Forest Biodiversity Maintenance: Instruments and Indicators in the Policy Implementation

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Abstract

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The global biodiversity loss within forest ecosystems has attracted attention during the last decades. Awareness increased both world-wide and in Sweden, which led to changes in the Swedish forests policy. In the Swedish Forestry Act of 1993 the environmental and production goals became equally important, and several new policy implementation instruments were taken into use. One of these was the Woodland Key Habitat Survey, in which indicator species are used to identify sites with conservation values. The first two papers in this thesis assess the relationships between the lichen indicator species found in the study area (in South-Central Sweden) and their growing-substrates and habitats, respectively. Both studies confirm that the indicator species showed habitat preferences which included old or deciduous trees. In Paper II also the habitat preferences of sedentary birds were assessed and the mixed deciduous habitats showed to be the more species rich, compared to pure coniferous forest. Paper III and IV evaluate the forest owners' intentions and knowledge of nature conservation, as well as their attitudes towards it. In paper III the conservation intentions of the forest owners were estimated on the harvest registration form and compared to the actual retention at the clear-cuts. The intentions were followed by associated practices, however, the retained amounts of stand structures were overall low. I conclude that the intentions did not increase over the study period, the retained amounts were too low to meet, *e.g.*, the Forest Stewardship Council standards, and, also, that such forms could become important information instruments to the forestry authorities concerning intentions and practices of the forest owners. In Paper IV the results of a questionnaire sent to non-industrial private forest (NIPF) owners within the study area, showed that knowledge about conservation and attendance to a recent educational programme, which included conservation information, were positively related to the attitude towards it. However, those occupied with land-use had a more negative attitude towards conservation than others. Also, in the ranking of operational goals for their own conservation efforts, only 7% of the respondents ranked 'long-term species survival' as their first priority, while the vast majority ranked 'forest health' as number one. In the fifth and last paper the usefulness of indicator species in monitoring systems adapted to NIPF owners, is discussed. In the questionnaire used in paper IV, NIPF owners were asked to mark all species that they could recognise, from a list of 12 forest species. The results showed that they had a weak knowledge of the listed lichens and fungi, but all four birds were recognised by more than 50%. Thus, in indicator species based monitoring systems for NIPF owners and the public only a few easily communicated and conspicuous species of documented indicator value should be used, *e.g.* vertebrates.

Keywords: Biodiversity, boreal forest, forest owners, indicator species, nature conservation, policy implementation.

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"Politics is the art of looking for trouble, finding it everywhere, diagnosing it incorrectly and applying the wrong remedies."

Groucho Marx

Contents

Appendix

Papers, I-V

The present thesis is based on the following papers, which will be referred to by their Roman numerals:

I. Uliczka, H. & Angelstam, P. 1999. Occurrence of epiphytic macrolichens in relation to tree species and age in managed boreal forest. Ecography 22: 396-405.

II. Uliczka, H. & Angelstam, P. 2000. Assessing conservation values of forest stands based on specialised lichens and birds. Biological Conservation: 343-351.

III. Uliczka, H. 2003. Nature conservation efforts by forest owners – intentions and practice in a Swedish case study. Silva Fennica 37(4): 459–475.

IV. Uliczka, H., Angelstam, P., Jansson, G. & Bro, A. Non-industrial private forest owners' knowledge of and attitudes towards nature conservation. (Submitted manuscript.)

V. Uliczka, H., Angelstam, P. & Roberge, J.-M. 2003. Indicator species and biodiversity monitoring systems for non-industrial private forest owners – is there a communication problem? Ecological Bulletins 51, in press.

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Introduction

Background

The extinction of species has caught much attention during the last three decades. This course of events threatens both large conspicuous species, such as tigers and gorillas, as well as small and to the public generally unknown, species, like epiphytic lichens. A major cause of the biodiversity decline is habitat loss brought about by deforestation.

In some parts of the world deforestation has lead to the disappearance of whole forest ecosystems. Not only have the trees disappeared, but also the inhabitants and users of the forests, *e.g*., fruit and leaf eating animals, epiphytes, cavity nesters and wood decomposing invertebrates. Agricultural land, grasslands or deserts have replaced the forests (Glanznig 1995; Conte 1999; WWF 2002). Normally, the forests, with their tall vertical structure, were more diverse and had longer and more complex food chains than these two-dimensional ecosystems (Briand and Cohen 1987; Brokaw and Lent 1999).

In the boreal and hemiboreal forests of Sweden the situation is different. These forests are still present; Sweden is forested to 55% of its total area (Skogsstyrelsen 2000). Sometimes it is even argued from the forestry sector that: "We have never had so much forest as we have today" (*e.g*. Skogs- och Träfacket 1998). However, this is a quantitative, not a qualitative truth. The statement is true only if the forests are viewed upon as 'trees standing together in large contiguous groups,' regardless of other properties. The total number of stems may be higher in today's young and dense stands, than in the old forests of the past (Linder and Östlund 1998), but according to the most recent red-list the Swedish forests contain much fewer forest specialists than before (Gärdenfors 2000). Hence, the Swedish forests are poor in terms of biodiversity, and the qualitative truth, from a holistic and ecosystem based perspective (Schlaepfer *et al*. 2002), is that we have never had so little forest as we have today. This is the problem which underlies the studies within this thesis.

The Swedish historical forest management and its implications for biodiversity

Due to a warmer climate between 6,000 and 4,000 BP, some of the deciduous taxa, *e.g*. beech (*Fagus*), oak (*Quercus*), hazel (*Corylus*), elm (*Ulmus*), lime (*Tilia*) and alder (*Alnus*), extended much further north than today (Huntley 1988). After that period a gradual change occurred in the composition of the dominating forest type. It has changed from a mixed coniferous/deciduous forest, or pure deciduous, into a structurally simplified and species-poor coniferous-dominated forest type, mostly made up by Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) (Björkman & Bradshaw 1996; Björse & Bradshaw 1998). Björkman and Bradshaw (1996) found that the diversity of woody species in Swedish forests has declined from about 14 original species, to 7 or less, at present. The more recent changes, during the last 1000 years, were not due to the cooling of the climate, but to land-use and the human use of forest products (Björse & Bradshaw 1998; Lindbladh *et al*. 2000). The rate of change was most rapid during the last 150 years, but this was only the culmination of a transformation initiated 850 years earlier (Lindbladh *et al*. 2000).

The pre-industrial agricultural use of the forests was mainly for slash-and-burn culture and grazing (Ericsson *et al*. 2000), which locally created a species rich forest-meadow system (Lindbladh & Bradshaw 1998) and allowed for a first successional stage of deciduous trees after the fields were abandoned. A widespread harvesting of leaf-hay may also have shaped the landscape up until the end of the 19th century (Slotte 2001). Farmers also used wood for potash production, house building and firewood (Nilsson *et al*. 1990). Forest fires were common, partly as fires were used in the slash-and-burn technique, but also as many wild fires occurred (Lindbladh & Bradshaw 1998), and until the end of the 19th century forest fires affected the presence of the early successional stage of deciduous trees on burns. Even though the impact of agriculture was considerable, most of the boreal forest landscape used to be characterised by continuous multistoried old-growth forest (Östlund *et al*. 1997; Axelsson *et al*. 2002).

The Swedish state finances have for several centuries, during the industrialisation period and still, to a large extent relied on the income from forestry. Natural resources have been efficiently exploited, *e.g.*, for export production of copper, iron and tar, for which Sweden had a dominant position on the world market as early as the 17th century (Sundberg *et al*. 1995). The mining industry had a large demand for forest products, such as charcoal (Attman 1986). Today, the mining industry is mainly closed down and the forests are used for other types of production, such as pulpwood and timber.

