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MONITORING BIODIVERSITY IN SCANDINAVIA: LESSONS FOR AUSTRALIAN FOREST MANAGEMENT

ROD KAVANAGH

2007 GOTTSTEIN FELLOWSHIP REPORT

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Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

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Dr Rod Kavanagh is a Principal Research Scientist and Programme Leader for the Forest Biodiversity and Ecology Research Group at the Forest Science Centre of the NSW Department of Primary Industries in Sydney. His research interests include studies of the ecology of a range of Australian forest-dependent vertebrate fauna, and experiments documenting the responses of many species to logging and fire. Throughout this work, he has focussed upon understanding the patterns and processes underlying the distribution and abundance of these species and in developing recommendations for minimising any adverse impacts caused by commercial forestry operations. He is currently working on sampling designs and methodologies for implementing a State-wide biodiversity monitoring programme to assess long-term changes in species abundance. Other research interests include work to evaluate the role of eucalypt plantations in restoring biodiversity in agricultural landscapes.

Executive Summary

Dr Rod Kavanagh was the recipient of a 2007 Gottstein Fellowship. This award provided an opportunity to investigate current developments in biodiversity monitoring in northern Europe and also to obtain an international perspective about the prospects for using species-based assessments as indicators of ecologically-sustainable forest management in Australia.

The award was used to fund travel to Sweden, Finland, Norway and Belarus. The primary host institution was the Swedish University of Agricultural Sciences at both the School for Forest Engineers campus at Skinnskatteberg and the nearby Grimsö Wildlife Research Station. The study tour itinerary and activities, as well as a list of key contacts and their affiliations, is presented in the Appendix to this report.

Investigations were made of all national biodiversity monitoring programmes in Sweden and Finland and a good insight was obtained about developments in the other two countries. These investigations included detailed meetings with senior agency policy and planning managers, monitoring programme managers and key permanent staff, site inspections, observations of field crews taking measurements, gathering of programme handbooks and reports, and supplementary internet searches to determine the degree of web-based documentation and reporting of monitoring programme outcomes.

Visits were made to several institutions and scientists responsible for conducting ecological research used to underpin the development of biodiversity monitoring programmes and to investigate the effects of forestry management practices on biodiversity. Special focus was given to current research being done on species groups (e.g. woodpeckers, owls, flying squirrels) having potential to serve as indicators of the effects of forestry practices on a broader range of species.

Every opportunity was taken to learn about the natural history and ecological characteristics of the forests of northern Europe and their associated fauna. This included participation in standardised fauna surveys in Belarus and field assistance in ecological research projects in Finland. Observations were made of current forestry management practices and nature conservation in all four countries.

In this report, I examine the policy framework that serves as the principal driver for biodiversity monitoring in Europe. I then summarise current thinking and approaches towards the implementation of biodiversity monitoring in an international context. I next make a series of broad comparisons between the four European countries visited and Australia in terms of their geo-political and ecological characteristics. Next, I briefly review the national biodiversity monitoring programmes of Sweden, Finland and Belarus. This is followed by an analysis of the strengths and weaknesses of these monitoring programmes in the context of their relevance to Australia. I conclude with some lessons learned that will assist the development and implementation of biodiversity monitoring programmes in Australia.

A summary of the key issues resulting from my combined experiences in this project, and which should be taken into account in Australia, include the following points.

1. There is little doubt that species and habitat monitoring is seen as an important priority internationally and as an integral component of good forest management. There is a strong focus on comprehensive, nation-wide monitoring programmes because of the need to report on national objectives and international commitments.
2. The sampling design used by most biodiversity monitoring programmes in Sweden and Finland was systematic sampling based on the national mapping grid. The spacing between sampling (grid) points was 25 km in several programmes, and a 10 x 10 km grid cell was the basis for monitoring biodiversity in others.
3. Biodiversity monitoring programmes are likely to be most effective if habitat variables, species occupancy and remotely-sensed data are collected from the same sites. This requires that sampling be undertaken within a set of nested plots which are appropriate for the species or other attributes being measured.
4. Biodiversity monitoring programmes should take a multi-species approach, recording all species detected using a standard set of survey protocols for a wide range of taxonomic groups. While the potential role of indicator species, and the efficiencies of recording a smaller sub-set of species, were recognised, few programmes in Sweden and Finland were restricted to recording only these species.
5. Biodiversity monitoring programmes should be designed so that they survey a large number of sites which are re-surveyed annually or within five years.
6. Species detectability issues need to be considered and this will require that sites are re-visited during the same sampling period.
7. Monitoring programmes are most likely to succeed if the programme goals, assumptions, survey designs and procedures are transparent and when progressive results are made available to the public in both summarised and raw data formats for independent analysis and interpretation.
8. Biodiversity monitoring programmes require strong government and institutional support to be effective. Monitoring programmes are expensive, long-term commitments. Adequate resources are needed for project management and to enable prompt, rigorous analysis and reporting of the data collected so that monitoring can be fine-tuned and managers can receive essential and timely feedback about their actions.
9. Biodiversity monitoring requires good communications and collaborations between scientists, managers, policy makers and the community.
10. Finally, the biodiversity monitoring programme underway in Alberta, Canada – while not visited in this study - incorporates many of the best aspects of the monitoring programmes observed in northern Europe. The Canadian programme has been operational for more than 10 years, including an extensive period of development and implementation, and this programme should also be given due consideration in Australia.

a)

b)

c)

d)

e)

f)

Photos: Sweden.

a) Mature Scots Pine forest
b) Mature Norway Spruce forest
c) Great Spotted Woodpecker nest
d) Recently harvested coupe
e) NILS field crew
f) Assessing cultural landscape


a)


b)


c)


d)


e)


f)

Photos: Finland.

a) Tengmalm's Owl using nest box
b) Eagle Owl chicks
c) Capercaillie
d) Stump harvesting following clearfell
e) Northern Flying Squirrel
f) Midnight sunset

a)

b)

c)

d)

e)

f)

Photos: Belarus

a) Floodplain Oak forest;
b) Caesium 137 contamination
c) Moose (Elk) hunting station
d) Don’t eat the mushrooms or berries!
e) Old Oak forest
f) Failed drainage ditches

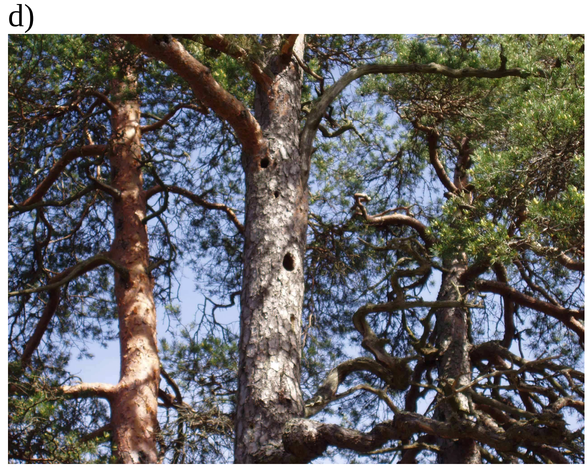

a)


b)


c)


d)


e)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Photos: Norway-Sweden.

a) Old Norway Spruce forest
b) Mixed deciduous – coniferous forest
c) Alpine forest
d) Red Squirrel in spruce forest
e) A common sight in Scandinavia
f) Black Woodpecker nest holes

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Background

Australia is party to various national and international agreements (National Forest Policy, Australian Forestry Standard, Montreal Process), Commonwealth-State Regional Forest Agreements and State legislation (e.g. NSW Threatened Species Act 1995) specifying that forestry activities be carried out in an environmentally-sustainable manner. An internationally-competitive and sustainable forest and wood products industry that strengthens Australian communities and meets consumer expectations is an objective expressed by national organisations such as the Forest and Wood Products Research and Development Corporation (FWPRDC Service Charter 2003). The development of appropriate species indicators is an essential part of this process.

In 1999, the FWPRDC (through the Wood and Paper Industry Strategy) funded a national study that investigated the feasibility of developing a practical, sensitive and cost-effective approach to the implementation of Montreal Process Indicator 1.2c for monitoring populations of representative species for forest management. This work culminated in a number of papers and reports (including Kavanagh *et al*. 2004 and Kavanagh & Stanton 2005). Qualified support was found for the indicator species concept, based on the identification of a set of species apparently sensitive to logging and their representation across a range of species assemblages. Other crucial issues needing to be addressed, in addition to the choice of species to monitor, include species detectability, survey effort and the statistical power of monitoring designs. Alternative methods include the use of forest structural and compositional attributes that may, potentially, serve as surrogates for the habitat requirements of a range of species. The objective of this research was to investigate international developments in these areas.

Policy framework

Since the early 1990's, there has been an increased awareness of the need for social, economic and environmental considerations to be incorporated into the process of sustainable development of natural resources, including forests used for wood production. Much of the impetus for policy development and management action can be traced back to the responses by individual governments to the 1992 Convention on Biological Diversity, or "Earth Summit" held in Rio de Janeiro. Australian Governments, including the States which are the land-managing authorities, committed to sustainable forest management with the National Forest Policy in 1992, became signatory in 1995 (along with 11 other countries) to the Montreal Process to develop and implement criteria and indicators of sustainable forest management and, between 1997-2001, implemented a series of 11 Regional Forest Agreements covering most of the important wood-producing regions in Australia. Two national reports, in 1998 and 2003, have been produced documenting the "State of the Forests" in Australia, based on the 7 criteria and 74 indicators adopted from the Montreal Process.

The response of governments in Scandinavia has been correspondingly swift. For example, since 1992, Sweden has become party to a number of pan-European agreements, including the European Union's "Habitat Directive" (1992) (to supplement the earlier "Birds Directive" in 1979) and its associated network of new protected sites known as Natura 2000, and the Helsinki Agreement of the Ministerial Council for the

Protection of Forests in Europe (MCPFE) (in 1993). In 1999 (and revised in 2005), the Swedish Government adopted a set of 16 national environmental objectives, based on the MCPFE principles, to define the state of the environment which policy aims to achieve, as well as a set of environmental and conservation targets to be achieved by 2020. The most comprehensive assessment of the status of sustainable forest management in 40 European countries ("State of Europe's Forests 2003", MCPFE Report) was structured according to the Pan-European Criteria (6) and Indicators (35) for Sustainable Forest Management (MCPFE).

