



S C O T T I S H
B I O D I V E R S I T Y
F O R U M



**Towards a strategy for Scotland's
biodiversity:**

**Developing Candidate Indicators of the
State of Scotland's Biodiversity**

February 2003
Paper 2003/6

Scottish Executive Environment Group

Towards a strategy for Scotland's biodiversity:

Developing Candidate Indicators of the State of
Scotland's Biodiversity

February 2003
Paper 2003/6

Towards a strategy for Scotland's biodiversity

Developing Candidate Indicators of the State of Scotland's Biodiversity

**prepared by the Action Plan & Science Group
of the Scottish Biodiversity Forum**

February 2003



**S C O T T I S H
B I O D I V E R S I T Y
F O R U M**

CONTACT

Further copies of this paper are available:

- On the Scottish Executive website at www.scotland.gov.uk/publications
- By post from:

Elaine McCall
SBF Secretariat
Scottish Executive Environment & Rural Affairs Department
Area 1-J (South)
Victoria Quay
Edinburgh
EH6 6QQ

E-mail: biodiversity@scotland.gsi.gov.uk

- From the Stationery Office Bookshop

CONTENTS

1	INTRODUCTION	1
1.1	WHAT ARE INDICATORS?	1
1.2	WHY ARE BIODIVERSITY INDICATORS IMPORTANT?	1
1.3	THE NEED FOR BIODIVERSITY INDICATORS IN SCOTLAND	2
2	OBJECTIVE	2
3	INFORMATION SOURCES	3
4	THE CANDIDATE INDICATORS	3
4.1	STATUS OF UK BIODIVERSITY ACTION PLAN PRIORITY SPECIES	5
4.2	STATUS OF UK BIODIVERSITY ACTION PLAN PRIORITY HABITATS	6
4.3	BREEDING BIRD INDEX	6
4.4	ABUNDANCE OF NON-BREEDING WATERBIRDS	7
4.5	ABUNDANCE OF SEABIRDS	8
4.6	VASCULAR PLANT DIVERSITY	9
4.7	WOODLAND TREE SPECIES DIVERSITY	10
4.8	TERRESTRIAL INSECT ABUNDANCE	11
4.9	PROPORTION OF NOTIFIED SPECIES POPULATIONS IN FAVOURABLE CONDITION ON PROTECTED SITES	11
4.10	PROPORTION OF NOTIFIED HABITATS IN FAVOURABLE CONDITION ON PROTECTED SITES	12
4.11	STATUS OF THE OTTER IN FRESH WATER HABITATS	13
4.12	SALMONID COUNTS	14
4.13	BENTHIC RIVERINE INVERTEBRATE DIVERSITY	14
4.14	ESTUARINE FISH SPECIES DIVERSITY	15
4.15	PROPORTION OF COMMERCIALY EXPLOITED FISH STOCK FISHED WITHIN SAFE LIMITS	15
5	DISCUSSION	16
5.1	TAXONOMIC AND ECOLOGICAL SCOPE	16
5.2	ACCURACY AND PRECISION	16
5.3	DISAGGREGATION	17
6	OVERVIEW AND CONCLUSIONS	18
7	ACKNOWLEDGEMENTS	18
8	REFERENCES	18

DEVELOPING CANDIDATE INDICATORS OF THE STATE OF SCOTLAND'S BIODIVERSITY

Jeremy Wilson, Ed Mackey, Scot Mathieson, Graham Saunders, Phil Shaw, Ian Walker, Allan Watt and Vicky West

on behalf of the Action Plan & Science Group of the Scottish Biodiversity Forum

1 Introduction

1.1 What are indicators?

Indicators are regularly monitored measures of pressures on the environment, current state of the environment and human responses to changes in that state. For example, the rate of extraction of peat from lowland peat bogs (a pressure indicator) affects the quality and extent of remaining bog habitats (a state indicator) and a Government response may be to encourage the production of peat alternatives (a response indicator). This 'pressure-state-response' model is now widely accepted as the basis for generating suites of environmental indicators to help focus attention on key issues within the very broad concept of sustainable development.

The UK now contributes to the development and application of indicators of sustainable development at all scales from global and European to national, regional and local. In a UK context, Government has now adopted a set of 150 indicators and 15 headline indicators published in *Quality of Life Counts: Indicators for a Strategy of Sustainable Development in the UK*¹. The distinction between a larger suite of general indicators and a smaller suite of 'headline' indicators reflects the need both to stimulate debate across a wide range of sectors of human activity with environmental impacts, and to identify key indicators with strong public resonance in order to focus attention on the three main pillars of sustainable development - social, economic and environmental.

1.2 Why are biodiversity indicators important?

Biodiversity (biological diversity at all scales from genes to species and to ecosystems) is a fundamental component of environmental state. Development is not sustainable if it results in unacceptable depletion in stock, or deterioration in condition of biodiversity, yet current environmental pressures (e.g. land use change, pollution, climate change and invasive species) threaten biodiversity as never before. Against this background, it is critical that any suite of indicators of sustainable development should include measures related to biodiversity state, the pressures upon it, and responses to biodiversity trends. *Quality of Life Counts* included six indicators that are measures of biodiversity state at the UK level; these are

- ◆ populations of wild birds,
- ◆ trends in plant diversity,
- ◆ number of native species at risk,

¹ www.sustainable-development.gov.uk/sustainable/quality99

- ◆ area of ancient semi-natural woodland in Great Britain,
- ◆ biodiversity in coastal and marine areas, and
- ◆ UK fish stocks fished within safe limits.

The first of these (populations of wild birds) is included amongst the 15 headline indicators in the UK Sustainable Development Strategy. Its direct impact on governmental policy is illustrated by the fact that DEFRA's Public Service Agreement targets² now include a commitment to "care for our living heritage and preserve natural diversity by reversing the decline in the number of farmland birds by 2020, as measured annually against underlying trends."

1.3 The need for biodiversity indicators in Scotland

Scotland is an economically, culturally, ecologically and politically distinctive country within the UK. Although the Scottish Parliament and Scottish Executive made a clear commitment to sustainable development at their inception, progress towards this goal must be quantified by the adoption of a full set of sustainability indicators (Dunion *et al.*, 2002). In partial fulfilment of this need, the Scottish Executive recently published *Meeting the Needs ... Priorities, Actions and Targets for Sustainable Development in Scotland*³. Although this report adopts only 24 indicators, it is recognised that the list will be reviewed in the light of emerging opinion. Currently, this set lists only one indicator that is considered a biodiversity indicator: a response indicator measuring the percentage of UK Biodiversity Action Plan species and habitats that are identified as stable or increasing in abundance/condition. A sea fisheries indicator (the proportion of commercially exploited fish stocks which are within safe biological limits) could be regarded as a second.