This industrial use of forest products started in the southern half of Sweden, and these forests were the first to be severely affected. Between 1650 and 1900 the forested area in Southern Sweden declined considerably (Wieslander 1936; Arpi 1959). Following the Forestry Act of 1903, which stated that regeneration of trees must be made after cutting (Bondeson 2001), the forest cover began to return to its former extent (Nilsson 1990). Thus, the present forest cover in Southern Sweden is almost twice as large as it was a hundred years ago. Consequently, most of these forests, if not already regenerated, are mature from a forestry perspective, but biologically they can be considered as young or middle-aged. Such forests rarely contain large trees, which differs from the past; studies in virgin forests suggest that a density of 10-20 living trees per ha with a diameter at breast height > 70 cm may have been typical for many of the southern Scandinavian forests (Nilsson *et al.* 2001).

Older forests are mainly found in the north. However, the northern forests have also undergone structural changes during the last centuries. The main changes are due to industrial forestry, but also earlier use, such as the potash production during the 17th to the19th century, may have affected these forests (Östlund *et al*. 1998). Hence, also in the northern forests old and large trees are scarce (Östlund 1993; Axelsson *et al*. 2002).

This situation is not unique to Sweden, similar forest changes have been reported in many other countries. Siitonen *et al*. (2000) found that in Finland both large pines and deciduous trees were about 10 times more frequent in old-growth than in mature managed stands. Also, large differences in the amounts of dead wood in managed and natural forests have been reported, *e.g*., in the above Finnish study, and in North America by McGee *et al*. (1999).

Even though some of the deciduous tree species declined or disappeared in Central and Northern Sweden after the change in climate, several other deciduous species tolerate the cold climate in these regions, *e.g*. birch (*Betula* spp.), sallow (*Salix* spp.), rowan (*Sorbus aucuparia*) and aspen (*Populus tremula*). The deciduous successional stage after fire used to cover 8% of the Swedish forest area (Zackrisson & Östlund 1991), but became severely reduced due to an active promotion (planting) of pure coniferous stands during the 20th century. Up until recently it was considered that effective forest management included the removal of deciduous trees, which was also stipulated by the authorities (Swedish Forestry Act 1979:429). Hence, in almost all of the forests these trees were removed, either mechanically or with herbicides. Axelsson *et al*. (2002) studied formerly mixed deciduous stands and found that they changed into mainly coniferous stands during two time periods, first in 1906-15, and then between the late 1960s and 1999, when the deciduous trees were totally removed from the stands.

It is, however, not enough to preserve forest to sustain deciduous trees. The deciduous component may decline over time even in unmanaged forests, due to the absence of natural disturbance regimes. Prohibiting disturbances can prevent the regeneration of deciduous trees. For example, fire suppression allows the late successional stages of conifers to prevail continuously (Linder 1998). Emulating natural disturbance regimes may thus be prescribed for biodiversity restoration (Angelstam 1998; Jasinski & Angelstam 2002).

A recently occurred problem for the regeneration of deciduous trees is the high densities of large herbivores, which prefer some deciduous tree species, *e.g*., sallow. rowan, and aspen, to pine (Shipley *et al*. 1998), when these are available. Thus, emerging deciduous seedlings will risk a high browsing pressure from herbivores, mainly moose (*Alces alces*) (Ericsson *et al*. 2001). When browsed every year they will not develop to tall trees, which can affect tree composition on the landscape scale.

The structural simplification of the forest habitats due to the management methods of the last two centuries has affected many forest species negatively (Esseen *et al*. 1996; Angelstam 1997; Nilsson 1997). In other parts of the world the problem could be the reverse regarding dominant tree species, mixed forests are diverted into pure deciduous ones, which also causes the loss of some bird species (Drapeau *et al*. 2000). In any case, the losses of substrates are the main reasons for the decline and disappearance of many forest living plants and animals (Bernes 1994; Berg *et al*. 1994; Gärdenfors 2000). The most commonly mentioned substrate losses causing the species declines in the managed Swedish forests are those of deciduous trees, old trees, and of dead wood in different stages of decay (Gärdenfors 2000).

Many studies point out the differences between managed and unmanaged forests in terms of species diversity and population densities (Järvinen *et al*. 1977; Nilsson 1979; 1997; Boström 1988; Gustafsson & Hallingbäck 1988; Angelstam 1990; Rose 1992; Vellak & Paal 1999; Edenius & Meyer 2002). Intensive management also compromises ecological food webs; species that in turn depend on the declining substrate specialists for food are at risk too. Also, instead of declining, some common generalist species can increase their densities. Thus, a turnover of species can occur, which, nevertheless, diminishes species diversity in the landscape (Väisänen *et al*. 1986; Haila & Järvinen 1990).

Forest policy and nature conservation

The exploitation of the forests during the 19th century resulted in logging exceeding the increment, and the re-growth of production forests was severely threatened. Thus, in 1896 a commission with the assignment to prepare suggestions for a new forestry legislation was appointed by the government (Bondeson 2001). The work of the commission resulted in the Forestry Act of 1903, which stipulated regeneration on all forest land after felling. No other conservation regulations were included in this legislation. Instead, the next change in the legislation, in 1948, further promoted industrial large-scale management methods, like single species plantations and clear-cutting, without any nature considerations taken at all. Thus, this post-war forest policy was aimed only at an increase in production, which also took place as the forest industry rapidly expanded (Bondeson 2001).

Nature conservation on privately owned land was not prescribed in the Swedish forest policy until 1975 (Lämås & Fries 1995). Its importance was then strengthened in the Forestry Act of 1979 (Swedish Forestry Act 1979:429; Ekelund & Dahlin 1997). However, also this time the policy was mainly aiming at securing production, only now for the wealth of the Swedish society instead of for the revenue of the forest owner (Bondeson 2001).

During the 1960s and 1970s, an interest in nature conservation arose in organisations concerned with environmental and biodiversity issues (Wirén 1985; Olsson 1992; Sörlin 1991; Wood 2000). The word ‘tree-hugger’ became a recognised and familiar term. Nature conservationists and other environmentalists began to raise the question of the lack of conservation efforts in forestry (Wirén 1985) and scientific studies on the subject were also initiated. For example, Nilsson (1979) showed negative effects on birds by forest management, and Eckerberg (1988) showed that few conservation measures were taken in common forest management - especially by the large forest companies.

During the 1980s and 1990s the issue of conservation in forestry became highlighted on the international level. Both the United Nations (United Nations 1982) and the European Union (Anon. 1998) developed strategies for multipurpose and sustainable use of forests, *e.g*., the National Forest Programme, a global framework based on the Tropical Forest Action Plans (*e.g*. Gluck *et al*

1998; Bisang & Zimmermann 2003). In 1992 Sweden signed the Biodiversity Convention in Rio along with 149 other countries (United Nations 1992). Also, environmental certification systems, *e.g.* Forest Stewardship Council (FSC), gained ground very rapidly in the large forest companies in Sweden during the 1990s (Elliott & Schlaepfer 2001a,b). There was a consumer demand for green-labelled timber (Crossley 1996) and an environmentally friendly profile became part of a marketing strategy. However, the private forest owners associations were negative towards the concept of certification and the FSC national standard, and while the large companies became certified, these owners did not (Elliott & Schlaepfer 2001a).