Current approaches to monitoring biological diversity

The most generally accepted definition of biodiversity, or more precisely biological diversity, is that proposed by the 1992 Convention on Biological Diversity as the "diversity within species, among species and of ecosystems". Many different views or interpretations exist as to how biological diversity should be measured in practice. Some consider biological diversity to be so complex that it is only possible to measure forest structural attributes that are expected to serve as useful surrogates for the habitat of many species (Franklin 1981). Others have expanded this view to consider biological diversity in terms of its composition, structure and function (Noss 1990) which, in practice, proposes to measure mostly habitat surrogates but also recognises the need to measure the spatial and temporal condition of species populations and communities. A different view was proposed by Gaston (2000) who emphasised the need to focus on species, and thus to measure changes in populations, pointing out that, while processes and functions may be important they are not the ultimate variables of interest. A sensible approach would seem to be somewhere in the middle; that is, to measure species as the primary goal but, recognising that not all species are known or can be measured, to include measures of likely habitat surrogates for a broad range of species as well. The task then becomes one of identifying which species and habitat attributes to monitor, given that it is not possible to measure every species, and setting management goals or targets for acceptable levels of species populations and habitat attributes.

The Montreal Process encompasses the range of these views, recognizing that "conservation of biological diversity" (Criterion 1) should be assessed at three levels; ecosystem diversity, species diversity and genetic diversity, using nine indicators. However, eight of these indicators include coarse habitat surrogates, such as remotely-sensed and mapped changes in the area of each broad forest type by growth (successional) stage and by land tenure, and lists of the numbers of threatened and forest-dwelling species. Only one indicator (1.2c) proposed that populations of "representative species" should be monitored throughout their range to provide early warning of major environmental changes. In Europe, the equivalent MCPFE criterion 4 also includes nine indicators, none of which prescribe monitoring of the changing abundance of species. However, the need to incorporate or improve assessments of populations of "representative" species in monitoring programmes is now widely recognized and much progress is being made in other arenas.

In Australia, and internationally, the conservation of forest biodiversity is currently approached in two ways: (a) through the reservation of poorly-represented vegetation types in national parks and other reserves; and (b) through the retention of nominated habitat elements in other managed forests, including riparian strips and old, hollow-bearing trees in Australian forests, and standing and fallen dead wood and deciduous trees in Scandinavian forests (e.g. Anon 1999a, 1999b, Anon. 2005, Heinonen 2005). However, forest managers and conservation biologists need to monitor both of these actions in terms of their achievement of stated objectives. This is best done by assessing directly the abundance of key (representative) species, or species groups, rather than by relying entirely on indirect assessments using habitat surrogates, which can be spurious. The focus on populations, in addition to habitat surrogates, is needed because managers require confirmation that their actions are having the desired effect. Furthermore, habitat requirements are poorly known for many species, and factors (e.g. introduced predators) other than habitat availability may interact to account for variations in the abundance (or presence) of species.

Much of the debate about species monitoring has centred around the question of “which species to monitor”. Indicator species, umbrella species, sensitive species and target or focal species have all been proposed as “management shortcuts” because of the practical and technical difficulties involved with counting every species. However, the indicator species concept is controversial for a number of reasons, including disagreements about what indicators are supposed to indicate, and how well they actually relate to the requirements and population status of other species (Landres *et al.* 1988, Noss 1990, Niemi *et al*. 1997, Caro and O’Doherty 1999, Simberloff 1998, Lindenmayer 1999, Hilty and Merenlender 2000, Lindenmayer *et al.* 2000). Not surprisingly, management for and monitoring of habitat surrogates at different spatial and temporal scales, along with the reservation of representative areas, has been seen to be a more attractive alternative (Lindenmayer and Franklin 2002). However, this does not absolve managers and conservation biologists from the need to monitor these actions in terms of their effects on biodiversity.

Noss (1999) makes the point that measuring change of any kind requires the use of indicators. He outlined the case for the rigorous use of ecological indicators, including indicator species, in which he emphasised the need for forest managers to begin with a clear statement of goals and objectives for management. Ecological indicators that reflect specific issues of concern, and progress towards goals, can then be identified and monitored. Ideal characteristics of indicator species include species that are sensitive to the management regime applied, and species that are common, widespread, and easy to monitor (Kavanagh 1991, Lambeck 1997, Noss 1999). Fundamentally, however, for a species to serve the role as an indicator of the status of other species of management concern it must display a strong pattern of co-occurrence with the assemblage of taxa for which it is proposed to be indicative. Because it is unlikely that one species will overlap the distributions of a large number of other species, it is important to consider a range of candidate species as indicators, including those from different functional groups (i.e. species of similar body size and ecological requirements) (Lambeck 1997, Noss 1999).

It has been argued that species, or species groups, that are sensitive to logging, and which are also associated with other species including those from different functional groups, should be among the candidates for long-term monitoring because of their potential to indicate major environmental change (Kavanagh *et al*. 2004, Fleishman *et al*. 2005, Kavanagh and Stanton 2005). These sensitive species are likely to form the main component of Indicator 1.2c of the Montreal Process, which seeks to monitor "Population levels of representative species from diverse habitats across their range", and thus provide an important indicator of sustainable forest management.

Species monitoring programmes currently underway, for example, in south-west Western Australia and Alberta, Canada, have largely avoided the difficult issue of which species to monitor by deciding to assess changes in populations for a very large number of species – indeed, for as many species as possible using a set of standard sampling procedures (Abbott and Burrows 2004, http://abmi.biology.ualberta.ca). This conservative approach has many benefits because it provides a comprehensive baseline assessment for population status of many species during the establishment phase and it does not preclude monitoring focus on selected indicator species when further information becomes available.

Additional considerations for species monitoring programmes include the stratification employed, sampling intensity and species detectability, and the consequent effects on the statistical power of the monitoring programme to detect change. Sampling designs that are too strongly focused on particular strata, or which attempt to incorporate too many levels with each stratum, run the risk of having either insufficient power or little flexibility to assess changes that may be occurring due to unknown or unexpected factors.

The award of the 2007 Gottstein Fellowship enabled me to visit Sweden, Finland, Norway and Belarus to learn about forestry and wildlife research and management practices in these countries. The principal objectives of the visit were to investigate current developments in monitoring and the prospects for using species-based assessments as indicators of ecologically sustainable forest management in Australia.

International geographical comparisons

Scandinavia (defined here as Norway, Sweden and Finland) and Belarus are among the most extensively forested countries in northern Europe, and each has a long history of forest utilisation and wildlife, particularly game, management. For perspective, it is useful to compare a number of geo-political, economic and ecological attributes of these four countries with Australia (Table 1). Australia, of course, has a vastly larger land area than any of these countries; even NSW is double the size of the largest country, Sweden. However, perhaps more surprisingly, the population size of Australia is also much larger, more than double the population of Sweden and Belarus and about four times larger than the populations of Finland and Norway. Both Sweden and Finland have a huge proportion (~ 70%) of their total land area covered by forest, most of which is highly productive and available for wood production (Fig. 1). Accordingly, the forest sector makes a large contribution to national Gross Domestic Product in these countries (excluding the huge scale of international forestry operations conducted by Swedish and Finnish-owned logging companies). By comparison, there is only about 20% forest cover in Australia (much of which is uncommercial), using the broad definition of forest employed by Australia's State of the Forests Report (2003) (Fig. 2). Levels of public ownership of forest land are similar between Sweden, Finland, Norway and Australia, but the proportions of forest protected in nature conservation reserves are quite different. In Belarus, all forest in the country is owned and managed by the state but, due to economic hardships, has only recently begun to develop its national conservation reserve system

Fig. 1. Distribution of forests in Europe. Source: European Forest Institute

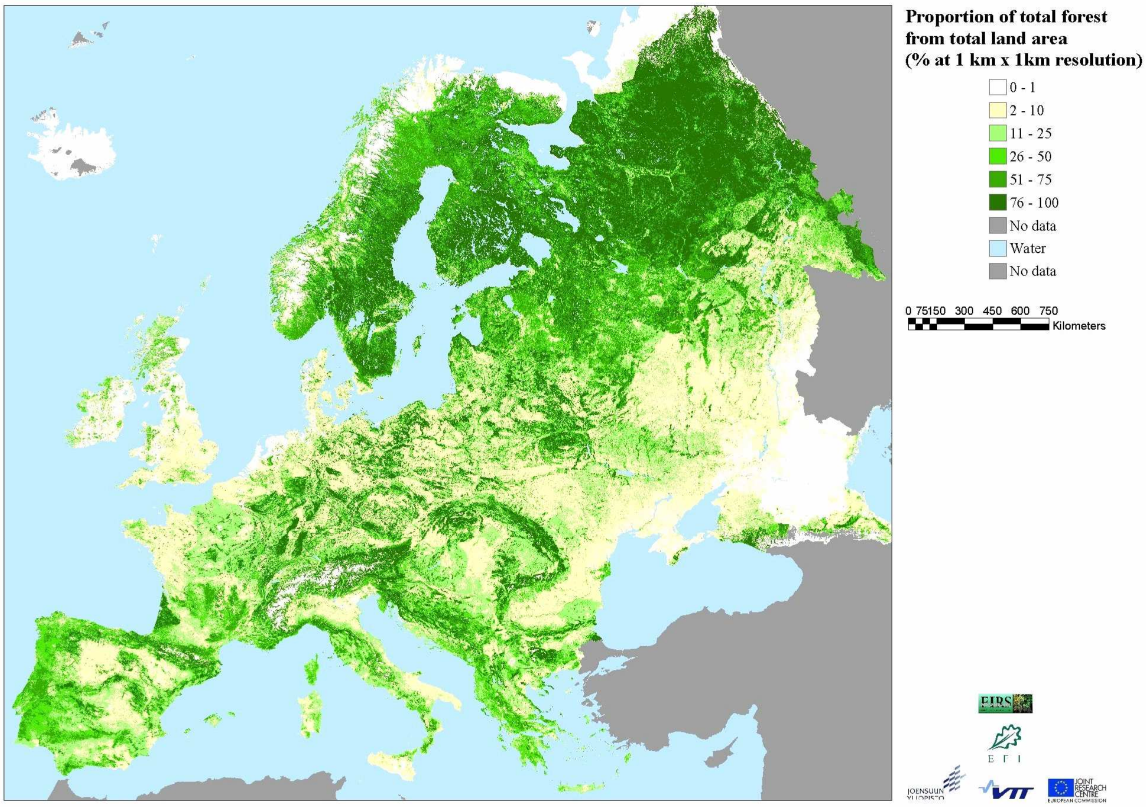


Fig. 2. Distribution of forests in Australia. Source: State of Australia's Forests (2003)