It is therefore essential to develop a wider suite of biodiversity indicators if we are adequately to assess the environmental sustainability of development in Scotland. In some respects, biodiversity indicators for Scotland may differ from those at the UK level, reflecting the need for indicators that highlight uniquely Scottish biodiversity resources. However, as far as is possible, indicators should be consistent with those reported on at UK and European levels, thus allowing Scotland's contribution to sustainable development to be measured in a consistent manner (Delbaere 1998; Delbaere & Pinborg, 2002).

2 Objective

The objective of this paper is to identify a suite of candidate indicators of the state of biodiversity in Scotland (i.e. a set of state indicators). In doing this, we have accepted a set of key 'tests' as the basis for recommending a list of candidate indicators of biodiversity state for Scotland. These key tests are that

- ◆ indicators should reflect the state of the wider ecosystems of which they are a part;
- ◆ indicators should have the potential to be responsive to the implementation of governmental policy;

² www.defra.gov.uk/corporate/busplan/01psa.htm

³ www.scotland.gov.uk/library5/rural/mtnsd.pdf

- ◆ indicators should be measured reliably on a regular (but not necessarily annual) basis, and be comparable with similar measures at larger geographical scales, e.g. UK and Europe; and
- ◆ indicators should have, or have the potential for, strong public resonance.

3 Information sources

This work is by no means the first contribution to the identification of biodiversity indicators for Scotland. Two existing reviews have formed the basis of this work.

First, in 2000, Scottish Natural Heritage (SNH) published, on behalf of the Scottish Environmental Indicators Group (SEIG), a candidate list of potential environmental indicators for Scotland (Singleton *et al.*, 2000). The report listed 14 biodiversity indicators, of which 11 were considered as indicators of biodiversity state. These were

- ◆ measures of net change in and interchange between broad land cover classes,
- ◆ trends in populations and ranges of native species,
- ◆ trends in the condition of designated sites,
- ◆ fragmentation of semi-natural habitats,
- ◆ changes in hedgerow length,
- ◆ potential viability and species composition of seed banks,
- ◆ *trends in populations of protected species,*
- ◆ *trends in native species at risk,*
- ◆ *trends in non-native species,*
- ◆ *trends in species where Scotland has a significant proportion of the global resource, and*
- ◆ *trends in migratory species.*

It is important to note that the last five of these indicators (in italics) were added during the final stages of report preparation. They are listed only in an appendix to the report and were not discussed in detail by SEIG. All five are effectively subsets of the second indicator in the list.

Second, SNH's publication *Natural Heritage Trends: Scotland 2001* (Mackey *et al.*, 2001) summarised changes over recent decades in the diversity, condition, management and exploitation of Scotland's natural heritage, and drew attention to emerging trends. Thus, although the publication was not designed to identify biodiversity indicators, it did seek to identify trends in measures of our biodiversity resource, and therefore provided a basis for identifying measures that currently satisfy the third criterion listed in section 2.

4 The candidate indicators

Fifteen candidate indicators of biodiversity state satisfy the criteria of ecosystem and policy relevance, data quality and public resonance. For each of these candidate indicators, listed in sections 4.1 to 4.15, this chapter provides a title, a definition, outline information on data source, availability, spatial resolution/coverage, and a comment on wider ecosystem and policy relevance. This information is summarised in Table 1.

Table 1. Summary of 15 candidate biodiversity indicators for Scotland.

Candidate indicator	Baseline	Reporting frequency (years)	Data resolution & coverage	Data source
Status of UK BAP species	2001	3	National summary	UK BAP Lead Partner reporting
Status of UK BAP habitats	2001	3	National summary	UK BAP Lead Partner Reporting
Breeding bird index	1994	1	Currently (2000) 244 1 km squares across Scotland	BTO/RSPB/JNCC Breeding Bird Survey
Abundance of non-breeding waterbirds	1960s	1	Freshwater and estuarine wetland sites across Scotland	BTO/WWT/RSPB/JNCC Wetland Birds Survey
Abundance of seabirds	1960s	15/1	Full seabird surveys across Scotland every 15 years, augmented by annual surveys of a sample of colonies	JNCC, RSPB, Shetland Oil Terminal Environmental Advisory Group
Vascular plant diversity	1990	8	195 1 km squares in 1990 and 203 in 1998, with 193 in common.	CEH/DEFRA Countryside Surveys
Woodland tree species diversity	1995-99	10	0.25% sample of Scottish woodland across 18,500 1ha plots.	National Inventory of Woodland and Trees (FC)
Terrestrial insect abundance	1960s	1	20 light traps and 22 butterfly monitoring transects throughout Scotland	Rothamsted Experimental Station (light traps) and CEH (Butterfly Monitoring Scheme)
Proportion of notified species populations in favourable condition on protected sites	2005	6	2,300 notified species populations across 1,129 SSSIs in Scotland, covering 12% of the land area	SNH
Proportion of habitat area in favourable condition on protected sites	2005	6	2,500 notified habitat areas across 1,129 SSSIs in Scotland, covering 12% of the land area	SNH
Otter status in freshwater habitats	1977	7	Checks for otter signs at 2,650-4,650 sites across Scotland	Vincent Wildlife Trust; future surveys arrangements under review by SNH
Salmonid counts	1990s	1	Coverage of all major salmonid river systems in Scotland	Scottish Fisheries Co-ordination centre

Candidate indicator	Baseline	Reporting frequency (years)	Data resolution & coverage	Data source
Benthic riverine invertebrate diversity	1970s	1	Sampling sites throughout Scotland's river network	SEPA
Estuarine fish species richness in major Firths (Forth, Clyde, Tay)	1980s	1	Data for Forth, Clyde and Tay; likely expansion under Water Framework Directive	SEPA
Proportion of commercially exploited fish stock fished within safe limits	1976	1	Reported by ICES fishing sectors, parts of four of which lie in Scottish waters	Advisory Committee on Fisheries Management

4.1 Status of UK Biodiversity Action Plan Priority species

Definition: The proportion of UK BAP priority species showing a net population or range recovery in Scotland.