Public concern together with the scientific evidences of a biodiversity decline put pressure onto policy-makers to change the forestry legislation from production-oriented into multiple-use oriented, *i.e.* to prompt the use of environmentally-friendly methods in forest harvesting in the legislative statutes as well as to take decisions on implementation instruments for nature conservation. Thus, in 1994 (SOU 1992; Swedish Forestry Act 1993; Lämås & Fries 1995; Angelstam & Pettersson 1997), there was a substantial change in the legislation concerning nature conservation. This time the goals for productivity and biodiversity became equally important. The first paragraph of the Forestry Act since then states that:

> "The forest is a national resource. It shall be managed in such a way as to provide a valuable yield and at the same time preserve biodiversity." (Swedish Forestry Act 1993, § 1)

The two goals are defined as such:

> *Environmental goal*
>
> "The productivity of forestland shall be preserved. Biodiversity and genetic variation in the forests shall be secured. Forests must be managed so that plant and animal species, which exist naturally in the forest ecosystems, can survive under natural conditions and in vigorous populations. Endangered species and vegetation types shall be protected. The forests historical, aesthetic and social values must be defended." (Skogsstyrelsen & Naturvårdsverket 1998)

> *Production goal*
>
> Forests and forestland shall be utilised efficiently aiming at a sustainable and valuable yield. The composition of the forest production must be such, that it has potential to satisfy different human needs in the future." (Skogsstyrelsen & Naturvårdsverket 1998)

When the legislation was under development, all involved parties, *e.g.* nature protection organisations, forest companies, and forest owner associations, agreed that the Forestry Act should lack penalties for non-compliance with the biodiversity goal (Regeringens prop. 1992/93:226). Thus, the Forestry Act in a sense is to be considered more as a political statement than a binding legislation. This was in line with the new political paradigm, *i.e.* policy-making should turn from a top-down hierarchical process, into an interaction between policy-makers, authorities, organisations, stakeholders, and other actors involved in forest management (Dykstra and Heinrich 1996; Appelstrand 2002; Schanz 2002).

Forestry is also regulated by a wide-ranging framework legislation, the Environmental Code, which was developed during the late 1990s, and came into force in 1999 (Environmental Code 1998; Nilsson 2001). This legislation governs different types of instruments for protection of forestland. For example, it dictates that small habitats with threatened animal or plant species may be declared as habitat protection areas by the government or by an authority assigned by the government.

Three instruments used in the forest policy implementation

When major legislative changes are to be implemented there is a need for arsenals of new means and methods as well as for new instruments and tools (Skogsstyrelsen & Naturvårdsverket 1998; Pregernig 2001; Hogl 2002). Instruments for policy implementation are the regulations and prescriptions, but it can also be, for example, financial incentives, such as compensation for setting aside forest areas and other subsidies, or information campaigns. Decisions on the political levels of government and parliament are mainly concerning the legislative instruments, *e.g.*, the municipalities' right to protect habitat by creating nature reserves, and the size of the budget for the financial means. Otherwise much of the instruments, methods, and tools used in the forest policy implementation process are developed and decided by the state authority, the National Board of Forestry (NBF). In this thesis I have examined some aspects of three of the currently used instruments/tools. These are:

1. *The concept of indicator species for Woodland Key Habitats* (Paper I, II, and V)

On commission from the Swedish government the NBF initiated a project called "The Swedish Woodland Key Habitat Survey" (WKHS) in 1993, with the objective to identify habitats for biodiversity maintenance (Nitare & Norén 1992). This was made by thorough inventories of the forests. By 2002 11.7 million hectares of privately owned forestland in Sweden had been surveyed for WKHs (Skogsstyrelsen 2002a) (other landowners were supposed to perform inventories themselves). The forests were surveyed for sites containing certain key elements of old-growth forests, or sites with presence of any of a set of more or less threatened or vulnerable species, so-called ‘signal’ species (Skogsstyrelsen 1994). The signal species, which were bryophytes, fungi, vascular plants and lichens, were thus tools by which the key-habitats were identified. Their presence was supposed to indicate the presence of other species with specific habitat demands or other forest features, like a certain state of naturalness, presence of natural disturbance regimes, and a high frequency of important habitat elements. The identified WKHs were registered in a database.

The WKHS serves as a practical instrument for conservation (Skogsstyrelsen 2002a) as well as an information instrument to both NBF and the forest owners. The latter group receives information on habitats with conservation values on their forestland. They can become economically compensated for setting aside WKHs, but in the guidelines NBF states that it first and foremost is their obligation to voluntarily set them aside (Skogsstyrelsen 2002b). In the first two papers in Appendix I examine some of the signal species and their habitat demands, in comparison to other species. In paper V the applicability of indicator species is discussed.

2. *The registration form for regeneration cutting* (Paper III)

Since 1975 forest owners are obliged to notify the NBF about planned management activities in their forests (Bondeson 2001). This is made on a registration form. A change, which came about with the Forestry Act, in 1994, was that a new version of the form was developed. On the revised version of the form also planned conservation efforts could be reported. The intentions of the forest owners in regard to which stand structures they report to retain at the clear-cuts, as well as what was actually retained, are examined in paper III in the appendix. Also, the usefulness of the form as a tool in conservation work is discussed.

3. *Information about forest biodiversity and nature conservation* (Paper IV)

As the implementation of the forest policy largely depends on voluntary efforts conducted by the forest owners, the NBF in 1989 initiated an educational programme on the subject of forestry and conservation measures in forest management. This programme, “Richer Forest” (Skogsstyrelsen 1990), was in 1999 replaced by another programme, named “Greener forest” (Skogsstyrelsen 1999), where the subjects of forest ecology and nature conservation gained even more attention. The fourth and last paper evaluates the effects of the non-industrial forest (NIPF) owners’ knowledge about nature conservation on their self-reported attitude towards it, as well as on their actions taken in practical management.

Study area

All five studies were performed within the municipality of Lindesberg in the old mining district of Bergslagen, in South Central Sweden. Lindesberg is located in the transition zone (Limes norrlandicus) between hemiboral and boreal forest.

Bergslagen has because of mining and its demand for wood, the longest history of industry-related forest exploitation of the Swedish regions. Recently the Local History Association of Lindesberg had slag dated by the ^{14}C-method, and found it to originate from the 12th century. The extent and intensity of forest use has been high since the late 17th century. Wieslander (1936) estimated that in Bergslagen in the 1740s, mining activities alone consumed 65% of the estimated annual increment of the forests. The wood resource was thus overexploited, as the consumption of firewood and wood for constructions was estimated to have used more than the remaining 35%.

The first two studies were made within the study area of the Grimsö Wildlife Research Station, with forests that, like most forests in the region, are dominated by Norway spruce and/or Scots pine (Björkhem & Lundmark 1975; Skogsstyrelsen 2000). The scarce deciduous component within the forests mainly consists of birch and aspen. In the matrix, deciduous trees have colonised abandoned fields and meadows of former farms. At these sites the deciduous component comprise on average 70% of the basal area (Enoksson *et al*. 1995).

The forests within the Lindesberg area has an ownership distribution as: private enterprises own 51%, the state and other public institutions own 10%, and share holding companies own 39%. This means that the ownership is roughly 50/50 between large companies and smallholders, which is about the same as the ownership pattern of the whole Swedish forest area (Skogsstyrelsen 2000).

Paper I and II

Rationales

At the time of the enforcement of the Forestry Act of 1993, knowledge on how much old-growth forest and threatened species that still remained, was rather limited. For that reason the WKHS project was much needed and hastily launched, which did not allow for time-consuming scientific evaluations before the implementation. As the concept was never comprehensively tested, the presumed natural forest indicator species, *i.e*. the signal species, were chosen on the knowledge of taxonomists and ecologists.

The key-habitats were identified by either the presence of the signal species, or the presence of certain habitat structures, which were considered as necessary for the presence of sensitive species. However, if the presence of the species should be treated as an interchangeable habitat property to the presence of the habitat structures they are supposed to require, these habitat structures should be well known. To acquire this knowledge, the habitat requirements of specialised species from several different taxa must be measured and quantified.