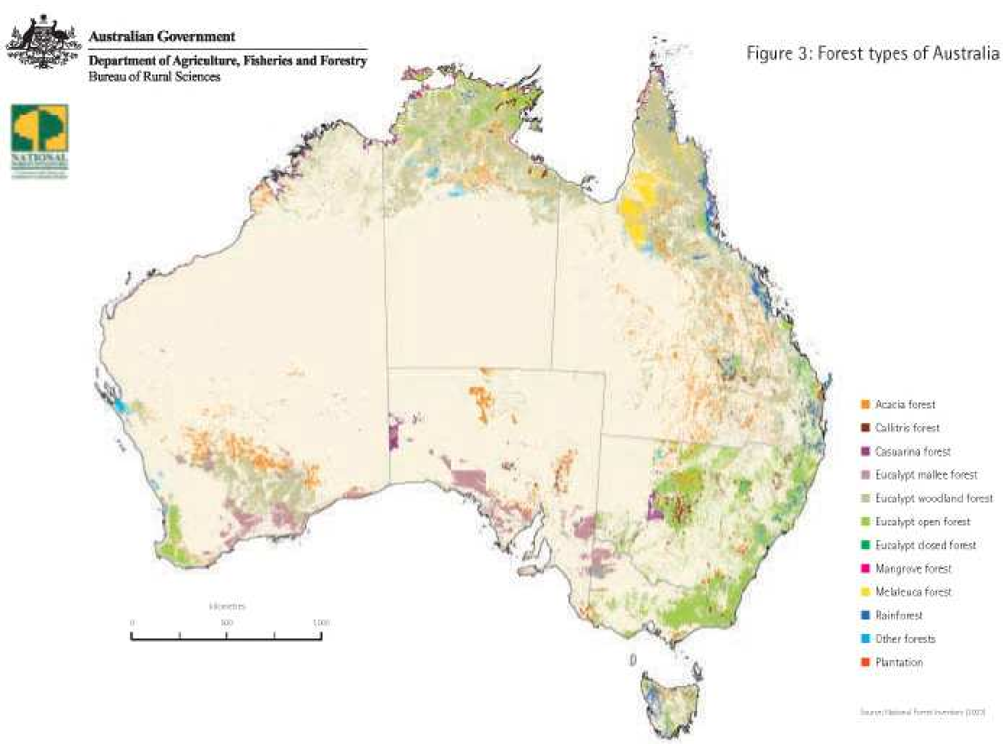


Table 1. Selected national and forest attributes by country.

Principal sources: State of Europe's Forests (2003), State of Australia's Forests (2003) and IUCN Red List of Threatened Species (2006); -, comparative data unavailable

Attribute	Sweden	Finland	Norway	Belarus	Australia	NSW
Population (,000)	8,833	5,178	4,488	9,971	20,500	6,500
Land area (,000 ha)	40,843	30,454	30,625	20,285	768,230	80,160
Forest and woodland (% of land area)	68	68	37	43	21	34
Contribution of forest sector to GDP (%)	6	10	-	-	1	-
Forest land ownership (% public, private)	20 80	28 72	24 76	100 0	29 71	32 68
Forest land (%) in conservation reserves	9*	8*	2*	-	13	17
Total vertebrate and selected invert. species	625	566	599	382	2,129	-
Animal species extinct	0	0	0	1	38	-
Animal species endangered	38+	28+	35+	19+	583	-

* WWF's State of Europe's Forest Protection (2003) report claims that only about 4%, 5% and 1% of forests are protected from logging in Sweden, Finland and Norway, respectively, and that much less has been reserved in the most productive zones in the southern portion of these countries. This report also claims that commercial logging occurs within some conservation reserves in Belarus.

+ WWF's State of Europe's Forest Protection (2003) report claims that greater numbers of vertebrate species are threatened in these countries. The numbers of animal species reportly extinct in these countries also appears to be incorrect.

(Kozulin *et al*. 2005). Sweden and Finland are both member states of the European Union, unlike Norway and Belarus, and this could explain partly why the latter two countries have smaller proportions of forest managed for conservation. During the past 15 years, the strong environmental policy directives of the European Parliament have proven to be important instruments for achieving a more equitable balance between wood production and nature conservation in Europe.

Some other points of difference are relevant and worthy of note. First, that Australian forests are floristically and structurally much more complex and diverse than any of the forests observed in northern Europe and, accordingly, also have much higher levels of biological diversity (Tables 1 and 2). Nonetheless, species of Australian fauna and flora have suffered proportionately greater declines in conservation status than species in northern Europe, although similar declines may have occurred much earlier in Europe. The second point of note is that the intensity of forest harvesting is much greater in Sweden and Finland than in most Australian forests. This is due largely to the greater economic value of the northern forests but also to the almost flat terrain found throughout Finland and much of Sweden which makes most of the landscape accessible to logging. While the topography in Belarus is also mostly flat, the lack of economic and technological development in this country has meant that Belarusan forests are relatively under-utilised compared with those in Sweden and Finland. It is this aspect which has enabled interesting comparisons to be made of the biological diversity in these northern countries.

Table 2. Dominant tree species on forest land in Finland, 1986-1994.

Source: National Forest Inventory for NFI 8 (www.metla.fi/ohjelma/vmi/nfi.htm)

These data demonstrate that forests in Finland (and also in Sweden, except for the nemoral forest zone in the south) are very simple floristically with 90% of the forest overstorey comprised of only two tree species.

Tree species		%
Scots pine	*Pinus sylvestris*	64.5
Norway spruce	*Picea abies*	25.7
Other coniferous		0.1
White birch	*Betula pendula*	1.3
Downy birch	*Betula pubescens*	6.2
Aspen	*Populus tremula*	0.3
Alder	*Alnus* spp.	0.4
Other broad-leaved		0.1
Temporarily non-stocked		1.5
Total		100.0
Forest land area	(million ha)	20.0

Woodpeckers are a group of birds that have well-known associations with older forests, and particularly forests that include a high proportion of deciduous trees and standing dead wood. I observed all 10 species of European woodpeckers in Belarus, some of which are now extinct (Middle-spotted Woodpecker) or endangered (White-backed Woodpecker, Three-toed Woodpecker) in Sweden and Finland. The Northern Flying Squirrel, another species of conservation significance (which does not occur in Sweden or Belarus), is now restricted to the small remaining patches of older and more diverse forests in Finland. Eight of Sweden’s 11 owl species are now listed as vulnerable, and this would also be the case in Finland had it not been for the extensive, voluntary nest-box programme in that country which has enabled many species to recover.

The major limitations to conservation planning for biodiversity in Scandinavia are the relatively small proportions of forested lands held in public ownership and the small areas (~ 25 ha) of individual land holdings held in private, predominantly family ownership. For example, there are approximately 360,000 private forest owners in each of Sweden and Finland, and a similarly large proportion of forest lands in Norway are held in private ownership. This greatly limits options for large-scale conservation planning and explains why none of these Scandinavian countries have a comprehensive nature conservation reserve system in place, particularly in the southern more productive regions. Sveaskog and Metsähallitus are the national forest services of Sweden and Finland, respectively, and they manage approximately 15-20% of forest lands, mainly in the north of these two countries. While these two forest agencies have a major brief to produce wood, they also provide governments with some flexibility to address the deficiencies in the conservation reserve system. Sveaskog has established 34 “Ecoparks”, totalling approximately 175,000 ha or 5% of its productive forest land, primarily for nature conservation but within which compatible forestry activities are permitted. A further 15% of Sveaskog’s productive forest land is planned to receive nature conservation emphasis.

Eriksson and Hammer (2006) identified three significant shortfalls in the management of forests in Sweden (and Finland) for biodiversity conservation in the context of timber production. They included: (1) the failure to fully integrate conservation and timber production objectives at the landscape scale and over longer time periods; (2) the lack of knowledge about the current and future status of “key habitats” and “reinforcement zones” with regard to connectivity and fragmentation in the landscape matrix; and (3) the limited knowledge about the biodiversity occurring within the dominating unreserved part of the landscape resulting in no effective feedback loops for adaptive management. The consequences of a forestry resource that exists primarily within the control of numerous small family landholdings or large private forestry companies is that any concessions to conservation tend to be small, static, unconnected and unrepresentative providing few opportunities for co-ordinated management of species at the landscape scale. These authors pointed to an urgent need for comprehensive broad-scale species monitoring programmes to address these issues.

National biodiversity monitoring programmes

Europe

Two major nature conservation policy initiatives of the European Parliament have binding implications for all member countries of the European Union in relation to biodiversity conservation and monitoring. The "Birds Directive" (79/409/EEC – 2 April 1979) aimed to ensure the conservation of all species of naturally-occurring birds in the wild within the European territory of member states. This was gradually interpreted as including all species and, in 2002, European nations pledged commitments to ensure "a significant reduction in the current rate of biodiversity loss by 2010". These commitments required monitoring systems to measure progress towards objectives. The European Bird Census Council (EBCC) was tasked to co-ordinate the development of appropriate indicators, sampling procedures and reporting systems for pan-European bird species monitoring programmes (Gregory *et al*. 2003, 2005). The "Habitats Directive" (92/43/EEC – 21 May 1992) was established to supplement the Birds Directive. This called for member countries to establish a network of sites, known as Natura 2000, which would be managed primarily for nature conservation. Monitoring of species conservation status and habitat condition was an obligation arising from Article 11 of the Habitats Directive, and this provision was not restricted to Natura 2000 sites. Article 17 required that monitoring results be reported to the European Commission every six years. The EU guidelines and framework for assessment, monitoring and reporting were finalised in 2005.

The Ministerial Council for the Protection of Forests in Europe (MCPFE) has now held four pan-European meetings to co-ordinate sustainable forest management programmes and reporting of progress on indicators of sustainability among member countries. In 2003, MCPFE produced the "State of Europe's Forests 2003" Report providing the most comprehensive assessment of the status of sustainable forest management in 40 European countries.