Data source: Lead Partner reporting to the UK Biodiversity Partnership and Scottish Biodiversity Forum includes a qualitative assessment of whether a species is showing evidence of recovery (in range or population depending on intensity of monitoring), of remaining stable or of deteriorating. For some species (mainly birds), quantitative data indicating progress towards numerical BAP targets are also available.

Data availability and reporting frequency: First available in Scotland from Jones *et al.* (2001). In future, data will be available via triennial reporting by Lead Partners to the UK Biodiversity Partnership and Country Biodiversity Groups.

Spatial resolution and geographical coverage of data: summarised at a national and country level. Coordination of Local Biodiversity Action Plan (LBAP) reporting may in future allow local breakdown.

Relevance to wider ecosystems: BAP priority species are found amongst lower plants (32 per cent of total), higher plants (16 per cent), marine invertebrates (3 per cent), terrestrial invertebrates (25 per cent), and vertebrates (24 per cent). They thus represent a broad taxonomic spectrum in a wide range of terrestrial, freshwater and marine ecosystems.

Policy relevance: The BAP process is a key mechanism by which UK Government has set out to fulfil its commitments to conserve and enhance biological diversity within the UK as a signatory to the Convention on Biological Diversity. This is therefore a key indicator not only of biodiversity state but also of the success of the UK Government's biodiversity policy. In Scotland, the Scottish Executive has adopted this as a biodiversity indicator of sustainable development.

4.2 Status of UK Biodiversity Action Plan Priority habitats

Definition: The proportion of UK BAP priority habitats showing recovery in extent and/or condition in Scotland.

Data source: Lead Partner reporting to the UK Biodiversity Partnership and Scottish Biodiversity Forum allows a qualitative assessment of whether a habitat is showing evidence of recovery (in extent or condition), of remaining stable or of deteriorating.

Data availability and reporting frequency: First available in Scotland from Jones *et al.* (2001). In future, data will be available via triennial reporting by Lead Partners to the UK Biodiversity Partnership and Country Biodiversity Groups.

Spatial resolution and geographical coverage of data: Summarised at a national and country level. Co-ordination of LBAP reporting may in future allow more local breakdown.

Relevance to wider ecosystems: BAP priority habitats occur in a wide range of ecosystems including mountains, heaths and bogs (15 per cent), forests and woodlands (12 per cent), freshwater habitats (9 per cent), coastal and marine habitats (43 per cent), and farm and grasslands (21 per cent). They thus represent a broad spectrum in a wide range of terrestrial, freshwater and marine ecosystems.

Policy relevance: The BAP process is a key mechanism by which UK Government has set out to fulfil its commitments to conserve and enhance biological diversity within the UK as a signatory to the Convention on Biological Diversity. This is therefore a key indicator not only of biodiversity state but also of the success of the UK Government's biodiversity policy. In Scotland, the Scottish Executive has already adopted this as a biodiversity indicator of sustainable development.

4.3 Breeding Bird Index

Definition: A multi-species index of the abundance or range size of the more common species of native wild breeding birds from 1994 onwards.

Data sources: Breeding Bird Survey, British Trust for Ornithology (BTO), Royal Society for the Protection of Birds (RSPB) and Joint Nature Conservation Committee (JNCC), national surveys of scarce species, and national breeding bird atlases.

Data availability and reporting frequency: The Breeding Bird Survey (BBS) has taken place annually since 1994 and aims to provide annual monitoring of the abundance of widespread breeding birds in the UK. Annual abundance changes, and abundance changes over the full span of the survey are reported each year (e.g. see Noble *et al.*, 2001), with confidence limits, for all species where the sample of surveyed sites is adequate. Data for individual species are amalgamated to create a multi-species index that is now published at the UK level as one of the headline indicators of sustainable development in *Quality of Life Counts*. The methods used to calculate this indicator from the individual species trend information are outlined in the Technical Annex⁴. The same methods could be used to generate a multi-species indicator for Scotland and, if sufficient sites are surveyed, this could be broken down by region or habitat. This, however, would require a substantial increase in the

⁴ www.sustainable-development.gov.uk/sustainable/quality99/techanal/h13ta.htm

number of survey squares covered on an annual basis. For species not adequately covered by the BBS in Scotland, these data could be augmented with abundance data from periodic, targeted surveys (e.g. for upland birds) and with range-change data from national breeding bird atlases co-ordinated by BTO at approximately 20 year intervals, with the next planned for 2008-2011. An indicator presenting information from BBS and Atlas data sets has already been produced by RSPB for Wales and has been proposed as a biodiversity indicator to the Welsh Assembly. A similar document is also being drafted for Scotland by RSPB.

Spatial resolution and geographical coverage of data: The BBS uses a transect survey method on randomly selected 1 km squares. Each surveyor visits a square twice within the breeding season, undertaking two 1 km transects across their square and recording all birds seen or heard. Birds are recorded in distance bands in order to allow density estimations to be made. In the latest reported year (2000), 244 survey squares were covered in Scotland and trend information was reported for 66 species, although for eight of these caution is advised because of the small number of survey squares on which the species was recorded. Individual species surveys normally sample a stratified random sample of survey sites (often 1 km squares), usually at intervals of 5-10 years. The national breeding bird atlases (Sharrock, 1976; Gibbons *et al.*, 1993) provide data on distribution and (in the most recent atlas) abundance at a 10 km square resolution from data collected over four successive years.

Relevance to wider ecosystems: The 66 species whose Scottish BBS trends were reported in 2000 comprise birds of a wide variety of terrestrial and coastal habitats including farmland, urban areas, woodland, uplands and wetlands. Birds are good indicators of the broad condition of habitats because of their wide-ranging habitat distribution and their position at or close to the top of food chains. They are also relatively easy to survey systematically and attract a large body of volunteer observers.

Policy relevance: There is probably a stronger research knowledge of the impacts of human-induced ecological change on bird populations than exists for any other group. Effects of agriculture, forestry, urban development, human disturbance, climate change, coastal reclamation, and pollution are all well studied in the UK, thus allowing predictions to be made concerning likely bird population responses to policy change. Of 26 bird species identified in the UK Biodiversity Action Plan, 11 are included in the UK *Quality of Life Counts* indicator for populations of wild birds, and seven would currently be included in a similar indicator in Scotland (grey partridge, skylark, song thrush, spotted flycatcher, linnet, bullfinch and reed bunting).