Thus, to evaluate the use of indicator species, some questions must be answered, *e.g.* which habitat elements these species require, and if they are restricted to the habitat elements that they are supposed to indicate the presence of. Since it is assumed in the WKHS concept that signal species indicate the presence of other demanding species (Skogsstyrelsen 2002a), it is also important to test to what extent other species are present at the sites where signal species are found.

Answers to the above questions can be assessed by measuring the occurrences of selected species along gradients of (1) density and (2) substrate properties, of the supposedly important habitat elements. These papers aim at clarifying how epiphytic macrolichens, and in paper II also sedentary birds, react in gradients of proportion of deciduous trees and of tree age, respectively. These two habitat properties were studied in paper I at the scale of individual trees, and in paper II on the scale of stands.

Indicator species

The use of vertebrate indicator species was criticised by Landres *et al*. (1988) as "lacking precise definitions and procedures." Niemi *et al*. (1997) examined the habitat association of bird indicator species, as defined by the U. S. Forest Service, and found a lack of consistent pattern. Following this result they doubted the ability to use a few species to indicate good conditions for others. Instead they argued for the development of techniques that improve habitat classifications and also for monitoring of trends in both habitats and the species within them.

Since many lichens are considered sensitive to air-pollution they have been used as bio-indicators of pollutants, such as SO_2 (*e.g.* van Dobben & ter Braak 1999). The use of lichen indicators of forest continuity has, however, also been criticised as being anecdotal or based on intuitional knowledge. Peterken (1993) suggested that the popular interest in 'Ancient Woodland Indicators' in Britain resulted in an example of an indicator list where the presence of these species was not backed by evidence of the forest history.

Contradicting the critique on the usage of indicator species, studies have been made during the last decade, which propose some species as useful indicators of forests with high conservation values. Kuusinen (1996a) found cyanobacterial lichens to be good indicators of forest continuity in Finland. Selva (1997) calculated the IEC-value (Index of Ecological Continuity) after the model of Rose

(1992), using a set of 30 lichen species. He found that high values of the IEC confirmed the ancient status of the investigated forest in 12 cases out of 15. He also suggested the total number of *Calicales* species as a good indicator of continuity. Tibell (1992) created an index by using twenty crustose lichens as index species. The index was highly correlated with forest continuity and with the number of threatened species. Gauslaa (1994) found *Lobaria pulmonaria* to be a good indicator of both continuity and a large number of rare species. Similarly, Nilsson *et al*. (1995) showed that where *L. pulmonaria* occurred, several red-listed beetles dependent on hollow trees were also found. Accordingly, some lichen species can be used as indicators for identifying key-habitats, which can contain a diverse stock of species. If such habitats are protected, there is a possibility that the species can spread to other localities nearby, which also was the assumption in the WKHS.

Birds, as lichens, have been used as bio-indicators of pollutants. However, at the time of the study in paper II, few studies had assessed the value of birds as indicators of forest qualities for practical nature conservation. Among those existing was a study by Jansson (1998), who found that when the lesser spotted woodpecker (*Dendrocopos minor*) was present in a patch of deciduous forest, the probability of presence of three other selected bird species (*Aegithalos caudatus*, *Parus palustris* and *P. caeruleus*) was very high. The presence of *A. caudatus* was the second best predictor of the presence of the other species. *A. caudatus* was also found to be an indicator of a deciduous component, as it needed at least a 5% of deciduous element in the landscape. Furthermore, Mikusinski and Angelstam (1998) had found that the diversity of woodpeckers in Europe declined with the length of the economic history, *i.e*. the longer a country had been industrialised, the fewer woodpecker species it contained. Since woodpeckers are sensitive to changes in their habitat (Angelstam & Mikusinski 1994; Scherzinger 1998), it seems that they could be good indicators of various types of natural forests (see also Mikusinski *et al.* 2001; Roberge & Angelstam 2003).

Criteria for indicator species

In order to make the knowledge and use of indicator species more widespread among forest owners, forest companies and other interested members of the public, the indicators are suggested to be selected following certain criteria (Landres *et al*. 1988; Noss 1990). Here I briefly review some of these:

• *Easily found*: The detectability of the species is important. A species should be easy to see, or hear, in the forest. Large sized species should be preferred, compared to small and inconspicuous ones, and species that can be surveyed around the year, compared to migratory species.

• *Easy to identify*: Species that are very difficult to identify because of their resemblance to other, not closely related, species, are of little value in this context.

For example, some lichen species can be difficult to distinguish from each other without chemical tests, especially crustose lichens, and some can change colour and texture depending on water content. However, if the species are closely related and have similar habitat requirements, their indicator value can be the same and thus identification to genus is enough.

• *Have narrow habitat requirements*: The niche of an indicator should be narrow and known. It should be sensitive to alteration and fragmentation of its habitat. In order to be a good indicator, it should also have a rapid and well-described response. Habitat specialists normally react faster to changes than habitat generalists.

• *Not too rare or too common*: A good indicator should most often be encountered when the conditions are right. Rare species will not be encountered very often even under good conditions, which will not serve the purpose of useful indicators. Very common species may be found in many marginal habitats, and will thus also be unsuitable. A species should also be used as an indicator only within its main distribution range, since outside that it might be too rare.

Studied species groups

Lichens

Lichens are a very complex and diverse group of species. They consist of two components working in symbiosis: fungi, the mycobiont, and algae, the photobiont (Moberg & Holmåsen 1992). Both the fungal and the algal components can be of many different species. The fungus most often belongs to the group Ascomycetes (During 1992). The algal component is mainly a green alga or a nitrogen fixing blue-green alga; a cyanobacterium.

The reproduction of lichens is also diverse. Both sexual and vegetative reproduction occur, but only the fungal component reproduces sexually. The vegetative ways of dispersal are by soredia and isidia, where the lichen buds off small units containing both fungal and algal cells, and by fragmentation, when small parts of the lichen breaks off and may be dispersed by the wind or birds.

Lichens are classified into three main growth forms. These are: foliose, fruticose, and crustose (Hale 1983). Fruticose lichens are bushy and often relatively large, while some foliose lichens have "leaves" too small to be seen without a magnifying glass. The crustose lichens grow as a crust over the substrate surface. There are also intermediate growth forms.

Of the more than 2000 lichen species in Sweden, between 500 and 600 grow mainly on bark, or sometimes on bare wood (Hallingbäck 1994). The rest grow on rocks of different minerals, on the ground, and on many other substrates, some of which are very specific, such as shed reindeer antlers. Epiphytic lichens on living trees are often tree-specific on one or a few tree species (Hallingbäck 1994). They are also often sensitive to climatic conditions within the habitat.

Availability of suitable substrate, tree species diversity, and tree density, are important factors that affect the occurrence and abundance of lichens. Other factors are fragmentation and isolation of the habitat, which affect dispersal distances (Andrén 1994). Some species are adapted to disperse in the forest interior, with its short dispersal distances. For example, Dettki (1998) found that *Alectoria sarmentosa* dispersed with much fewer, but larger sized, fragments than *Bryoria* spp. The *Alectoria* fragments were transported shorter distances than the *Bryoria* fragments. Inefficient dispersal can cause a decline of a species; only fast and efficient dispersers will finally inhabit a forest landscape with large clear-cuts made in short time intervals. These differences in dispersal abilities may thus make the slowly dispersing species suitable as indicators of habitat continuity.

Sedentary birds

The boreal landscape in its pre-human state was a mosaic of lakes, open mires, burns, deciduous patches on old burns and different types of old-growth forests (Sjöberg & Ericsson 1997). The European birds are thus adapted to a mosaic landscape, and the landscape is still a mosaic, but even so many sedentary forest bird species have declined during the last decades (Mönkkönen & Welsh 1994). The composition of the mosaic has changed; it now has more farmland, clear-cuts, and pure, even-aged coniferous stands, which has affected the bird species negatively. For many of the bird species the population decline is entirely due to the new and efficient land use practises, such as intensive forest management (Nilsson 1979; Angelstam & Mikusinski 1994; Tucker & Heath 1994). The impact of fragmentation of the original habitat on forest birds is severe (Wilcove & Robinson 1990).

