scotland, and of the social values of biodiversity, important in sustaining the environment in which we want to live.

Thus, conserving and enhancing Scotland's biodiversity must go hand in hand with meeting the social and economic needs of Scotland's people. The futures of many of Scotland's rural and coastal communities are reliant upon the sustainable use of natural resources, on land, in fresh water, along estuaries and at sea.

It is a truism that change is everywhere and that change is inevitable. Scotland's biodiversity resource never has been static and never will be static. Biological and earth science processes are dynamic, though they are often perceived over very different time periods. This is clearly stated in chapter 2 by the passage

> "Trends reflect change and environmental change is continuous. Scotland's environment is the result of several thousands of years of change, with ecosystems developing under particular combinations of edaphic, topographic and climatic influences, and the activities of people. Directly or indirectly, human influence has come to be a dominant cause of the change in recent times".

This again brings out the inter-dependence of Scotland's biodiversity and the activities of its people. A key message of chapter 2 is that

- there will be potentially large, but relatively unquantifiable, effects on biodiversity due to anthropogenically-induced climate change;
- soils are "the largely unseen foundation" of much of Scotland's terrestrial and freshwater biodiversity; and

- the data give a partial and approximate view of some of the more obvious trends in Scotland's biodiversity, both favourable and unfavourable.

Regardless of how we analyse the state of Scotland's biodiversity, or attempt to find data sets that tell us about trends, there will always be questions about what is happening now. It is to be able to attempt to answer such questions, in a situation of incredible complexity, that we need to have some indicators. Developing candidate indicators of the state of Scotland's biodiversity (Wilson *et al*, 2003)provides information that could help to create that suite of indicators, highlighting 15 sets of data that can be used to indicate trends in Scottish wildlife. Other indicators will need to be added to the scientific set to reflect the social and economic aspects of biodiversity, and as a total package these will also be able to assist in the assessment of whether or not development in Scotland is becoming more sustainable.

Biodiversity is itself a cross-cutting issue, having ramifications in all aspects of Scottish life. Biodiversity must therefore be a part of the many other strategies and policies that relate to water and land use in Scotland. Examples of such policies and strategies that either do, or should, consider biodiversity include fisheries, aquaculture, the coastal zone, agriculture, forestry, the natural heritage, and pollution prevention. In particular, the lack of a soil sustainability (protection) strategy in Scotland is an omission that needs to be rectified urgently.

Research about Scotland's biodiversity is important, not only in relation to filling the gap in our knowledge, but also in finding ways of managing the natural resources of Scotland most effectively and in ameliorating the effects of some of newer impacts, such as developing technologies and climate change. The Scottish Biodiversity Forum has developed a research strategy (Anon., 2002) which highlighted three particular research themes that need development. These are

- research related to monitoring and surveillance,
- research related to BAP-specific issues (including management of habitats and ecosystems, the effects of non-native species, re-introductions, genetic research, the impacts of pollution and the development of best-practice guidance), and
- research on cross-cutting issues (including species diversity, genetic diversity, land use, ecosystem function, climate change, economic valuation and public perceptions of biodiversity).

The UK has about 440 published plans for habitats (habitat action plans - HAPs) and species (species action plans - SAPs); these are all considered to be priority habitats and priority species at the UK level. The 32 local authorities in Scotland are working either individually or together to write and publish 26 local biodiversity action plans (LBAPs). There is at times a mis-match between the UK-level and local-level HAPs, SAPs and LBAPs. The differences of approach, which could be viewed as ‘top-down’ and ‘bottom-up’, need to be resolved. Despite the amount of information in chapters 1 and 2, there has not yet been a ‘middle-out’ approach. The APSG therefore sees it as important that there is a full integration of UK level, Scotland level and local level plans.

Finally, a taxonomic initiative is needed in Scotland so as to understand fully what species exist on the land and in the freshwater of Scotland and in the seas around Scotland, and to understand something about the genetic variability of some of these species. Sweden has undertaken to produce an inventory of all species in its territory within 25 years. Scotland probably starts from a better knowledge-base than Sweden and is likely to have a smaller fauna and flora (only about 65 per cent that of Sweden for groups that can be compared). It would certainly be a challenge, but with the scientific and academic expertise that exists in

Scotland today, it would not be impossible to create an inventory of Scotland's biodiversity during the coming decade or two.

The APSG's hope, in editing three of its working papers into this publication, is that the material will stimulate both thinking and action. Will it be possible, in say 10 years time, to state that we really know more about Scotland's biodiversity, and have carried out the actions to halt or reverse declines? Will it be possible for a much larger section of Scotland's population to identify with the need to protect Scotland's biodiversity and to use it wisely? This publication is only one small step in our wish to answer 'yes' to such questions.

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do a little change a lot

Small changes in the way we perform everyday tasks can have huge impacts on Scotland's environment.

Walking short distances rather than using the car, or being careful not to overfill the kettle are just two positive steps we can all take.

This butterfly represents the beauty and fragility of Scotland's environment. The motif will be utilised extensively by the Scottish Executive and its partners in their efforts to persuade people they can do a little to change a lot.

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