4.4 Abundance of non-breeding waterbirds

Definition: An annual multi-species index of the non-breeding abundance of a range of wildfowl and wader species.

Data source: Wetland Bird Survey (BTO), Wildfowl & Wetlands Trust (WWT), RSPB, JNCC.

Data availability: The Wetland Bird Survey (WeBS) aims to identify population sizes, determine trends in numbers and distribution, and identify important sites for waterbirds in the UK. Core counts are made annually at c. 2,000 wetland sites, including all habitat types, but with estuaries and large, still waters predominating. In addition, monthly co-ordinated counts are made (mostly by volunteers) between

September and March. Data from other sources (e.g. goose roost counts) are also included. Annual abundance indices are produced for a wide range of species (see Musgrove *et al.*, 2001 for further details) with data runs extending back to the 1960s. Abundance indices are currently published separately for Great Britain and Northern Ireland, and no multi-species index is currently published as an overall biodiversity indicator. Further development of this indicator for Scotland would require the calculation of a multi-species index for individual countries within the UK (see, for example, Atkinson *et al.*, 2000), and consideration of whether this should be broken down by species group (e.g. ducks, geese, waders) and/or by habitat (e.g. estuarine vs inland water).

Spatial resolution and geographical coverage of data: WeBS sites are selected and their boundaries defined by observers in conjunction with national WeBS organisers. Of 248 'important' WeBS sites identified by Musgrove *et al.* (2001) (i.e. those hosting internationally important populations or populations of regional importance in areas with few wetlands), 81 are in Scotland. This includes good coverage of all of the major estuarine firths in Scotland (Cromarty, Forth, Tay, Clyde and Solway). These data were sufficient for Atkinson *et al.* (2000) to publish long-term trend summaries for 18 wildfowl species and 11 of 18 wader species wintering in Scotland.

Relevance to wider ecosystems: The UK, including Scotland, is of outstanding importance for waterbirds. It lies on some of the major migratory flyways for Arctic-nesting species, and large numbers of these species are attracted either on migration or to overwinter by a combination of mild climate and extensive areas of wetland, especially invertebrate-rich estuaries. Over half a million waders and wildfowl were counted at Scottish sites in the winter of 1998/99. Although waterbird populations on these sites could be an indicator of the wider condition of coastal and estuarine habitats, the migratory nature of most species can make it difficult to distinguish effects of ecological change at those sites from effects of change on breeding grounds elsewhere. However, the importance of many of these bird populations in an international context suggests that an indicator of their trend is justified in its own right. For example, WeBS sites of international importance exist in Scotland for 20 species (great northern diver, Slavonian grebe, whooper swan, pink-footed goose, Greenland white-fronted goose, greylag goose, barnacle goose, shelduck, wigeon, gadwall, pintail, shoveler, oystercatcher, ringed plover, knot, dunlin, bar-tailed godwit, curlew, redshank, turnstone).

Policy relevance: International legislation (e.g. 'Ramsar' Convention on Wetlands of International Importance especially as Waterfowl Habitat, EU Birds Directive and EU Habitats and Species Directive) requires designation of important sites for legal protection. The UK has also ratified the Agreement on the Conservation of African-Eurasian Migratory waterbirds (AEWA) of the Bonn Convention on the Conservation of Migratory Species of Wild Animals. This requires the identification, protection and appropriate management of sites and habitats for migratory waterbirds, and explicit in the agreement is that adequate monitoring programmes are in place to fulfil these objectives.

4.5 Abundance of seabirds

Definition: An annual multi-species index of the breeding abundance of seabirds.

Data source: Full seabird surveys, augmented by annual surveys of a sample of seabird colonies (JNCC, RSPB, Shetland Oil Terminal Environmental Advisory Group).

Data availability and reporting frequency: Full seabird surveys have been undertaken approximately every 15 years (1969-1970, 1985-1987, 2000-2002), augmented by annual surveys of a sample of seabird colonies under the JNCC Seabird Monitoring Programme (e.g. Upton *et al.*, 2000). No multi-species index is currently published. Development of a seabird indicator for Scotland therefore requires development of methods for calculation of a multi-species index for individual countries within the UK that combines data from annual sample surveys with the occasional (approximately every 15 years) full surveys.

Spatial resolution and geographical coverage: Data are collected at a range of colonies. Annual JNCC data collection focuses on species such as fulmar, shag, kittiwake and the auks, for which changes in populations or breeding success may provide evidence of more general changes in the marine environment. Key sites for this monitoring include several sites in Scotland (Isle of May, Fair Isle, Canna, Orkney Mainland, St. Kilda, Grampian coast). RSPB monitoring focuses on seabird colonies on its network of reserves, many of which are in Scotland. In Shetland, Aberdeen University, under contract to SOTEAG, monitor fulmar, guillemot and razorbill annually on sample plots, with more complete counts of shag, kittiwake and black guillemot every two or more years. Despite this complex of data sources and survey protocols, population trend information is published at a regional level for several species (though excluding more mobile species such as gulls, Arctic terns and common terns, for which the annual sample of pairs monitored is considered too small for reliable trend assessment). Any multi-species indicator derived from this data source could therefore be reported at a national level, but with the potential for a breakdown to the regional level.

Relevance to wider ecosystems: Scotland's breeding seabird populations are of international importance, accounting for over half of the global population of great skuas, northern gannets (and probably storm petrels), over one-third of Europe's Manx shearwaters, and at least 10 per cent of the European populations of at least ten other species (Lloyd *et al.*, 1991). Seabird populations are thus an important component of marine and coastal ecosystems in their own right, but those species high on the food chain feeding primarily or solely on other marine organisms are good indicators of changes in the marine environment as a whole.

Policy relevance: Commercial fisheries are closely linked to seabird population performance. The sand eel fishery is known to have had a substantial, negative impact on food availability for species such as Arctic tern, whilst monofilament drift nets were considered the main cause of unnatural mortality of auks during the 1980s. On the other hand, other species (e.g. fulmar) have benefited from commercial fishing discards. Human introduction of non-native predators (e.g. rats, cats, ferrets, mink) can have a severe impact on breeding success and adult survival rates. Both chronic oil pollution from illegal discharges by vessels, and occasional accidental spills can have impacts on seabird populations, but the former are more likely to cause long-term population losses.