Declining bird species often depend on insects, which in their turn depend on dead wood or deciduous trees (Ehnström & Waldén 1986). Consequently, the intensive management, promoting only living coniferous trees, is highly disadvantageous for these birds (Enoksson *et al*. 1995). An area cleared from trees by a natural disturbance, such as a fire or a storm, should in most cases have a first succession of deciduous trees, which would last more than a 100 years. As described above, this stage is now to a large extent omitted, which partly causes the drop in numbers of bird species and individuals.

Some bird species start to decline earlier than others; *i.e*. they react differently to changes (Morrison *et al*. 1992). Such differences in vulnerability may for example make certain species suitable as indicators of habitat properties or changes not always evident to the human eye. Also the use of only sedentary birds may guarantee that detected population changes are reactions to environmental changes within these regions, not elsewhere, *e.g*., in the winter feeding grounds of migratory birds.

Materials and Methods

In the first paper of the Appendix I studied the effects of tree species and tree age on the presence and abundance of a set of 33 fruticose or foliose macrolichens (paper I) in 90 circular plots with a 10 m radius that were representative for this area. Very common lichen species were excluded on the basis of the criteria for indicator species. Twenty of the species in the set were in use as 'signal' species in the WKHS project, and the remaining 13 species were chosen as having a possible indicator value. I sampled the four most common tree species, pine, spruce, aspen and birch, for macrolichens at 0-2 m from the base of the tree. The dataset from the lichen survey was used in both of the papers.

To assess the effects the amounts of deciduous trees and old trees, respectively, had on species numbers of different taxa I used the same set of lichens and surveyed a set of 22 sedentary bird species (paper II). The birds were known to presently occur, or have had permanent populations, in this region (SOF 1986). I compared bird and lichen species numbers between three habitat types: mixed forest, old-growth coniferous forest and managed coniferous forest at the 3 x 30 plots in a 150 km^2 area and related the occurrence of both sets of species to stand parameters.

Results and discussion

From the set of 33 macrolichen species I found a total of 17 on the sampled 1533 trees, six of these were signal species. As I predicted the majority of the signal species were not encountered. Though, it is possible that they exist elsewhere in this region. However, if these species have specific habitat demands, and also are inefficient dispersers, they may not be able to disperse from their scattered refuges through the hostile matrix of managed forest.

Pine and spruce had a total of 11 lichen species, ten on each, respectively. Old pines generally had a lower abundance of the fruticose lichens and a higher abundance of the foliose lichens *Hypogymnia farinacea* and *Imshaugia aluerites*, than similarly aged spruces. Presumably this was due to differences between these trees in the structure of the tree substrate. The structure of the bark is important; the rough bark of old trees creates a larger surface and a more stable substrate for lichens than the smooth bark on young trees. The stability of the substrate may also be the reason why coniferous trees with a low growth rate had significantly more signal lichen species than those with a high growth rate.

A total of 15 lichen species were found on the deciduous tree species, nine on birch and eleven on aspen, respectively. Six of the species were exclusive for aspen, including the two signal species *Collema subnigrescens* and *Leptogium saturninum*. The five species that aspen shared with other tree species often showed a lower abundance on aspens, with the exception of *Evernia prunastri*. Aspen thus differed greatly from the other tree species in the lichen composition, which implies that it is a very important tree species for the enhancement of biodiversity. Birch is the most abundant deciduous tree species in the boreal forest, but aspen should be actively promoted by forestry. Other deciduous tree species, which could not be sampled in this study due to their low densities, are also valuable for lichen diversity. While sampling six forest tree species for lichens Kuusinen (1996b) found the most species on *Salix*, which is thus also important to retain.

Birch was colonised earlier by the target lichens than the other tree species. The explanation for this may be that the bark of the birch often becomes rough quickly, which makes it suitable for fruticose lichens.

This study thus confirms the earlier observations that some lichen species prefer old trees. On all four tree species, there was an increase in the number of lichen species with the age of the trees. I also found a significant increase in lichen abundance with tree age in 30 cases (out of 40 possible).

The signal species *Hypogymnia farinacea* and *Bryoria furcellata* occurred more frequently than *Alectoria sarmentosa* and *Bryoria fremontii*, which were found only on old trees in remnants of old forest, but not on mature trees in the surrounding managed forest. I suggest that the former two species should have a lower indicator value in this region. Also *Usnea subfloridana*, which is not a signal species, could be selected as a low ranked indicator species in conifer-dominated forest, as it preferred old conifers or deciduous trees. *Bryoria capillaris* and *Usnea filipendula* seemed to be the fastest colonisers, as they both were present on young trees, and thus they have no value as indicators in this context.

I could not detect a competitive situation between common and rare species, as the most abundant or largest lichens did not exclude other species. The length of the longest fruticose lichen was positively correlated with the total number of lichen species on the tree. Shade had a negative effect on the number of species.

In conclusion, the signal lichen species encountered showed a preference for old trees or aspens. This result, together with the generally low number of signal species, point at the importance of promoting these trees for the preservation of biodiversity in the managed boreal forest.

In paper II, the species, *i.e.*, lichens and birds, found in the managed forest, were, with one exception, subsets of the species found in the mixed and the old-growth forests. Both the total number of bird species and the species diversity were highest in the mixed forest. There was also a positive correlation between the number of bird species and the proportion of deciduous trees per plot. The conifer-dominated forest types did not differ in bird diversity and species number. I argue that the main reasons for the absence of such a difference were the previous loss and the fragmentation of the old-growth forest in this landscape. The patches of old-growth coniferous forest are very small and their proportion of the studied area is less than 1% (Angelstam 1997). Hence, a threshold in the amount of habitat for the occurrence of some of the old-growth conifer specialists, may already have been passed.

Four species, all specialising on deciduous trees, were exclusive to the mixed forest and one was exclusive to the old-growth forest. The four bird species that were not encountered all require extensive areas of old-growth forest (Väisänen *et al*. 1986; Angelstam & Mikusinski 1994).

The number of lichen species per plot increased in relation to the percentage of old trees. The total number of lichen species decreased from the mixed forest, with 15 species, to old-growth, with 11 species, and further to the managed forest, with 8 species. The diversity index of lichens was, as for the birds, greatest in the mixed forest, but unlike the bird study the other two forest types differed, with old-growth having the higher diversity. Also in contrast to the bird study, the mean number of lichen species per plot was highest in old-growth, while the other forest types did not differ from each other. However, the lichen abundance was highest in the mixed forest. I argue that the main reason why there was no increase in lichen species numbers with proportion of deciduous trees was the very low abundance of old deciduous trees and the short habitat continuity, as this forest type exists mainly on former farmland.

Only the two most abundant of the six encountered signal species were present in the managed forest, however they were found at more than twice as many plots in the old-growth forest. The presence of signal species was positively correlated to the presence of the remaining species of the set, which suggests that these signal species are valid indicators of habitat quality for other species.

Paper III, IV, and V

Rationales

That information is given does not guarantee that information is received. Furthermore, not even received information always changes an attitude, let alone a practice (Tarrant & Cordell 1997). Thus, a legislation that is supposed to be complied with through the use of 'soft' instruments like information campaigns, and lacks retaliating penalties for insubordination to it, may become inadequately implemented. A low grade of implementation fulfilment was also the critique which came from the National Audit Office (Riksrevisionsverket 1999) concerning the efforts of the NBF on the achievement of the environmental goal of the Forestry Act. The goal is to be reached trough changed management methods, *e.g.*. larger amounts of tree retention. Thus, it was of interest to examine what the forest owners were doing in terms of intended and taken nature conservation measures, and also what they thought and felt about their mission as keepers of biodiversity.