Sweden

The Swedish Environmental Protection Agency and the Swedish Forest Agency (both under the same Minister) share primary responsibility for conserving and managing forest biodiversity in Sweden. The Swedish Environmental Protection Agency (www.naturvardsverket.se) funds much of the conservation, monitoring and species recovery actions throughout the country – activities that are implemented by a wide range of institutions, including regional County Boards, Universities and NGO's. The Swedish Forest Agency (www.skogsstyrelsen.se) "regulates" forestry activities throughout the country, principally by setting non-compulsory targets for environmental management (www.skogsstyrelsen.se/targets) in accordance with the 16 Swedish National Environmental Objectives (http://miljomal.nu/english/english.php) which are based on directives from the parliament of the European Union (Ministerial Council for the Protection of Forests in Europe).

Objective 12, Sustainable Forests, includes targets to achieve additional areas (900,000 ha) of forest land to be excluded from forest production by 2010. Other targets call for increasing proportions of dead wood to be retained within stands that are logged, and for the protection of increasing areas of mature forests with a deciduous tree element and areas of old forest. Objective 16, A Rich Diversity of Plant and Animal Life, includes targets calling for a halt to the loss of biological diversity in Sweden by 2010, improvements in the conservation status of threatened species by 2015, and sustainable use of biological resources by 2007. The Swedish Government has established an Environmental Objectives Council to monitor progress in achieving these targets.

Overview

Sweden has two national monitoring schemes (RIS and NILS) that use remote sensing and plot-based measures of a range of forest attributes that are expected to serve as habitat "proxies" or habitat surrogates for biodiversity. Both schemes also record the relative abundance of most plant species occurring on the plots but animals are not recorded. The only national scheme to systematically monitor changes in the abundance of any vertebrate species is the Swedish Breeding Bird Survey, although there are a number of regional schemes for assessing changes in the abundance of species within certain vertebrate and invertebrate groups (e.g. large mammalian carnivores, small ground mammals, butterflies). Species audits for plants and animals occurring within areas designated for nature conservation are also done to fulfil the requirements of the European Union's "species and habitat directives" (e.g. Natura 2000 sites and Woodland Key Habitats) and these audits may form the basis of future monitoring programmes. Artportalen (or "species gateway"), which is based entirely on the undirected and opportunistic contributions of volunteers, is a national scheme for recording the occurrences of any and all species of plants and animals in Sweden. The popularity of this scheme has resulted in the rapid accumulation of a massive database of species records throughout the country which, despite the lack of information about survey effort, is capable of reflecting broad trends in the abundance of species. There are no monitoring programmes in Sweden that comprehensively measure both the occurrences of vertebrate species and relevant habitat attributes at the same plots.

Swedish National Forest Inventory (RIS)

The objective of the RIS is to describe the status of, and changes in, forest resources in Sweden. A total of approximately 10,400 permanent plots are re-measured every 5-10 years (i.e. 20% measured every year) as well as approximately 3,100 temporary plots (each measured once) (Fig. 3). The Swedish National Inventory of Forests is managed by the Department of Forest Resource Management and Geomatics, Swedish University of Agricultural Sciences (SLU), in Umeå. In 2003, RIS was formed by amalgamating the National Forest Inventory, which had been running for 84 years (since 1923), and the Swedish Forest Soil Inventory (which commenced in 1962). Every year, 60 field workers are employed during summer (when there is no snow cover) and they are co-ordinated by approximately 20 staff from the Department who also collate the data for annual reports. Results from the Swedish National Forest Inventory are presented as 5-year averages in a comprehensive series of publications, including raw data tables, graphs and spreadsheets, available for downloading from the website (www.resgeom.slu.se see also www-ris.slu.se).

The RIS sampling plots are located systematically throughout Sweden (Fig. 3). Plots are 7-10 m radius and located at regular intervals (approximately 200 m) along survey "tracts" (rectangular routes of approximately 10 km) to ease the logistic burden of sampling in remote areas. Each tract is designed to enable two field technicians to complete the required measurements at all plots in one day. Attributes assessed at each plot include:

- Tree and shrub layer – all trees measured and some epiphytes. Data available are species proportions, stand age, stem volume, number of stems, mean diameter (DBH), type of forestry treatment, and amounts of standing and fallen dead wood;
- Ground vegetation – cover-abundance for each species or attribute;
- Humus layer and mineral soil – soil samples;
- Site conditions – soil moisture, topographic position, forestry disturbances;
- Position in landscape – GPS co-ordinates, etc.

Currently, work is being done to develop inventory methods using a combination of satellite imagery and field data.

Fig. 3. Distribution of sampling points, Swedish National Forest Inventory (RIS)

National Inventory of Landscapes in Sweden (NILS)

The general aim of NILS is to monitor the pre-requisites (habitat proxies) of biodiversity from a landscape perspective across all terrestrial landscape types. It more closely targets the reporting requirements of Sweden's National Environmental Objectives and includes cultural (agricultural and urban) landscapes, wetlands and alpine areas, as well as forested landscapes. Funding for the programme is provided by the Swedish Environmental Protection Agency. Approximately 30 field technicians are employed each summer and the programme is managed by the Department of Forest Resource Management and Geomatics, Swedish University of Agricultural Sciences (SLU), in Umeå. A total of 631 5x5 km grids are systematically located throughout Sweden using the national grid system (Fig. 4). Aerial photo coverage is obtained every five years for all of these grids and used to report changes in forest and other land cover attributes. Also, twelve 20 m radius nested plots (also includes one 10 m radius plot and three 0.28 m radius plots) are permanently located near the perimeter of the central 1x1 km grid square and, together with the belt transects linking them, are sampled every five years. Each square takes two field technicians 2-4 days to complete the required measurements. The attributes measured at each plot include:

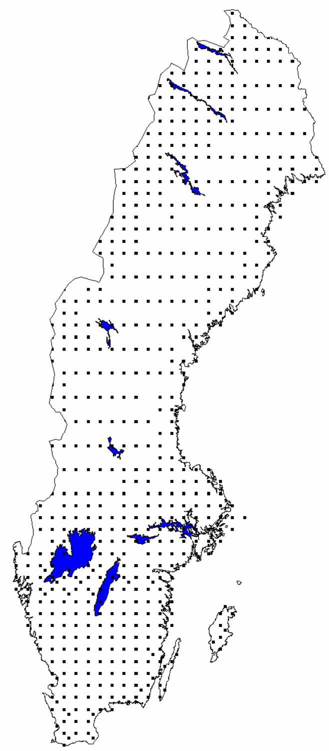
- Tree, shrub, ground vegetation – stem counts and cover-abundance for all vascular plants, bryophytes and lichens. (Note: amounts of standing and fallen dead wood are not recorded on NILS plots, instead being measured by RIS, since mid-1990's. However, NILS will begin recording dead wood in streams in 2008);
- Ground vegetation – cover-abundance for each species or attribute;
- Photographic record, and assessment of forestry and other changes;
- Presence of cultural features of interest (e.g. old buildings);
- Position in landscape – GPS co-ordinates, etc.

The belt transects record linear landscape features, including:

- Roads, stone walls, fences, ditches, streams, cattle tracks, forest edges, etc.

Details are available from the following website: www-nils.slu.se

Fig. 4. Distribution of sampling points, National Inventory of Landscapes in Sweden (NILS)



Swedish Breeding Bird Survey

The national bird inventory is carried out on 716 x 8 km fixed routes (each formed as a 2 x 2 km square) systematically distributed 25 km apart throughout Sweden based on the national grid. About 500 bird survey routes are co-located with NILS so that they include the central 1 x 1 km grid square, although only three of the eight bird count stations (where all birds seen and heard are counted within a five minute period) coincide with NILS habitat assessment plots. Bird surveys along these fixed routes are done within a prescribed time period using a standard measure of sampling effort for all diurnal bird species. Nocturnal birds are not systematically recorded. About half of the surveys are undertaken by experienced volunteers and the other half by paid ornithologists to ensure that the more remote locations are surveyed at the right time and in the standard manner. Results are expressed as the total numbers of birds recorded, by species, per route per year. This measure provides an index of change in the relative abundance of species. Funding for the programme is provided by the Swedish Environmental Protection Agency. These funds are used mainly to support the employment of one permanent and several temporary staff to manage the programme which is administered from the Zoology Department at the University of Lund. The Swedish Breeding Bird Survey has been adopted by several of the country's 21 regional county administrative boards as part of their regional species monitoring responsibilities and this provides additional funding.

Details of the programme are available from the following web site: www.biol.lu.se/zooekologi/birdmonitoring/Eng/index.htm

The Swedish Breeding Bird Survey is Sweden's contribution to the European Bird Census Council's (EBCC) pan-European bird monitoring programme (www.ebcc.info/Sweden.html).

Artportalen

Artportalen, or "species gateway", is a voluntary scheme for reporting observations of all birds, mammals, reptiles, amphibians, fish, insects, fungi and plants anywhere in Sweden. Features that make Artportalen so popular with its many contributors include instant downloading of all non-restricted data (active nest sites for threatened species are restricted) contained within the national database, the capacity to export raw data to Excel files for private analysis, and very attractive summary graphics and reports. About 10 million records for birds only have been contributed since the programme began in 2000 with a 40% annual increase in the numbers of records and participants. In 2005, the website received 119 million hits from contributors and people viewing the site. Artportalen is administered by the Swedish Species Information Centre and the Swedish Ornithological Society using funding provided by the Swedish Environmental Protection Agency.

Data from Artportalen are used to develop the Swedish Species Atlas. The database managers have also developed a "species recording index" which they claim will overcome limitations caused by the lack of a measure of survey effort, thus providing an important new index of changing species population trends regionally and throughout Sweden. This index is possible only because of the large database available and the high frequency of new contributions from throughout the country.