4.6 Vascular plant diversity

Definition: Mean count of vascular plant species per 1 km square.

Data source: Countryside Survey, Department of Environment, Food & Rural Affairs (DEFRA); Centre for Ecology and Hydrology (CEH).

Data availability and reporting frequency: Countryside Surveys of 1990 and 1998 (Haines-Young *et al.*, 2000). Use as an indicator relies on future Countryside Surveys at regular 8-10 year intervals.

Spatial resolution and geographical coverage of data: 195 1 km squares in 1990 and 203 in 1998, with 193 common to both surveys, allowing estimation of change. Sample squares are selected randomly from within 16 land classes to give representative coverage of Scotland. The overall indicator of plant diversity across the full sample of squares could be broken down to give measures of trend in diversity within each of the broad habitat types recognised by the Countryside Survey.

Relevance to wider ecosystems: Being based on stratified sampling across 16 land classes, this indicator will be an important measure of biodiversity at the primary producer level across terrestrial ecosystems within Scotland. Changes in plant diversity are sensitive indicators of a wide range of anthropogenic changes to different habitats including agrochemical use on farmland, effects of atmospheric deposition on fertility and pH, grazing pressure and muirburn.

Policy relevance: Likely to be a sensitive indicator of biodiversity response to government policies on agriculture, forestry, atmospheric emissions and management of water. At the UK level, this indicator has been adopted as one of the six *Quality of Life Counts* indicators of biodiversity state.

4.7 Woodland tree species diversity

Definition: Plot species richness in woodlands. Comparison of broad-leaved, mixed and conifer woodland (by main tree species, by age).

Data source: Square structure assessment from the National Inventory of Woodlands and Trees (NIWT) (Forestry Commission).

Data availability and reporting frequency: NIWT 1995-1999. Inventory to be repeated every 10 years.

Spatial resolution and geographical coverage of data: 0.25 per cent of woodland area in Scotland. One per cent of woodland in Scotland was surveyed in 1 ha plots. The structure assessment was carried out in the south-west quarter of each plot (approx 18,500 plots in Scotland). Up to five species recorded at each of five vertical layers (upper canopy, lower canopy, shrub, field and ground layer).

Relevance to wider ecosystems: As an indicator of woodland, this indicator concerns the diversity of the tree flora in 17 per cent of Scotland's land area. The species richness of woodland is of interest in its own right, particularly that of native woodland, since an increase in the diversity of the tree species will lead to increases in the associated animal diversity, especially of invertebrates.

Policy relevance: The Scottish Forestry Strategy includes the conservation of semi-natural woodland and enhancing the biodiversity of other woodlands and forest. On a UK scale, the UK Forestry Standard also encourages the increasing diversity of tree species and use of open space, which should lead to a greater diversity of the

woodland environment. At the UK level, this indicator is being considered for one of the UK Indicators of Sustainable Forestry.

4.8 Terrestrial insect abundance

Definition: Annual abundance indices of butterflies, and nocturnally active insects attracted to light traps.

Data source: Rothamsted Insect Survey (RIS) and Butterfly Monitoring Scheme (BMS) organised by CEH.

Data availability and reporting frequency: The RIS currently runs light traps of standard design and on every night of the year. The larger Lepidoptera are counted, providing an unparalleled data set that permits monitoring of the abundance trends of a wide range of species characteristic of a range of different ecosystems and habitats (Woiwod & Harrington, 1994). There is scope to increase the range of taxa counted to include some dipteran families, Trichoptera and microlepidoptera that are also attracted to light (Young & Rotheray, 1997). The BMS is based on transects walked weekly through the butterfly flying season (Pollard, 1977). Neither the RIS nor the BMS data are currently used to generate multi-species indicators of abundance, and some analytical work would need to be carried out to develop this.

Spatial resolution and geographical coverage: The RIS currently has 20 light trap sites scattered across Scotland, with data runs extending back to the 1960s in a few cases (M. Young, pers. comm.). The BMS currently has 22 survey transects with data extending back to the late 1970s in a few cases, and data from a further three Environmental Change Network sites potentially available from the mid-1990s. In both cases, the quality of these data sets as the basis for an indicator of terrestrial insect abundance would be enhanced by active encouragement of the establishment of new survey sites giving a wider geographic cover and representing the full spectrum of land use types.

Relevance to wider ecosystems: Lepidoptera and other flying insects occupy all terrestrial ecosystems in Scotland, and are known to be sensitive indicators of a wide variety of anthropogenic influences (Woiwod & Harrington, 1994). This is particularly so because of the rapidity of their population responses to environmental influences relative to the response of longer-lived plants and vertebrates.

Policy relevance: Insects are sensitive indicators of environmental change in a wide variety of habitats subject to policy influence (e.g. agriculture and forestry), as well as to many anthropogenic processes amenable to policy influence (e.g. agrochemical use, air pollution). Four species of butterfly and several macro-moths found in Scotland are UK BAP priority species.

4.9 Proportion of notified species populations in favourable condition on protected sites

Definition: The proportion of notified species populations considered to be in favourable condition on SSSIs. A 'notified species population' is the occurrence of a species on an SSSI on which it meets the site selection criteria, and is listed in the citation for that site.

Data source: SNH.

Data availability and reporting frequency: The statutory agencies have agreed to assess the condition of all notified interests on SSSIs at least once every six years, the first report being due in 2005. This will show the number of notified interests deemed to be in favourable or unfavourable condition or destroyed. In successive reporting cycles these reporting categories will be expanded to show the direction of change, e.g. 'unfavourable - improving', 'unfavourable - declining'. Since in the majority of cases population size is unknown, all populations are likely to be treated equally for reporting purposes.

Spatial resolution and geographical coverage: There are 1,129 biological and 'mixed' SSSIs in Scotland, supporting over 2,300 notified species populations. SSSIs are widely distributed, and cover over 12 per cent of the land area of Scotland.

Possible biases: Many of the species on which this indicator is based are nationally scarce, or dependent on very specific habitat conditions, and may therefore show a heightened sensitivity to change. Also, by virtue of their protected status, trends in notified species populations may not be representative of populations of the same species in the wider countryside. Taxonomically, the sample shows a distinct bias in favour of vertebrate (especially bird) and vascular plant species.