In an inquiry by the WWF, the question: "How important is it for you that forests in your country are well protected?" was marked as important by 92% of the Swedish respondents, and 65% wanted more forests to become protected (WWF 2003). Generally positive attitudes towards nature conservation have been found amongst the dominating part of the public (*e.g*. Kangas & Niemelainen 1996; Bengston *et al*. 2001). Bengston *et al*. (2001) suggested that 'ecosystem management', the term used in North America for sustainable forest management (including social factors and other multipurpose objectives), has become a non-controversial issue. Lämås & Fries (1995) stated that: "The new Swedish forest policy presupposes a consensus in the forestry sector of the importance of maintaining biodiversity," implying that all involved actors should be of the same opinion. However, this may not always be the case. For example, the NIPF owners, who have the ultimate control over the conservation measures in almost 50% of the forest landscape, are more or less 'invisible stakeholders' (Gamborg 2002), *i.e*. their opinions are not visible in the policy decision process.

Small forest holdings, with rotation cycles that exceed the expected lifetime of the owners, provide few, but large, income events over time. This may lead to short-term decisions, based merely on the forest owners' economical self-interests. Thus, even if the forest owners have accessed the information about nature conservation, and are aware of the equality of the goals of the Forestry Act, they may be driven by other sets of values and needs, *e.g*. utilitarian and economical. Based on their actual values and needs, their opinions may be the best predictors, or indicators, of the future state of forest biodiversity. In the third paper of this thesis I therefore examined forest owners' intentions about tree retention for conservation purposes on their clear-cuts, and also compared these intentions to what was actually present after the fellings. In paper IV, I focused on what the NIPF owners actually had received in terms of information about forestry and conservation, and how that information, as well as personal attributes and values, affected their attitudes and practices.

The NIPF owners are supposed to have received information about the WKHS and the signal species used. However, for these owners, the practical applicability of such indicator species based monitoring systems may be limited due to low species knowledge. According to the criteria (see above) of a functional indicator species it should be easily found and identified. The 'signal' species used in the WKHS are many (almost 500) and mainly inconspicuous, and could thus be suspected to be unknown to many forest owners. In paper V this hypothesis is assessed and the implications are discussed.

Materials and Methods

Regeneration felling, and other major management activities, on sites larger than 0.5 ha must be notified to the Regional Forestry Board at least six weeks in advance. This is done on a registration form, where the owner reports details like position and size of the target stand. The second page of the form is devoted to conservation measures of different kinds, which are derived from the prescriptions of the Forestry Act (Skogsstyrelsen 1993).

I retrieved data from all of the 1,665 forms from the years 1995-2000 in Lindesberg on the following items: owner-category ('Forest company,' 'Private,' 'the Church,' and 'Municipality/other companies'), stand size; regeneration mode; regeneration species; sensitive biotopes and cultural values; considerations to plant- and animal species; protection zones, and number of check-marks in the section for "Considerations to trees, tree groups and dead trees," where different stand structure items were specified. On each form I counted the number of check-marks in this section and compared the mean numbers between years and different owner categories. I also visited 40 clear-cuts and compared the retained stand structures to the intentions given on the form.

In paper IV a sample of the Lindesberg population of NIPF owners (N = 681) were surveyed on their opinions on and knowledge about conservation, by a mail questionnaire with 28 questions. The questions were divided into the five contextual categories: 'attitude towards forest conservation,' 'general knowledge of forest conservation,' 'forestry related education,' 'relation to the forest,' and 'personal data.' To obtain indexes for attitude (Attitude-score) and general knowledge on biodiversity conservation' (GKBC), respectively, the replies to several questions in each context-group were ranked and pooled. Also the alternatives of forestry related education were ranked and each respondent was given a total sum of 'forestry education points' (FEP).

In paper V a question from the questionnaire, on which of twelve selected forest species the NIPF owners could identify, was used as a base for a discussion on the applicability of indicator species. The proportion of the NIPF owners who reported knowledge of the species was given for each species, and the mean FEP of those who recognised a species was compared to the one of those who did not.

Results and discussion

During the study period (1995-2000), 7.5% of the total forested study area was reported to be harvested, giving a mean harvest rate of 1.3% per year, and a mean rotation cycle of about 83 years. Short rotation cycles have implications for many of the slow dispersing species. Some species, for example certain lichens, have habitat requirements that include old trees (Rose 1992; Kuusinen 1996a; Uliczka & Angelstam 1999) and may thus not persist in this landscape.

Only on 6% of the forms at least one regeneration species was deciduous. As these tree species exist in reduced densities (Swenson & Angelstam 1993; Enoksson *et al*. 1995), this area already lost some deciduous specialist species. For the re-colonisation and maintenance of such species, forestry has to provide habitats with deciduous trees to a greater extent than today.

The section 'Considerations to plant- and animal species' was used only 8 times, none of these for a woodland key-habitat. In the National Forest Inventory (Skogsstyrelsen 2002a), 5% of all regeneration areas contained species for which this section would be appropriate to use. An expected result in this study would thus be about 80 forms. That the section was used ten times less may be because sensitive species or key-habitats were absent, or because the forest owners had no knowledge of them, or that they ignored them. Several small key-habitats were found in the area in the WKHS. It is, however, not known if all of them are still intact (Regional Forestry Board, pers. comm.).

There was an increase in the mean number of check-marks in the stand structure section during the period. However this may, most likely, be an effect of the addition in 1998 of three items. The lack of a clear increase in check-marks may imply that there was no increase in intentions concerning conservation measures during these years. If so, the policy instruments available during the study period were not efficient enough for the reaching of the environmental goal in a voluntary way.

Only 47% of the check-marks were represented by a corresponding stand structure in the field. For example, 20 check-marks for 'trees with cavities' were recorded but no such trees were detected. Evidently, the owners sometimes check-marked stand structures that they would like to protect if found at the site.

There was a positive relation between the number of check-marked items on the form and the number of retained stand structures found in the field. Tall stumps, dead wood, and tree groups were also correctly marked in 65-75% of the cases. Thus the forest owners may have tried to preserve stand structures of conservation value. However, despite this positive relation, the stand structures had low mean amounts from a conservation viewpoint. All of them were less abundant than what is recommended by FSC.

When the 40 clear-cuts were divided in 4 groups, based on the number of check-marks, only dead wood was more abundant in the last group than in the first. However, when divided into only two groups, there were significantly higher amounts of 'other' trees, tall stumps, and dead wood, in the group with the highest number of check-marks. These results suggest that the check-marks actually meant something to the forest owners in terms of commitment. There is thus a possibility that the check-marks can be used as indicators of real conservation efforts.

Concerning the form as a tool for reporting nature conservation efforts, I suggest that it did not fulfil its purpose. It seemed to be unclear to the forest owners. Making such forms easily understandable and adapted to a conservation purpose could facilitate, *e.g.*, a use of the check-marks as indicators of real efforts. If the forest owners knew that their reported intentions were registered and used, their interest in filling in the form correctly could increase. Their intentions concerning stand structures could, for example, be registered in a database, which would give an overview of the nature conservation status. Also, the form could give recommendations on a few, well-defined stand structures, *e.g.*, the quantified habitat demands of selected indicator species (*e.g.* Bütler *et al.* 2003). Furthermore, the commitments made on the form could become coupled with the use of economic compensations, *e.g.*, tax-deduction. Several other countries use similar types of forms. Also for these countries, I suggest to consider the design, logic, and usefulness of their forms. In this work psychological expertise is probably necessary to add to that of biologists and forest officers.