Details of the programme can be viewed on the website: www.artportalen.se

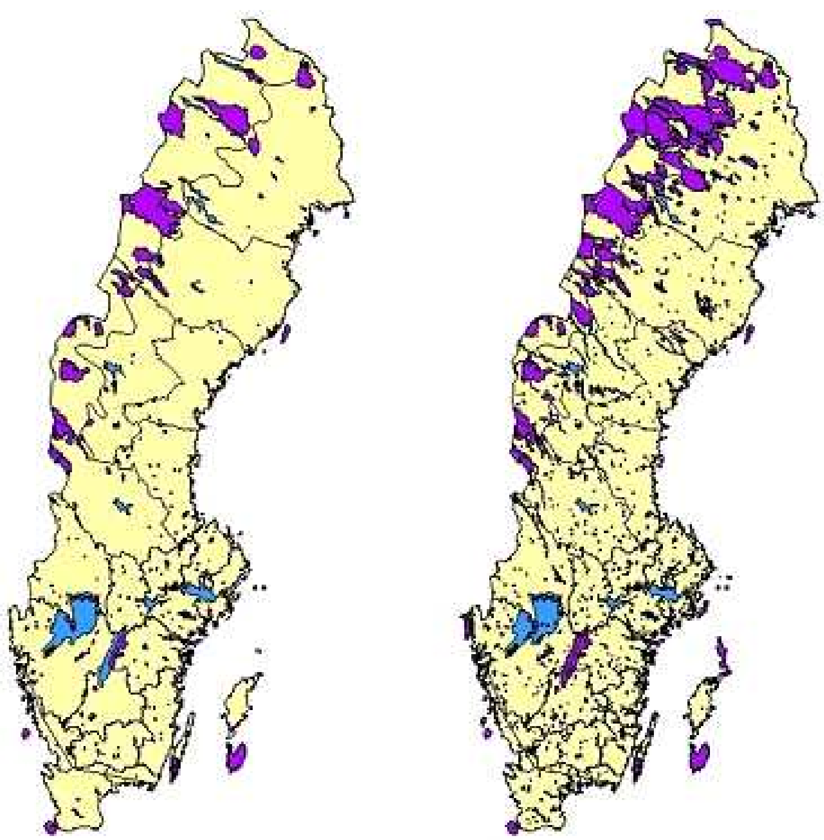
The programme is now being developed for use in New Zealand (www.nzbrn.org.nz)

Natura 2000

The Natura 2000 sites are part of Sweden's response (and that of other EU member countries) to implementation of the Habitats and Birds Directives. Sweden has about 90 of the priority habitats and just over 100 species of priority flora and fauna as listed in Appendices 1 and 2 of the Habitats Directive. An additional 60 or more of the bird species listed in Annex 1 of the Birds Directive nest regularly in the country. In Sweden, a total of 4081 sites (as at October 2006) totaling 6,426,436 ha had been selected for the Natura 2000 network (Fig. 5). Approximately 60% of these sites are already protected as nature reserves, national parks, etc. and the remainder are subject to special conservation agreements with private landowners. The Swedish Environmental Protection Agency co-ordinates the efforts to create the Natura 2000 network in Sweden but the Swedish County Administration Boards (CAB) are the agencies responsible for nominating sites for inclusion following consultations with landowners and relevant authorities. The CAB's are also responsible for preparing and implementing management plans for each site. Natura 2000 requires all EU member states to take steps to ensure all habitats and species in the network receive "favourable conservation status". So, following an intense initial establishment phase, efforts are now being directed into conservation management and monitoring of the special values of these sites.

Fig. 5. Natura 2000 sites in Sweden (up to August 2004).

Left: Sites designated under the EU Birds Directive; Right: Sites designated under the EU Habitats Directive.



The overall framework for the proposed monitoring system in Sweden, and appendices describing specific monitoring methods for a selection of Natura 2000 habitats and species, were described by Abenius *et al*. (2004). A baseline inventory of all Natura 2000 sites and other protected areas began in 2004. These baseline surveys placed emphasis on mapping the extent of different habitats, on estimating population sizes for priority species, and in collecting other data needed to set conservation objectives. This information was then used to inform an "objectives-based" approach to the proposed monitoring system. This approach takes the view that analysis and assessments of the conservation status of habitat types and species require decisions about desired population targets and the desired condition of specified habitat features. Monitoring therefore becomes a matter of tracking progress towards these conservation objectives which are formulated with reference to the definitions of "favourable conservation status" in the Habitats Directive. These conservation objectives are primarily concerned with factors that can be influenced by management.

The sampling procedures and survey methods used in the proposed monitoring programme will, as far as possible, be co-ordinated with the network of plots set up under NILS and RIS (the national forest inventory). Several variables of importance for Natura 2000 monitoring are already being recorded on NILS plots. Monitoring sites for rarer habitats and species will be located within the larger 1 x 1 km or 5 x 5 km permanent squares used in the NILS programme. This alignment of sampling also provides access to the aerial photographs taken every 5 years over each 5 x 5 km NILS square, thus permitting assessments of many parameters describing habitat extent and condition. Natura 2000 species conservation targets apply to relatively few, intensively surveyed, species. The Artportalen database is intended as the principal monitoring tool for the majority of species. Article 17 of the EU Habitats Directive requires reporting every six years for the results of Natura 2000 surveys and conservation measures and these results are to be made publicly available. The Swedish Species Information Centre and the Swedish Environmental Protection Agency share responsibility for reporting the results of the Natura 2000 monitoring programme.

Further details can be viewed on the website: www.internat.naturvardsverket.se

Woodland Key Habitats

Woodland Key Habitats are areas with high quality conservation values that are regarded as core areas for biodiversity. The Swedish definition of a Woodland Key Habitat is an area where one or more red-listed species occur, or where the nature of the forest indicates a strong likelihood of finding red-listed species. A key habitat can be any size from a single ancient oak tree to a larger area of several hundred hectares of old coniferous forest. Key habitats were identified on the basis of forest stand structure, stand history and known occurrences of signal and red-listed species. The total area amounts to almost 164,000 hectares on private forest land, which corresponds to 1.14% of the productive forest land. The average size of a key habitat is 3.1 hectares (median size 1.4 ha). This programme, which began in 1993, was undertaken by the Swedish Forest Agency, principally as a means for redressing the major shortcomings of the national conservation reserve system due to the large proportion of productive forest land held in private ownership. Temporary protection for many of these areas was initially obtained using short-term conservation agreements involving payments to landowners. Today, the Woodland Key Habitats concept is widely recognized as a practical instrument for conservation within the Swedish forest sector and is included in different forest certification standards. Woodlands Key Habitats are used for conservation planning by public authorities and are used by private forest companies to avoid logging within sensitive areas.

Monitoring of the biological characteristics of key habitats began in 2000. These assessments focused on 11 different habitat types and 67 selected indicator species whose presence was considered likely to indicate high biological values and which were expected to provide an early warning system regarding general loss of biodiversity. These indicators included vascular plants, lichens, mosses and wood-inhabiting fungi, but no vertebrate or invertebrate species. By 2003, 491 woodland key habitats had been re-assessed.

Details of the programme can be viewed on the website: www.skogsstyrelsen.se

Large carnivores and game species

The 21 County Administrative Boards in Sweden are government agencies whose regional boundaries date back to 1634 when the counties were created. Their function is to co-ordinate development of the country in line with goals set in national policies. This includes responsibilities for nature conservation and environmental protection. As mentioned above, the CAB's prepare conservation plans for every Natura 2000 area. However, they also play a role in species monitoring programmes through their statutory responsibilities, which include the issue of hunting licences for game species (e.g. Elk (Moose), Roe Deer, Brown Hare, Mountain Hare, Fox, etc.). Hunting organisations provide statistics for the numbers of game species taken. For large carnivores, each CAB is required to record annual statistics about the numbers of wolves, wolverines and lynx in each region and to send these data to the national wildlife research organisation (Grimsö) for compilation and national reporting. Population estimates for large carnivores are undertaken in winter using sampling transects to search for evidence of animal tracks in the snow.

Small ground mammals

Voles and lemmings in northern Europe (and North America) undergo dramatic "boom-crash" population cycles at regular intervals. Much research has been undertaken to explain the cause of these cycles and modern consensus is that they are induced by predators (Newton 1998, Klemola *et al*. 2000). The consequence is that many predator species also suffer marked population changes at regular intervals. This degree of synchrony and dependence between predators and prey is unknown within Australia, probably due to our low productivity landscapes and highly variable climate. Indeed, it is remarkable to observe the wide range of predators that specialise on taking such few species of small ground mammals in northern Europe and to note the incredible abundance that enables these population cycles to develop. In Sweden, voles and lemmings have been monitored continuously since the early 1970's, primarily with the view to document this phenomenon and to use the results to predict changes in predator populations. However, unexpected results of this long-term monitoring have shown a gradual decline in the numbers of voles throughout Sweden since the 1980's, especially for one species, the Grey-sided Vole. This has now led to questions about the relative importance of ongoing habitat destruction and climate change, the latter because of the warmer winters experienced over the past two decades. The small mammal monitoring programme is co-ordinated by one scientist (Dr Birgir Hörnfeldt) from the University of Umeå using funding provided by the Swedish Environmental Protection Agency under the Swedish Environmental Monitoring Programme (www.emg.umu.se/research/lemmings/project_small_mammal.htm).

Finland

The Ministry of the Environment (www.environment.fi) has overall responsibility for the organisation of biodiversity monitoring in Finland. Co-ordination of these activities has been assigned to the Finnish Environment Institute (SYKE), but most of the actual monitoring work is conducted by various government institutes, including the Finnish Museum of Natural History (University of Helsinki), Metsähallitus (previously the Finnish Forestry and Parks Service), the Finnish Forest Research Institute (METLA), the Finnish Game and Fisheries Research Institute, independent experts and some NGO's. A good summary of environmental monitoring programmes in Finland is provided by Niemi (2006).

Overview

The same drivers for monitoring programmes apply in Finland as for Sweden, i.e. the Convention on Biological Diversity (1992), the EU Birds and Habitats Directives and the EU resolution in 2001 to halt the decline of biodiversity in Europe by 2010. Finland has its own legislated policy responses, including Finland's Nature Conservation Act and Decree, the National Action Plan for Biodiversity in Finland 1997-2005 and, in 2005, the country finalised its proposals for a re-organisation of national biodiversity monitoring in Finland. As a result, 60 national biodiversity monitoring programmes were agreed, just over half of which apply within forested environments. These monitoring programmes range from multi-taxonomic groups (e.g. national forest inventory), to broad species groups (e.g. butterflies, moths, birds, reptiles) to individual species (e.g. White-backed Woodpecker, Osprey, White-tailed Eagle, large mammalian carnivores). Most of the species monitoring programmes focus on species that are threatened nationally or internationally and are designed to provide data for evaluations of the conservation status of these species. Other objectives are to inform planning of suitable protection and management measures and evaluation of their effectiveness.