Relevance to wider ecosystems: Species for which SSSIs have been designated span a wide range of taxonomic groups and are integral to most or all of Scotland's terrestrial and freshwater ecosystems.

Policy relevance: Under the Wildlife & Countryside Act 1981, SSSI notification and management is the principal mechanism available to statutory conservation agencies for safeguarding important areas for wild flora and fauna. The SSSI series also underpins sites designated under the EU directives and through international agreements. Thus, some 37 per cent of SSSI notified species populations have also been, or will be, notified under the Wild Birds Directive, Habitats Directive or the Ramsar Convention.

4.10 Proportion of notified habitats in favourable condition on protected sites

Definition: The proportion of notified habitats considered to be in favourable condition on SSSIs. A 'notified habitat' is the occurrence of a habitat on an SSSI on which it meets the site selection criteria, and is listed in the citation for that site.

Data source: SNH.

Data availability and reporting frequency: The statutory agencies have agreed to assess the condition of all notified interests on SSSIs at least once every six years, the first report being due in 2005. This will show the number of notified interests deemed to be in favourable or unfavourable condition or destroyed. In subsequent reporting cycles these reporting categories will be expanded to show the direction of change, e.g. 'unfavourable - improving', 'unfavourable - declining'. It is also likely that subsequent reports will show the total area of notified habitats assigned to each condition category, providing a more meaningful appraisal. Area measurements are not currently available, however.

Spatial resolution and geographical coverage: There are 1,129 biological and 'mixed' SSSIs in Scotland, supporting over 2,500 notified habitats. SSSIs are widely distributed, covering over 12 per cent of the land area of Scotland.

Possible biases: Many of the habitats on which this indicator is based are nationally scarce, and may show a heightened sensitivity to change. However, by virtue of their protected status and management, any change in the condition of notified habitats on SSSIs may not be representative of trends in the wider countryside.

Relevance to wider ecosystems: Notified habitats on SSSIs span the full spectrum of inter-tidal, terrestrial and freshwater ecosystems.

Policy relevance: Under the Wildlife & Countryside Act 1981, SSSI notification and management is the principal statutory means available to government conservation agencies for safeguarding important areas for wild flora and fauna. The SSSI series also underpins sites designated under the EU directives and through international agreements. Thus, some 30 per cent of SSSI notified habitats have also been, or will be, notified under the Habitats Directive or the Ramsar Convention.

4.11 Status of the otter in fresh water habitats

Definition: The percentage of freshwater sites at which otter signs are detected in Scotland.

Data source: Extensive, systematic otter surveys were conducted in Scotland during 1977-79, 1984-85 and 1991-94 by J. & R. Green, on behalf of the Vincent Wildlife Trust (VWT).

Data availability and reporting frequency: VWT has no plans to continue with the survey programme in Scotland. SNH has therefore commissioned a statistical review of the three surveys to identify options for refining the methodology and reducing the sample size, with minimal adverse impact on data quality. The cost of future surveys is likely to remain high, however, and might best be met by a consortium of organisations.

Spatial resolution and geographical coverage: Past surveys have involved checking for signs of otters at 2,650-4,636 sites, distributed over most of Scotland. These have yielded estimates of range size, and a crude measure of population density, based on the percentage of sites occupied. Changes in percentage occupancy may be calculated for all sites covered during successive surveys. The number and distribution of survey sites is such that a regional breakdown of occupancy rates could be provided.

Possible biases: The methods used are relatively straightforward and easily repeatable, but may be sensitive to variation in observer ability; all three surveys to date have been conducted by the same two observers.

Relevance to wider ecosystems: Extensive river and loch systems are required to support self-sustaining populations of otters, whose presence is an indication of low pollution levels and a plentiful supply of fish and other prey items. The species declined over much of its European range in the latter half of the 20th century. Pressures include habitat fragmentation, reduced food supply, disturbance, persecution, acidification and other pollution effects. A sudden decline during the 1950s-60s has been

attributed to a rise in levels of persistent organochlorine pesticides and PCBs in the freshwater environment.

Policy relevance: The otter is a BAP priority species and is listed in Annex II of the Habitats Directive. Its role in convincing the public of the need to control environmentally damaging pollution illustrates its potential as a flagship species.

4.12 Salmonid counts

Definition: Annual estimated population size statistics for salmon and sea trout in Scotland.

Data source: District Fishery Boards, Fishery Trusts and Freshwater Laboratory Aberdeen.

Data availability and reporting frequency: Co-ordinated by Scottish Fisheries Co-ordination Centre.

Spatial resolution and geographical coverage of data: Extensive coverage of major salmonid river systems throughout Scotland.

Relevance to wider ecosystems: Integrates estuarine and riverine water quality, fish habitat quality in rivers, fishing pressure and climate change effects on salmonids at sea.

Policy relevance: River fish populations need to be protected and restored for Water Framework Directive purposes. A number of salmon rivers are candidate Special Areas of Conservation (EU Habitats Directive).

4.13 Benthic riverine invertebrate diversity

Definition: Annual data on biological diversity of invertebrates in Scotland's running waters.

Data source: Scottish Environment Protection Agency (SEPA) aquatic monitoring programme.

Data availability and reporting frequency: Held by SEPA, publicly available.

Spatial resolution and geographical coverage of data: Extensive network of biological sampling sites throughout Scotland's river network.

Relevance to wider ecosystems: Integrates effects of water quality, habitat quality and flow regime, along with airborne deposition of pollutants (acidification, eutrophication), land use and water use in each river catchment. May be disaggregated by geographical location, river type, altitude, etc.

Policy relevance: Major objective under Water Framework Directive (WFD). Links to Urban Waste Water Directive and Nitrate Directive. Most Natura 2000 (candidate Special Areas of Conservation) rivers are included in network.

4.14 Estuarine fish species diversity

Definition: Annually aggregated data on diversity and abundance of fish in major Scottish estuaries.

Data source: SEPA environmental monitoring programme.

Data availability and reporting frequency: Held by SEPA, the data are accessible.

Spatial resolution and geographical coverage of data: Data from mid-1980s to present for Clyde and Forth. There is an ongoing commitment to continue collection. Data are also held for the Tay, but the number of estuaries is likely to be extended for WFD purposes.