In paper IV a total of 393 (women 22%; men 77%) questionnaires were received (response rate = 58%). Ninety percent of the respondents were > 40 years and 28% of them worked at least part-time with forestry. Fortyfive percent of the women and 88% of the men considered themselves as active forest owners. Most of them lived adjacent to their forest and 82% visited it more than 25 times per year. The forest holdings had a median size of 35 ha and the income from the forest was 'insignificant' to 44% of the respondents and 'dominant source of income' to only 7%.

The estimated GKBC was positively related to the Attitude-score. The forest owners who had attended an NBF educational programme had high GKFBs, and also a strong tendency for a positive attitude. The educational campaigns thus probably affected the NIPF owners' attitude towards conservation. Also, those who reported to have set aside areas for conservation purposes during cutting, had higher GKBC, FEP, and Attitude-score, respectively, than those who had not done so.

Active NIPF owners, and those with a land-use related occupation, had higher GKBCs than passive ones. GKFB was also positively related to the income from the forest and to formal education level, but negatively correlated to age.

Those with land-use related occupations had a lower Attitude-score than the others. However, the Attitude-score was positively related to the number of forest species that the respondent reported to be able to identify and to the yearly number of visits in the forest. It thus seems as when the owners have a personal relationship with the forest, they also want to know more about it and protect its innate values. Though, this was income-based; when the income from forestry was important to the owners, the reluctance to diminish it by performing conservation efforts seemed to be greater.

The prediction that older NIPF owners should have a more utilitarian attitude than younger owners was supported. As also found by Kangas & Niemelainen (1996), the willingness in this study to pay more taxes for more forest reserves, was reduced with increasing age.

For women, there was a positive effect on the Attitude-score of formal education. For men, instead vocational training was related to a higher Attitude-score. FEP was not related to the Attitude-score. Those that worked with forestry, or preferred large-scale management methods, or answered 'the production goal' as the most important one, all had high FEP. FEP was lower for those who had an 'insignificant' income from their forestry than for the others.

I could trace signs of less positive attitudes towards conservation, *e.g.*, more land-users than others did not accept the equality of the two goals of the Forestry Act, by choosing the production goal as the single most important. This result may be due to a forestry education that stressed the production goal at the expense of the environmental goal, and probably focused on large-scale management methods. The results thus suggest that education in forestry, including conservation, does not automatically induce a positive attitude towards conservation.

In the ranking of operational goals for their own conservation efforts only 7% ranked 'long-term species survival' as their first priority. These also had the most positive attitude. The majority ranked forest health as number one. However, if the respondents believe that conservation measures should improve the health and vigour of the trees, this belief may negatively affect their conservation practises. They may, for example, remove damaged or dead trees, which counteracts the preservation of biodiversity (Gärdenfors 2000).

In comparisons between genders, men < 55 years of age had the highest GKBC of all groups and women > 55 years of age had the lowest. However, women < 55 years of age with high education had significantly higher Attitude-scores than all others. This result was to be expected; other enquiry studies (*e.g*. Tarrant & Cordell 2002) have reported that females and younger persons have lower utilitarian values of nature than their respective counterparts. The female forest owners in this study also showed a different ownership pattern than the men. They owned less forest, had less forestry education, lived further away from their forest, and were less dependent on the forest revenue than the men.

Indicators of a positive attitude towards conservation were that the forest holding should not constitute the sole base of income of the forest owner; the occupation of the owner should not be land-use related; the owner should visit the forest frequently; be below middle age, and female. The forest owners most inclined to preserve biodiversity are thus those who are the least likely to work within forestry themselves, which makes it important that reliable, *i.e*. green labelled, leasing opportunities for the practical management are available.

The communication of indicator species to NIPF owners (Paper V)

In one question in the questionnaire used in paper IV, the respondent was asked to check-mark the forest species, from a list of twelve that he or she was certain to recognise in the field. The species list was chosen to range from species that presumably would be well known by the public in general, over species that would be known by foresters, to those that would require relatively educated knowledge on species, such as 'signal' species from the WKHS (Nitare 2000).

The proportions of forest owners who reported to be able to identify the lichens and fungi, together with the fern *Matteuccia struthiopteris*, were all below 50%. All bird species and a by cultural tradition commonly known spring flower (*Hepatica nobilis*) received percentages of recognition above that figure. Also, the recognition of the former species generally required a FEP (see paper IV) higher than the total mean of 3.5.

This study showed that the current system based on indicator species may be of limited value for practical implementation in small, privately owned forests, because most of the signal species were not recognised by most owners. An indicator system adapted to both the NIPF owners and the public could instead include more conspicuous indicator species (see Morrison *et al*. 1992). For use in an efficient conservation and monitoring tool, the communication value of a species should thus be considered together with its indicator value. In that respect, vertebrates with a demonstrated indicator value should be considered because they could become well-known by the actors. Additionally, such species often have large habitat requirements, which may make them potentially good for large-scale conservation planning.

I suggest that a monitoring system based on a few species with (1) a high indicator value for each of the main forest type of regional conservation interest, and (2) a likewise high level of recognition (or possibility to reach such a level of recognition) should be developed. These species should be communicated to all forest owners and become integrated in forestry education. Such a system may be possible to develop since relationships have been found between the species richness of certain birds, *e.g*. some woodpeckers, and the number of species of other forest birds (Jansson 1998; Mikusinski *et al*. 2001). In this work another species based concept, the so called umbrella species, could possibly be combined with the indicator concept into a multispecies approach. The umbrella species concept has been proposed as a tool for setting minimum standards for, *e.g*., size of reserves, amounts of habitat structures, and processes in ecosystems (Roberge & Angelstam 2003). If less conspicuous species such as non-vascular plants are to remain part of such an indicator system, then special measures should be taken to increase general knowledge about those species among NIPF owners.

Conclusions

The concept of indicator species was valid for the lichen species found in these studies; where they were present other species were also more frequent. The signal species were also mainly found on old or deciduous trees at study plots with surrounding old trees, *i.e*. a longer continuity of the tree layer at the site. The lack of many of the signal species implies that these will serve a purpose as indicators of older and more natural forest, where they still exist.

The second study shows that the presence and the distribution of the focused bird and lichen species partly depend on different forest elements. Hence, indicator species should be selected from different taxonomic groups and for several forest features such as disturbance regimes, successional stages, habitat sizes, and continuity (Angelstam 1998). A further step would be that the requirements of such specialised species should be measured and translated to quantitative guidelines to be used in practical forest management. Furthermore, the low knowledge of NIPF owners on signal species implies that an indicator system with a coarser degree of resolution may suit them better, *e.g.*, birds should be included and fewer species should be used.

I could not show that the increase of information on nature conservation during the 1990s had any impact on the conservation intentions of the forest owners. This may imply that on the forest owner population level no change in conservation intentions occurred during the studied time period. Also, the amounts of for conservation purposes retained stand structures on the clear-cuts, were generally low. However, an important finding was that the intentions reported on the registration form were largely followed by associated practices in the field. This implies that such forms could be further developed into tools for communication between forest owners and the Regional Forestry Boards. The data derived from forms adapted to this purpose could also be used as indicators of real efforts and thus of the state of nature conservation in forest landscapes.

A large proportion of the more demanding species of lichens and birds was missing in all the forest types in my studies. This speaks for an urgent restoration of old and deciduous trees (see Angelstam & Andersson 2001). If many of the forest owners continue to retain only small amounts of these stand structures, as was shown in paper III, and continue to be negative or indifferent towards conservation, the forestry will never reach the environmental goal of the Forestry Act. Instead, the forests will lose even more species. That those occupied with land-use had the least positive attitude towards conservation was a discouraging result for the reaching of this goal. These are clearly the ones with the most influence over the practical forest management. Thus, this result has clear implications for the future decision-making concerning the means and the instruments used in the forest policy implementation.