Finnish National Forest Inventory

The National Forest Inventory (NFI) is a monitoring system producing nationwide and regional information on forests and forest resources, including tree species, wood volume, tree growth and form, forest structure, forest health, physical site characteristics, land use and land ownership. These data are also used to provide information about rates of carbon sequestration by forests and levels of certain habitat surrogates likely to be important for biodiversity (e.g. amounts of dead wood, stand component comprised of deciduous tree species). The first inventory, which covered all of Finland, was conducted in 1921-1924. Fieldwork for the 10th NFI began in 2004 and will be completed in 2008. Field sampling is carried out at more than 5,000 locations (clusters) throughout Finland, at which more than 150 variables are recorded within each of 70,000 sample plots. Sampling plots (14 or 18, located 250 m or 300 m apart) are grouped within "L-shaped" or rectangular clusters (approximately 7 km apart depending on region) that are systematically spaced on a grid pattern across the country. Sampling plots have a maximum radius of 12.52 m and are re-measured every 5 years. Detailed measurements are taken for 10 trees in each sampling plot (Tomppo 2000). Satellite imagery (Landsat TM and Spot) is also used to capture landscape scale data and research is ongoing to better classify digital spectra arising from these tools. The National Forest Inventory is administered by the Finnish Forest Research Institute (METLA) from which approximately 35 permanent staff, including researchers, run the programme and about 40 field staff are employed each summer to conduct the field sampling.

Further details can be found on the website: http://www.metla.fi/ohjelma/vmi/nfi.htm

Finnish Breeding Bird Monitoring Scheme

The Finnish Breeding Bird Monitoring Scheme is very similar to the Swedish Breeding Bird Survey and both have the same conceptual basis (Järvinen and Väisänen 1981, Koskimies and Väisänen 1991). Birds are counted during the breeding season at fixed transect routes located 25 km apart throughout the country, and these locations are aligned with the national mapping grid. Transect routes are 6 km long and follow a rectangular path 2 x 1 km (compared to Sweden's 8 km transects which follow a 2 x 2 km square path). All birds observed along the transect routes are recorded continuously (compared to at fixed sampling points in Sweden) in one of two perpendicular distance categories: those observed within a 25 m belt either side of the transect line, and those observed more than 25 m from the transect line. Any changes in vegetation type, forest structural condition or recent disturbances are recorded within a 50 m belt either side of the transect lines. The Finnish scheme also records bird data as the "number of pairs" counted or estimated for each species, rather than the exact number of individuals observed (as in Sweden). Bird surveys along these fixed routes are done within a prescribed time period using a standard measure of sampling effort for all diurnal bird species. Results are expressed as the total numbers of pairs recorded, by species, per route per year. This measure provides an index of change in the relative abundance of species. Nocturnal birds are not systematically recorded. Most of the surveys are undertaken by experienced volunteers and the programme is co-ordinated by the Finnish Museum of Natural History within the University of Helsinki.

Raptor Monitoring Scheme

This national monitoring programme for diurnal and nocturnal birds of prey, termed Raptor Grid, began in 1982 using volunteers from the Finnish Bird Ringing Centre with funding support provided by the Ministry of the Environment. Populations of birds of prey are assessed annually within 10 x 10 km grid squares (mean=120) based on the national mapping grid and spread over the country (Saurola 2007). The aim is to find all nests, or at least all occupied territories, of the birds of prey in the squares. Since 1986, the monitoring was made more effective by gathering all information from the ringers (bird banders) about the nest sites checked and nests found outside the squares as well. This has resulted in more than 40,000 potential nest sites being checked annually for Finnish birds of prey. The species included in the program consist of all species of birds of prey except the Golden Eagle, White-tailed Eagle, Peregrine Falcon and Osprey, all of which have their own monitoring programs. In 2004, 129 raptor grid squares (130 in 2003) were assessed and altogether approx. 45,400 birds of prey territories (46,010 in 2003) were checked in Finland (Niemi 2006). One of the truly remarkable features of species monitoring programmes in Finland is the high level of involvement and commitment by experienced amateur naturalists, especially ornithologists. For example, in just one year (1989), a total of 4889 nests (from 7799 identified territories) of nine owl species were located and 16,419 owls were individually banded (Saurola 1992). These data provide important information about species nest site characteristics, breeding performance and long-term population trends. The extensive use of artificial nest boxes throughout most forested areas in the country has not only enabled these data to be collected, but it has supported populations of many bird species from major declines throughout Finland due to intensive forest management practices.

The Finnish Bird Ringing Centre has its administrative centre in the Finnish Museum of Natural History, University of Helsinki.

Lintuatlas

Lintuatlas is the Finnish equivalent of Artportalen in Sweden but, unfortunately, there is no English-language version. Lintuatlas actually refers only to birds but there are several other parallel species atlas schemes for other taxonomic groups, all of which are co-ordinated by the Finnish Museum of Natural History. In addition to birds, there are three monitoring programs for insects, one for molluscs, one for reptiles and amphibians and one for plants. The basis for all species atlas programmes is data collected from within approximately 3,800 10 x 10 km grid squares which are aligned with the national mapping grid throughout Finland. Records contributed to the various atlas schemes may be either systematically recorded or opportunistically collected, and for most taxa repeat sampling is undertaken at fixed locations or transects within a selection of the grid squares. Most sampling is done by enthusiastic, amateur naturalists. Some interesting findings include the gradient in species richness for butterflies and moths from about 2,000 species in southern Finland to about 1,000 species in central Finland, to about 500-600 species in northern Finland. For birds, two very comprehensive atlases have been produced covering the periods 1974-1977 and 1986-1989, and a third bird atlas is currently underway (2006-2010). Progress on the third bird atlas can be viewed at the following website: www.lintuatlas.fi/birdatlas_public_result.php

Natura 2000

In Finland, the Natura 2000 network of protected areas is based mainly on existing nature reserves. Most of the network is managed by Metsähallitus, which is the Finnish national forests and parks agency with the dual aims (Divisions) of managing forests for both wood production and nature conservation on public lands (www. metsa.fi). However, in recognition of the low representation of forests (only 8% in public ownership) in conservation reserves in southern Finland, the METSO programme (Forest Biodiversity Programme for Southern Finland) was established in 2002 as a joint initiative of the Ministry for Agriculture and Forests and the Ministry for the Environment (www.mmm.fi/metso). The objective of the METSO programme is to conduct an extensive inventory (more than 5,000 km^2 was surveyed during 2002-2006) of the nature conservation values of privately-owned forest lands in southern Finland with the view to augment existing reserves using various market-based instruments or payments to landowners. Some of these areas may eventually be included within the Natura 2000 network. In the meantime, Metsähallitus has also been conducting inventories to collect the basic information on the natural habitat types and species found in the protected areas which it manages. These baseline inventories will be followed up with monitoring (still under development) to assess changes in the "favourable conservation status" of the natural habitat types and species which it manages under the EU Habitats and the Birds Directives.

An area of special interest for Metsähallitus is monitoring changes in biodiversity within a selection of forested areas following habitat restoration efforts. This programme recognises that forest management outside of reserves has resulted in much lower frequencies of fire, the exclusion of deciduous trees from forest stands, and marked reductions in the volume of standing and fallen dead wood. Accordingly, some 20 Natura 2000 areas in southern Finland are now the subject of habitat restoration efforts which include prescribed burning, creation of small (0.1 ha) gaps, and supplementation of the amounts of dead and decaying wood. Species responses to these treatments are monitored to detect changes in relative abundance for plants, beetles and fungi.

Wildlife Triangle Scheme for monitoring game species

The Wildlife Triangle Scheme was developed in 1988 by the Forest Game and Fisheries Research Institute in co-operation with the central organisation of hunters in Finland. It provides annual information on relative abundance and changes for 30 wildlife species, most of which are game species, in about 1000 locations scattered throughout Finland (Pellika *et al*. 2005). The main goal of the WTS is to provide information on wildlife populations to game administrators and local hunting organisations. The Scheme uses about 1600 permanent census locations (wildlife triangles), of which 800-1000 are censused annually, involving about 7000 volunteers, mainly hunters. The census line in the WTS forms an equilateral triangle, with 4 km sides giving a total length of 12 km. This rigid shape and total length is believed to increase the probability that different forest vegetation types in the landscape will be well represented in the sample while remaining practical for field workers to follow (Pellika *et al*. 2005). Of the 30 wildlife species targeted, 17 are considered to have been sampled reliably enough to construct regional and national indices for species richness and relative abundance over time. These species are: Mountain Hare, Red Squirrel, Lynx, Wolf, Wolverine, Pine Marten, Red Fox, Stoat, White-tailed Deer, Moose, wild forest Reindeer, Roe Deer, Capercaillie, Black Grouse, Hazel Grouse, Willow Grouse and Otter. The bird species are counted in summer using a three-man chain flushing the birds from a 60 m wide census belt along the transect. The results are converted to an estimate of density (individuals/km^2) in forests. In winter, the tracks of mammals crossing the triangle line are counted and an index of the abundance for each species is given as track density (tracks/10 km/day). These data are aggregated in different ways to provide spatial and temporal comparisons for individual species, and to derive indices representing different species assemblages (e.g. predators and prey species). In the 15 years from 1989-2003, the Wildlife Triangle Scheme reported a significant decline in wildlife species richness within 11 of the 133 (50 x 50 km) grid squares throughout Finland, and an increase in 5 of these grid squares (Pellika *et al*. 2005). Major declines were reported in numbers of Lynx, Stoat, Pine Marten and Red Squirrel.

Norway

My visit to Norway was brief and informal (a long weekend) with no official meetings. The visit was undertaken to gain some impression of the forest types, management practices and landscapes present in this country. An internet-based search of the wildlife research and management activities, nature conservation achievements and species monitoring programmes in Norway revealed many parallels, but also some important differences, to those already described above for Sweden and Finland. These observations are discussed in context elsewhere in this report.

Belarus

Belarus, also known as "White Russia", declared its independence of the disintegrating Soviet Union in 1991. Belarus has had a long and troubled history, having been dominated, invaded and sometimes devastated by a succession of foreign powers over the past 1200 years. In 1986, 23% of the country was contaminated by nuclear radiation following the Chernobyl disaster just across the border in Ukraine. Despite these setbacks, Belarus is beginning to overcome its economic hardships although it remains deeply indebted to the Russian Federation for its energy supplies. However, it is not all bad news. The northern part of Belarus is characterised by extensive coniferous forests and numerous lakes while the southern part of the country has a landscape made up of low-lying swampy and riverine areas supporting mainly broad-leaved deciduous forests on the floodplains and coniferous forests on the slightly higher ground. These forests are part of the continuous band of boreal forests known as Taiga which stretches all the way from northern Europe, including Scandinavia, across Russia to Japan. The forests of Belarus do not have the same history of intensive management as that observed in Sweden and Finland and, as such, provide an interesting contrast with these Scandinavian countries in terms of their biological diversity.