Relevance to wider ecosystems: Link to riverine fish populations and marine commercial stocks. Integrates effects of water quality and habitat structure. Links to fish-eating bird and mammal populations.

Policy relevance: Health of estuarine fish assemblages is an ecological objective for Scottish estuarine waters under the Water Framework Directive. Healthy fish populations are also required to support a number of intertidal Special Protection Areas and marine Special Areas of Conservation in estuaries.

4.15 Proportion of commercially exploited fish stock fished within safe limits

Definition: Proportion of commercially exploited fish stock fished within safe limits. This could be subdivided into 'Continental shelf species' and 'deep-water' species.

Data source: International Council for the Exploration of the Seas (ICES).

Data availability and reporting frequency: The ICES Advisory Committee on Fisheries Management (ACFM) produce a comprehensive advice document which is the basis for calculating EU member state fish quotas. Produced annually, the report indicates which species are considered outside biological limits, together with all of the available supporting data.

Spatial resolution and geographical coverage of data: Reporting is done on the basis of 'ICES Fishing Areas' and individual stocks may be contained within one or more of these areas. The Scottish North Sea sector is within ICES Fishing Areas IVa and IVb, while the west of Scotland Atlantic sector corresponds to Area VIa and a small part of VIIa (Irish Sea). Where stocks of a single species are assessed separately by ICES areas the status of the individual stock must be stated separately. This is because it is possible (although unusual) for one species to be outside safe biological limits in, for example, the North Sea while a west of Scotland stock may be assessed as healthy.

Relevance to wider ecosystems: The effects of past and present levels of fishing intensity are still the subject of much debate. There is, however, an overwhelming consensus of scientific opinion that fishing has, and continues to have, an impact on the entire north-eastern Atlantic region and may even be the main ecological structuring force on the benthos in areas of intense exploitation. Estimates for the North Sea suggest that a quarter of the total biomass of exploitable fish species is presently removed by people every year. Some stocks, such as cod, are now considered to be in danger of

collapse, a condition similar to that of the Canadian cod fishery of the early 1990s and from which there have been very few signs of recovery. Recent research has also suggested that a continuous removal of predatory fish such as cod may be implicated in the observed increases in the number of juveniles and smaller species of both exploited and non-target groups.

Policy relevance: The conservation of commercial fish stocks is of prominent international importance and Scottish waters constitute one of the primary European fishing areas. The fishing industry has historically been an important feature of Scottish culture and trade and the commercial exploitation of fish and shellfish stocks remain a major contributor to Scotland's economy. Currently, there is a revision of the EU Common Fisheries Policy (CFP) in progress and it is likely that recommendations will include large reductions in catches and a greater attention to wider ecological considerations. Separate UK BAP Grouped Species Action Plans have been published for both commercially-exploited Continental shelf fish and deep-water species.

5 Discussion

Adoption of the above indicator set would be a necessary and desirable, but not sufficient, step towards monitoring of trends in Scotland's biodiversity resource. For the indicator set to be fully fit for purpose, ongoing work and resourcing will be needed to

- ◆ identify the potential for improving the taxonomic and ecological scope of the indicator set, and develop new indicators, especially socio-economic ones, where possible;
- ◆ improve the statistical accuracy, precision and representativeness of individual indicators through improvements in geographical coverage, sampling intensity and frequency of reporting; and
- ◆ where data quality permits, develop methods for disaggregating indicator trends by smaller geographical regions (e.g. LBAP areas).

5.1 Taxonomic and ecological scope

The choice of indicators made above has been dictated almost entirely by the availability of data sets that satisfy the key test of data quality. For many taxonomic groups, adequate data on species distributions and abundances simply do not exist at present. For example, Scotland supports 58 per cent of Europe's bryophyte species diversity (Mackey *et al.*, 2001) making this one of the taxa for which Scotland's resource is most important at a European scale. Yet, no regularly reportable indicator for bryophytes as a group is possible given currently available data. Similarly, it is not yet possible to construct indicators to report on the biodiversity within soil ecosystems, or to monitor trends in genetic diversity within species. In an ideal world, indicators for all of these aspects of Scottish biodiversity should be reported.

5.2 Accuracy and precision

For indicators to be useful, it must be possible to assign a statistical probability to the changing values between reporting episodes so that we can confidently say whether the indicator is increasing, decreasing or stable. Even within the 15 candidate

indicators discussed above, data quality varies, and many would benefit from the greater comprehensiveness and statistical precision that would be provided by increases in the number of sampling sites and/or frequency of reporting. For example, the Breeding Bird Survey in Scotland reported trend information for 66 species in 2000. This compares with 100 species in England; the difference being largely a function of the larger number of sample survey squares in England, and that is itself a function of the higher observer density. Similarly, the Butterfly Monitoring Scheme and Rothamsted Insect Survey are currently restricted each to approximately 20 sites in Scotland, thus greatly limiting their geographic coverage and representation of major land use types.

In addition, in many cases, further consideration needs to be given to the influence of potential biases in current data sets, and to data analysis that will be required before an indicator can be reported formally. In the case of birds, for example, should we develop methods to combine annual survey information (e.g. BBS) and data collected with longer periodicity (e.g. national surveys of single species and Atlas surveys) in order to present a single index, or should these data sources be presented independently? Issues surrounding combining both abundance and geographical range in a single index are raised by Usher (2002).

5.3 Disaggregation

Several of the indicators proposed in the list in Table 1 include the theoretical possibility of disaggregation to allow reporting, for example, by environmental pressure, by habitat or by geographical region within Scotland. Disaggregation by habitat (farmland, woodland) is already a feature of the *Quality of Life Counts* breeding bird indicator at UK level, and a similar approach (perhaps with different main habitat categories) could also be adopted in Scotland.

Disaggregation by environmental pressure (e.g. climate change) may require pooling data from various species and habitats within the existing indicator set to create a new indicator. For example, it might be possible to draw on data for certain birds, butterflies, fish and benthic invertebrates to produce an indicator based on species considered to be highly sensitive to climate change trends.

Geographical disaggregation within the BAP process is most likely to be reflected in the desire for a framework for reporting biodiversity indicators within LBAP areas. Currently, no such framework exists in Scotland, although some local authorities have adopted biodiversity indicators, and in England candidate lists of biodiversity indicators have been published for local authorities to consider and select from⁵.

In all of these cases, further work is needed to consider the feasibility of such approaches since disaggregation carries the penalty of reduced sample size, and hence reduced statistical precision. For example, even for a relatively well-monitored group such as birds, the Breeding Bird Survey in Scotland is unlikely in the foreseeable future to include enough survey plots to allow adequate reporting of population trends within individual LBAP areas.

⁵ www.local-pi-library.gov.uk/index.shtml

6 Overview and Conclusions

Any consideration of the status of Scotland's biodiversity involves questions about what is happening now, and any attempt to put that status in its proper historical context involves questions about what has happened in the past. To have the answers to such questions, in a complex world, requires us to adopt indicators and support the data collection that underpins them. Just like an indicator of the value of stocks and shares, or an indicator of the cost of living, the indicator tells us about the broad direction in which we are moving. Not everything will be moving in the same direction or at the same speed as the indicator. But an indicator does tell us, on balance, if things are moving in the direction that we want, and hence if our actions and policies are being successful. Biodiversity as a concept is so complex that there is no one indicator that could tell us this broad pattern of movement; instead we shall need a suite of indicators. Here, we have provided 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.

7 Acknowledgements

The authors would like to thank all the members of the Action Plan and Science Group for their time and effort in improving this paper throughout its preparation. In particular, Michael Usher contributed to the final section, and Mark Young assisted with discussion of statistical aspects of the reporting of biodiversity indicators.

8 References

- Atkinson, P.W., Austin, G.E., Burton, N.H.K., Musgrove, A.J., Pollitt, M. & Rehfisch, M.M. (2000). WeBS Alerts 1998/9: Changes in Numbers of Wintering waterbirds in the United Kingdom at National, County and Special Protection Area (SPA) Scales. *British Trust for Ornithology Research Report* 239.
- Delbaere, B.C.W. (ed.) (1998). *Facts & Figures on Europe's Biodiversity: State and Trends 1998-1999*. European Centre for Nature Conservation, Tilburg.
- Delbaere, B. & Pinborg, U. (2002). Moving towards implementing biodiversity indicators and monitoring: case studies from Europe. Unpublished background paper to side-event at the 6th Conference of the Parties of the Convention on Biological Diversity.
- Dunion, K., Holbrook, J. & Sargeant, B. (2002). The role of indicators in reporting on the state of Scotland and its environment. In *The State of Scotland's Environment and Natural Heritage*, ed. by M.B. Usher, E.C. Mackey & J.C. Curran. The Stationery Office, Edinburgh. pp. 289-303.
- Gibbons, D.W., Reid, J.B. & Chapman, R.A. (1993). *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991*. Poyser, London.
- Green, R. & Green, J. (1997). *Otter Survey of Scotland 1991-1994*. The Vincent Wildlife Trust, London.
- Haines-Young, R.H., Barr, C.J., Black, H.I.J., Briggs, D.J., Bunce, R.G.H., Clarke, R.T., Cooper, A., Dawson, F.H., Firbank, L.G., Fuller, R.M., Furse, M.T., Gillespie, M.K., Hill, R., Hornung, M., Howard, D.C., McCann, T., Morecroft, M.D.,

- Petit, S., Sier, A.R.J., Smart, S.M., Smith, G.M., Stott, A.P., Stuart, R.C. & Watkins, J.W. (2000). *Accounting for Nature: Assessing Habitats in the UK Countryside*. Department of the Environment, Transport and the Regions, London.
- Jones, A.T., Bain, C., Easton, C. & Ramsay, J. (2001). Report of Working Group into Analysis of Lead Partner Reporting. Unpublished report.
- Lloyd, C., Tasker, M.L. & Partridge, K. (1991). *The Status of Seabirds in Britain and Ireland*. Poyser, London.
- Mackey, E.C., Shaw, P., Holbrook, J., Shewry, M.C., Saunders, G., Hall, J. & Ellis, N.E. (2001). *Natural Heritage Trends: Scotland 2001*. Scottish Natural Heritage, Perth.
- Musgrove, A., Pollitt, M., Hall, C., Hearn, R., Holloway, S., Marshall, P., Robinson, J. & Cranswick, P. (2001). *The Wetland Bird Survey 1999-2000 Wildfowl and Wader Counts*. BTO/WWT/RSPB/JNCC, Slimbridge.
- Noble, D.G., Raven, M.J. & Baillie, S.R. (2001). The Breeding Bird Survey 2000. *BTO Research Report 265*.
- Pollard, E. (1977). A method for assessing changes in the abundance of butterflies. *Biological Conservation*, **12**, 115-134.
- Sharrock, J.T.R. (1976). *The Status of Breeding Birds in Britain and Ireland*. Poyser, Berkhamsted.
- Singleton, P., Holbrook, J., Sargent, B. & Mackey, E.C. (2000). Potential Environmental Indicators for Scotland. *Scottish Natural Heritage Review* No. 126.
- Upton, A.J., Pickerell, G. & Heubeck, M. (2000). *Seabird Numbers and Breeding Success in Britain and Ireland, 1999*. Joint Nature Conservation Committee, Peterborough.
- Usher, M.B. (2002). Scotland's biodiversity: trends, changing perceptions and planning for action. In *The State of Scotland's Environment and Natural Heritage*, ed. by M.B. Usher, E.C. Mackey & J.C. Curran. The Stationery Office, Edinburgh. pp. 257-269.
- Woiwod, I.P. & Harrington, R. (1994). Flying in the face of change: the Rothamsted Insect Survey. In *Long-term Experiments in Agricultural and Ecological Sciences*, ed. by R.A. Leigh & A.E. Johnston. CAB International, London. pp. 212-223.
- Young, M.R. & Rotheray, G.E. (1997). Insect Biodiversity in Scotland. In *Biodiversity in Scotland: Status, Trends and Initiatives*, ed. by L.V. Fleming, A.C. Newton, J.A. Vickery & M.B. Usher. The Stationery Office, Edinburgh. pp. 104-116.

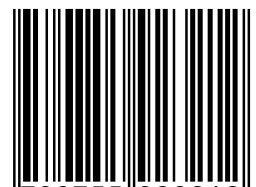


Small changes in the way we perform everyday tasks can have huge impacts on Scotland's environment.

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.

ISBN 0-7559-2321-9



9 780755 923212