National biodiversity monitoring schemes

On May 17, 2004 the Council of Ministers of Belarus issued an Order directing that a national system for monitoring fauna be carried out throughout the country. A total of 139 species were listed for particular attention. These included: 20 species of mammals that are hunted, 13 species of game birds, 29 species of fish that are hunted, 60 rare and threatened species (25 invertebrates, 3 fish, 2 amphibians, 2 turtles, 23 birds and 5 mammals) listed on the Red Book for Belarus, and 17 species (13 birds and 4 mammals) for which Belarus has international conservation and reporting obligations. The Academy of Science in Belarus was given primary responsibility for national biodiversity monitoring. All programmes are directed through the Institute for Zoology within the Academy, but the Institute for Botany also has an important role in mapping vegetation communities throughout the country, including areas regarded as being of High Conservation Value according to 12 main criteria.

A number of new monitoring programmes are currently in the early stages of implementation. The most comprehensive programme underway targets areas outside of national parks. This programme operates in six regions throughout the country. Permanent sampling points (5-6) have been established in each region. All vertebrate species (including the 139 priority species) are surveyed within variable-radius plots that are of a size that is appropriate for the species groups of interest (e.g. 20 m radius for salamanders, or 20-30 km for Greater Spotted Eagles). The location of sampling points is not random, but placed within localities known to contain many species of interest for monitoring. Monitoring within national parks will also employ similar permanent sampling points, also located in places known to be important for species of interest, but additional data will be collected to facilitate “ecosystem monitoring”. These additional data include plant species composition, water chemistry and levels of various industrial pollutants and toxins, including radiation.

Prior to the 2004 directive, Belarus had a long history of monitoring, particularly for 10-15 species of birds and mammals that are the subject of regular hunting and for an additional 10-15 species of birds and mammals that have long been recognised as threatened species. Since 1966, in certain areas, hunters organisations have kept detailed records of population size, fecundity and numbers culled for several of the most popular hunted species, including elk and deer. Wolf numbers, of which there are about 2,500 in Belarus, have also been closely monitored (and culled). Monitoring of threatened species has been based around known nest sites for the species of interest. Currently, there is no national monitoring and reporting scheme for all species of birds in Belarus but consideration is being given to adopting the European Bird Census Council’s recommended methods (www.ebcc.info) which are similar those used in Sweden and Finland.

Regional biodiversity monitoring schemes

Each region has a Director of Land Management which includes national parks, nature reserves, forestry operations and agricultural collectives as well as some associated processing facilities including timber sawmills. The Director of the region that I visited (Turov and Lyaskovichi) in southern Belarus was also responsible for tourism, marketing, science and management of the internationally-recognised Pripyatsky National Park which is listed as an Important Bird Area (IBA). This region has its own Deputy Director (Science) who explained biodiversity monitoring procedures in the Park and surrounding forestry areas.

Prior to 2004, there were many ad hoc efforts to monitor populations of the same groups of about 10-15 species of birds and mammals that are regularly hunted and another 10-15 species of birds and mammals that are regarded as threatened. Since 2006, these species have been monitored throughout the Park and surrounding forestry areas using 12 transects which vary in length from 3.7-15.2 km (mean ~ 9.5 km). Counts of individuals for all target species and, where possible, non-target species are made along these transect lines. Records of target species are plotted onto vegetation / compartment maps. Also, area searches are made within 9 “areas” ranging in size from 2–376 km^2 (median 12 km^2). The objective is to record occupancy, relative population density or numbers of territories for wide-ranging species within the selected target species group by directing monitoring efforts to known nesting, roosting or foraging locations. The number of target species surveyed in each area ranges from 1 to 7 species. These procedures appeared to be transitional prior to incorporation within the new national species monitoring programmes which have yet to be implemented in the region.

Analysis of biodiversity monitoring programmes

Monitoring programmes in northern Europe did not appear constrained by the need to identify a short-list of species to serve as indicators of change in the relative abundance or conservation status of other species. There was a general awareness that some species (e.g. woodpeckers, saproxylic beetles, bracket fungi, deciduous trees, epiphytes) are both much more sensitive than others to intensive forestry practices and also correlated with species richness of other taxa, thus satisfying the dual requirements of an appropriate indicator species for monitoring (Angelstam and Mikusinski 1994, Mikusinski *et al*. 2001, Roberge and Angelstam 2006). However, rather than designing monitoring programmes for these species specifically, the approach seemed to be one of quantifying those elements of habitat that are limiting the occurrences of these sensitive species (Angelstam *et al*. 2004b, Bütler *et al*. 2004). This information (e.g. required amounts of standing and fallen dead wood, stand basal area of certain deciduous tree species) was then provided as habitat targets for management (Anon. 2005). The perception is that, despite these significant advances, ecosystems are too complex to expect that a limited subset of species could serve adequately to monitor the status of all species likely to be present (Angelstam *et al*. 2004a, Roberge and Angelstam 2004). The implications of this are that much broader suites of species are included within species monitoring programmes.

All three Scandinavian countries visited utilise extensive and long-term plot-based assessments of forest stand condition, floristics and structural composition to keep track of forest growth rates and estimate the sustainability of wood supply. While similar forest inventories also occur in Australia, their value as surrogate measures of habitat for biodiversity is much more limited. The national forest inventories of Sweden, Norway and Finland, which all began more than 80 years ago, now routinely measure additional site attributes. The Swedish NFI, for example, also records the amounts of standing and fallen dead wood, the cover-abundance of understorey plant species and ground cover, and some epiphytes. The long-term measurements taken at permanent plots also enable the changing nature of forest stand conditions throughout the landscape to be quantified. The data collected from these national forest inventories are aggregated up for regional, national and international reporting and the summaries are published regularly on-line. Detailed results from the Swedish NFI, in the form of comprehensive raw data tables, graphs and Excel spreadsheets, are available for downloading and independent analysis.

Monitoring programmes are likely to be most effective if, at the same locations, they incorporate measures of site physical, floristic and structural characteristics with species counts for a broad range of animal taxa using variable-radius plots, and place these results into a landscape context using remotely-sensed data. The Swedish NILS programme included many elements of this model but, in my view, gave too much attention to exact measurements of minor landscape details (e.g. actual positions of vegetation edges, roads, minor tracks, ditches, stonewalls) and not enough to measurements of animal species occurrences, especially for vertebrates. Indeed, apart from the co-located sites used by the Swedish Breeding Bird Survey (for which only three of the eight bird count stations actually coincided with NILS habitat assessment plots), there were no assessments made for vertebrate fauna. Butterflies were monitored within a range of vegetation types that occurred within a selection of NILS 5 x 5 km grid squares.

At least four major species monitoring programmes in both Sweden and Finland used the national mapping grid in each country to position the locations of their sampling points (or sampling window) for all forest attributes (i.e. plant species composition, forest stand structure, site attributes, animal species counts and remote-sensing of landscape context). Many other programmes employed a "grid cell" approach for species surveys and data recording and, again, these programmes were aligned with the national mapping grid. This is an important step forward because it effectively by-passes the need to decide which stratification scheme is most appropriate. The complexity of this task, and the range of different viewpoints to incorporate, is one reason explaining the inertia for implementing monitoring programmes in Australia. Advantages of the grid-based approach to monitoring include greater flexibility to detect unknown threatening processes, including climate change. This is also likely to outlast monitoring programmes that employ a narrow set of issues, or current fads, as the basis for site stratification. A grid-based approach to monitoring also provides ease of aggregation of data across spatial scales to facilitate local, regional and national reporting.

The spacing of sampling points for grid-based monitoring programmes in Sweden and Finland was set variously at 10 or 25 km, and sub-plots were spaced at various intervals up to 250-1000 m within a sampling window of 1 x 1 km or 2 x 2 km around each grid point. Depending on the scale of movement for the species of interest, sampling at each grid point was usually undertaken within a series of nested plots of different sizes and, when multiple sub-plots were employed, the data were averaged for the point. An increasing tendency was observed for monitoring points and sub-plots to be marked permanently, often unobtrusively, so that later measurements could be taken at the same points. Portable global positioning units were standard issue to fieldworkers to aid this process.

The interval between successive measurements has been decreasing over the decades for the longest-running monitoring programmes from 8-10 years to about 5 years. Article 17 of the EU Habitats Directive stipulates that the main results of monitoring programmes (including Natura 2000) have to be reported to the Commission every six years. Most other monitoring programmes undertake annual assessments, while the Swedish NILS programme re-samples its plots every five years. Surprisingly, the issue of varying detectability for attributes measured or assessed in monitoring programmes did not appear to be a major concern, or at least it was rarely mentioned. Perhaps this was because many of the attributes assessed are relatively immobile but, clearly, sampling frequency within measurement periods is an important consideration for reducing the incidence of recording false absences in animal surveys (Wintle *et al*. 2005). MacKenzie and Royle (2005) recommend that sampling units be surveyed a minimum of three times when imperfect detection of species is likely.

The need for strong government and institutional support for biodiversity monitoring programmes to be effective has been highlighted by Field *et al*. (2007). These authors point to the need to secure adequate funding that is sufficiently long-term to allow changes to be detected over and above the natural temporal fluctuations that occur. Monitoring programmes are expensive but it is counter-productive not to allocate adequate resources for prompt, rigorous analysis and reporting of the data collected so that monitoring can be fine-tuned and managers can receive essential and timely feedback about their actions. My impressions of biodiversity monitoring in Scandinavia are that most programmes are given a high level of government and institutional support and this may be due in part to the “concensus culture” evident among northern Europeans and the level of respect and cooperation observed between scientists, managers and policy-makers. All programmes were managed and co-ordinated by a core group of permanent staff and, in several notable programmes, large numbers of temporary staff were employed to conduct surveys during the summer field season.

I was impressed by the efforts of the Swedish Government, through the Forest Agency (Skogsstyrelsen), to set conservation targets for a wide range of environmental variables (Anon. 2005). This process provides a clear articulation of what success would mean in the context of monitoring results and management responses. To date, this has not yet extended to the setting of population targets for species sensitive to forest management activities, however, population targets have been set for some high profile species (e.g. wolves in Sweden – which are about to be exceeded!).

I did not have an opportunity to assess whether any of the observed monitoring programmes had sampling designs that were capable of providing sufficient statistical power to find ecologically significant changes, should there be any. The Swedish NILS programme appeared to be comprehensive but the first published reports are not due until 2008. The long-running national forest inventory and game species monitoring programmes in Scandinavia appeared to be serving their intended purposes, as were the national breeding bird survey programmes and Finland’s raptor monitoring scheme. The insurance provided in all of these programmes, that is, large numbers of sites surveyed, should help to provide the necessary statistical power for many taxa. As a general sampling strategy, MacKenzie and Royle (2005) suggest that, for rare species, more effort should be devoted to surveying more sites while, for common species, more effort should be devoted to repeated surveys at the same (fewer) sites. Large numbers of sampling sites also permit the efficient use of occupancy (presence-absence) modelling which is a flexible technique for incorporating both species detectability information and site (habitat) variables within a species metapopulation framework (i.e. when species appear and disappear at different sites within the management area of interest).

Public acceptance and support of species monitoring programmes are most likely to succeed if the programme goals, assumptions, survey designs and procedures are transparent and when progressive results are made available to the public in both summarised and raw data formats for independent analysis and interpretation. As mentioned above, the Swedish national forest inventory exemplifies this approach, but many of the other monitoring programmes investigated in this study also contained these elements. The Swedish national species recording scheme, Artportalen, is another outstanding example which undoubtedly explains its strong public support and popularity.

Lessons for Australia

This study has provided an opportunity to investigate current developments in biodiversity monitoring in northern Europe and also to obtain an international perspective about the prospects for using species-based assessments as indicators of ecologically sustainable forest management in Australia. Based on these experiences, I now attempt to summarise some of the key issues that should be taken into account when designing and implementing forest biodiversity monitoring programmes in Australia.

First, there is little doubt that species and habitat monitoring is seen as an important priority internationally and as an integral component of good forest management. There is a strong focus on comprehensive, nation-wide monitoring programmes because of the need to report on national objectives and international commitments.

> The urgency to embrace biodiversity monitoring in Scandinavia may be due to a recognition that the existing conservation reserve system is inadequate, and difficult to improve, because the majority of productive forest land is held in small, privately-owned blocks. While Australia's conservation reserve system is more comprehensive, we should not be complacent because there is currently little feedback to managers of conservation reserves or wood production forests about the effects of their actions on biodiversity. The developing threat of climate change, including longer droughts and more wildfires in Australia, could lead to greatly reduced populations of many species and this also requires monitoring.

Secondly, the sampling design used by most biodiversity monitoring programmes in Sweden and Finland was systematic sampling based on the national mapping grid. The spacing between sampling (grid) points was 25 km in several programmes, and a 10 x 10 km grid cell was the basis for monitoring biodiversity in others.

> In New South Wales, we have recently proposed that biodiversity monitoring should be standardised on the basis of a 20 km grid covering the State (Kavanagh and Binns, unpublished). On public forest lands (conservation reserves and State Forests), it is proposed that sampling intensity be increased to incorporate all 10 km grid points (657 and 236, respectively), with provision available to sample additional points from the 5 km grid to address specific questions.

Third, biodiversity monitoring programmes are likely to be most effective if habitat variables, species occupancy and remotely-sensed data are collected from the same sites. This requires that sampling be undertaken within a set of nested plots which are appropriate for the species or other attributes being measured. In the Swedish NILS programme, sub-plots were located variously within a 1 x 1 km window (plants and site attributes), a 2 x 2 km window (birds) and a 5 x 5 km window (landscape context), all centred on a permanent grid point.

> Consideration should be given to increasing the range of attributes that are measured or assessed at existing forest inventory plots in Australia. Also, plot measurements should continue after the stand has been logged.

Fourth, biodiversity monitoring programmes should take a multi-species approach, recording all species detected using a standard set of survey protocols for a wide range of taxonomic groups. While the potential role of indicator species, and the efficiencies of recording a smaller sub-set of species, were recognised, few programmes in Sweden and Finland were restricted to recording only these species.

Fifth, biodiversity monitoring programmes should be designed so that they survey a large number of sites which are re-surveyed annually or within five years.

Sixth, species detectability issues need to be considered and this will require that sites are re-visited during the same sampling period.

Seventh, monitoring programmes are most likely to succeed if the programme goals, assumptions, survey designs and procedures are transparent and when progressive results are made available to the public in both summarised and raw data formats for independent analysis and interpretation.

Eighth, biodiversity monitoring programmes require strong government and institutional support to be effective. Monitoring programmes are expensive, long-term commitments. Adequate resources are needed for project management and to enable prompt, rigorous analysis and reporting of the data collected so that monitoring can be fine-tuned and managers can receive essential and timely feedback about their actions.

Ninth, biodiversity monitoring requires good communications and collaborations between scientists, managers, policy makers and the community.

Finally, the biodiversity monitoring programme underway in Alberta, Canada incorporates many of the best aspects of the monitoring programmes observed in northern Europe. The Canadian programme has been operational for more than 10 years, including an extensive period of development and implementation, and this programme should also be given due consideration in Australia. Further details can be viewed at the following website: http://abmi.biology.ualberta.ca.

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Appendix 1. Itinerary and key contacts for study tour of forestry and wildlife research and management practices in Sweden, Finland, Norway and Belarus, and current developments in species monitoring programmes.

Date	Location	Activity	Contact	Affiliation
30 April	Sydney-Helsinki	Flight to Finland		
1-2 May	Hauho	Owl research and monitoring Forest management practices	Dr Pertti Saurola	University of Helsinki
3 May	Helsinki-Stockholm	Flight to Sweden		
4-6 May	Arboga	Forest species identification Orientation	Robert Axelsson	Swedish University of Agricultural Sciences
7 May	Skinnskatteberg	Study tour planning and objectives	Dr Per Angelstam Dr Jean-Michel Roberge	Swedish University of Agricultural Sciences
8-9 May	Stockholm	National programmes for species and habitat monitoring	Dr Krister Mild Dr Per Angelstam Dr Jean-Michel Roberge	Swedish Environmental Protection Agency Swedish University of Agricultural Sciences
10 May	Stockholm-Minsk	Flight to Belarus	Dr Per Angelstam Dr Aliaksandr Puhacheuski	Swedish University of Agricultural Sciences Academy of Science, Belarus
11-20 May	Turov Pripyatsky National Park	Museum Natural History, Turov Forest species identification Forest and wildlife management practices Model Forest applications Fauna surveys Species monitoring programmes	Dr Per Angelstam Dr Jean-Michel Roberge Dr Aliaksandr Puhacheuski Dr Anatolyi Uglanets	Swedish University of Agricultural Sciences Academy of Science, Belarus Pripyatsky National Park
21 May	Minsk	Monitoring methods for vertebrate fauna	Dr Marina Dmitrenok Dr Ruslan Novitsky	Academy of Science, Belarus

22 May	Minsk-Stockholm	Flight to Sweden		
23-26 May	Riddarhyttan	Forest species identification Research projects Seminar PhD defence Species monitoring	Dr Grzegorz Mikusinski Dr Henrik Andrén Dr Chris Haney Dr Jens Karlsson Dr Jan-Olaf Helldin	Grimsö Wildlife Research Station Swedish Biodiversity Centre
27-28 May	Skinnskatteberg	Forest species identification Manuscripts	Dr Per Angelstam Dr J-Michel Roberge	Swedish University of Agricultural Sciences
29 May	Skövde	Habitat and species monitoring Forest inventory methods	Dr Per-Anders Esseen Dr Anders Glimskar Dr Sture Sundquist	National Inventory of Landscapes in Sweden (NILS and NFI) SLU, Umeå
30 May-2 June	Skinnskatteberg	Habitat and species monitoring Manuscripts	Dr Per Angelstam Dr Jean-Michel Roberge	Swedish University of Agricultural Sciences
3 June	Stockholm-Helsinki	Ferry to Finland		
4 June	Helsinki	Habitat and species monitoring programmes	Petri Heinonen Dr Jussi Paivinen Dr Risto Väisänen Dr Jari Valkama Jaako Kullberg	Metsähallitus (Forestry Division) Metsähallitus (Nature Conservation Divn.) Finnish Museum of Natural History
5 June	Hauho	Owl and raptor monitoring program	Dr Pertti Saurola	University of Helsinki
6 June	Lammi Research Station Hauho	Water and species monitoring programs Owl research and monitoring	Professor Lauri Arvola Dr Pertti Saurola	Lammi Research Station University of Helsinki
7-10 June	Kauhava	Predator-prey research Forest and wildlife management practices	Professor Erkki Korpimaki	University of Turku
11 June	Turku-Stockholm	Ferry to Sweden		
12-17 June	Riddarhyttan	Research projects Habitat and species monitoring programmes	Dr Per Angelstam Dr J-Michel Roberge Dr Håkan Sand Dr Jens Karlsson Dr Petter Kjellander	Grimsö Wildlife Research Station

18 June	Jönköping	Swedish Environmental Objectives Forestry regulatory processes	Erik Sollander Dr Per Angelstam	Swedish Forestry Agency Swedish University of Agricultural Sciences
19 June	Lund Kristianstad	National bird species monitoring program Model Forest participatory management	Dr Martin Green Dr Per Angelstam Sven-Erik Magnusson	Swedish Breeding Bird Survey, University of Lund "Water Kingdom" Biosphere Reserve, Kristianstad
20 June	Malmo-Oslo	Train to Norway		
21-23 June	Bergen	Informal forest inspections Species monitoring programmes (internet)		
24 June	Oslo-Lindesberg	Bus to Sweden		
25-26 June	Falun	Forest management practices Manuscripts	Dr Grzegorz Mikusinski Dr Jean-Michel Roberge	Swedish University of Agricultural Sciences
27 June	Uppsala	Species monitoring programmes	Dr Jan Terstad Martin Tjernberg Tord Snäll Dr Johan Nilsson Professor Lena Gustafsson	Swedish Species Information Centre Department of Conservation Biology, SLU
28-29 June	Stockholm-Sydney	Flight to Australia		