Some of the results in paper IV, *e.g.* that women with high education but little forestry knowledge had the most positive attitude towards conservation, indicate that the information which is most powerful in affecting attitudes towards nature conservation comes from other parts of society, not from the NBF. Nevertheless, those who had undertaken the new educational programmes by NBF had a more positive attitude than those who had other forestry education, which indicates that the information instrument is starting to work well. The instruments and tools of NBF that were studied in this thesis were thus good, however not perfect.

Personal reflections

Forestry is a field full of traditional thinking and yet many different wills are going to rule it in the future. It may be on the margin of the scope of this thesis, but nevertheless I will address some of the things that have occurred to me to be problematic.

I believe that biologists overestimate the interest of the average forest owner in learning about forest species, let alone saving them. Also, the politicians overestimate the forest owners' willingness to forgo profit by retaining habitat. Moreover, there is a built in problem when biodiversity is supposed to be maintained using old management methods, *i.e.* clear-cutting of large areas together with short rotation cycles. Retained structures may impede, *e.g.*, scarification and planting; methods still very much in use. Additionally, the legislation contradicts itself, for example, when it states that dead wood should both be retained and taken away. Thus, the biodiversity of the Swedish forests is not yet on safe ground.

A multidisciplinary approach to the field of forestry has been proposed in the National Forest Programme. I strongly agree with this idea, and think that this is necessary if we are to achieve better solutions for conservation. Not only do biologists and trained foresters have different traditions and perspectives, social scientists and economists are taught in yet other traditions. These people thus think in different ways; biologists most often think of species and ecological processes, trained foresters about trees and increment, economists about revenue, and social scientists think of the actors, *i.e.* people. To understand the ways in which actors think and act is, however, of paramount importance for the species, and thus also for biologists. It is no longer possible to plan for biodiversity while ruling out the people; instead the social-ecological approach should be adopted (Olsson 2003). Hence, specialised scientists must share their knowledge and methods by integrating other scientist of different disciplines in their work.

When I think about the NIPF owners, specifically, and how to change their behaviour to become more environment-friendly, I find something which is strikingly different from the rest of society. We ask them to leave their money, i.e. retained trees, on their land. From no other group of people do we demand a voluntary sacrifice of income from their own properties. We do, for example, not demand from farmers that their crops should be managed to provide scenic beauty or rare species. If they do so, by keeping grazing cattle on old unfertilised pastures, they are economically compensated, most often from the EU. Hence, the forest owner should do for free what his/her neighbour, the farmer, is paid for. We also do not demand from any employees that they give away a part of their salary, other than taxes. All who work or gain profit pay taxes, and so do the NIPF owners. However, they are expected to pay extra for the sake of biodiversity. The signal from society is that they should do so for moral reasons; it is immoral to let species go extinct.

What can we expect when we ask such a thing? Probably that the NIPF owners will try to do a trade-off by minimising their economical losses, by retaining as little as possible, whilst still not becoming obviously immoral. It is however explicitly stated in the policy that conservation efforts should turn from the mere preservation of reserves, into practices that permeate the general forest management. How are we going to create incentives for the forest owners to incline them to perform conservation efforts of significant dimensions?

The fundamental question of conservation is about ethical standards. Today's forest policy lacks sticks (penalties) as well as carrots (rewards). Ethical standards change over time, e.g., what was a "necessary and educational spanking" in the 1950s, is "child abuse" today. I propose that a setting and a raise of the ethical standards concerning conservation could be made faster by the use of carrots. Instead of focusing on changing the people to fit the system, by believing we could just inform biodiversity-loss away, we can instead change the system to fit the people. People want carrots. It should thus be rewarding to retain habitat. For example, to reallocate some of the economic means into a system where it is tax-deductible to retain habitat (at least above a minimum level) could be better than compensating only those forest owners who are setting aside reserves. In that way the financial compensations will be available to all forest owners; a system which by them may be considered as 'fair.'

Penn (2003) argued as follows: "I suggest that education is necessary but insufficient because people also need incentives. Individual incentives are likely to be the most effective, but these include much more than narrow economic interests (e.g., they include ones reputation in society). Moralizing and other forms of social pressure used by environmentalists to bring about change appear to be effective, but this idea needs more research." If Penn is right, it may be that the giving of information, e.g. the NBF educational programmes, does not suffice as incentive. We may also need "individual incentives." I will try to illustrate this point by giving an example of a rewarding implementation instrument: local contests on the most biodiversity-friendly clear-cut of the year.

The arguments for such an instrument are as follows: We have almost innumerable sports and lotteries, and also contests for the biggest pumpkin and the prettiest flowerpot. Humankind is indisputably adapted to compete and, preferably, to win. Another evolutionary driving force which shapes us, is sometimes coupled with winning, i.e., "indirect reciprocity" (Alexander 1987). According to this theory, a helpful action may be returned, not by the beneficiary of that action, but by a third party. It has, for example, been shown that sponsorships and charity donations (if known by the public), as well as a previous generous behaviour to others, are economically rewarding for the donors and also enhances political careers (Wedekind & Milinski 2000; Milinski et al. 2002a,b). Reputation is thus a valid currency in many social contexts. Also, mutual trust, based on former experiences, is an important constituent in social-ecological systems (Olsson 2003). Hence, we can receive benefits, social as well as financial, by doing our best to be seen by others as good and trustworthy persons, with high morals. (This may sound cynical to some, but demonstrated generosity may most often be an 'honest signal', i.e. the person who displays it really is generous and cooperative, since if it was most often dishonest, the response (trust) would not have been integrated in our evolutionary make-up (see, e.g., Burnham et al. 2000; Milinski et al. 2002b)).

A contest would serve several purposes, which all are important. First, society will prize what society considers good. Then there will be no doubt that retention of habitat for conservation purposes is the ethically correct thing to do; it is prized. This concept would thus serve to set the ethically sound standards to manage forests. Second, many objects for demonstration will emerge, of how a biodiversity-friendly clear-cut should look. Third, carrots will be added to the system. One carrot is the prize-money. However, even with a considerable prize-sum, this concept would probably be inexpensive compared to other economical compensations. Another desirable carrot is that the forest owner will gain a good reputation, for example, by being displayed in the local newspaper for his/her good nature and high morals. Such a reputation may be beneficial to the forest owner in other contexts - a reward does not have to be economical.

Here I have argued from perspectives derived from evolutionary psychology (e.g. Zimmer 1998; Bouchard & Loehlin 2001) and game-theory. In none of the scientific papers I have found on the subjects of forestry, biodiversity, and policy, have these perspectives been mentioned. However, Schlaepfer et al. 2002 formulated some principles for sustainable management of forests and landscapes, such as: holistic, ecosystem based, integrating, adaptive, and based on good science and the precautionary principle. These principles must not only be considered in management, but must also become parts of the overlying policy implementation instruments. One principle was that sustainable management should take "cognitive, emotional and moral reactions into account." To my knowledge, these aspects have been sadly overlooked. However, Pregernig (2001) investigated the different personal values of forestry professionals and how their opinions affected the implementation of the policy instruments. Also, Götmark et al. (2000) interviewed forest owners and found that these would dislike having a state reserve on their land without receiving sufficient economic compensation. They would also not voluntarily create buffer zones, with reduced forestry, around state owned reserves adjacent to their own landholding. Perhaps they felt that this would come close to an immoral confiscation of their property, which would undoubtedly counteract society's wish that they should behave morally by retaining habitat.

I thus suggest that it would be easier to elaborate functional policy instruments if we tried to find out how relevant actors would, or could, respond to them. I am confident that we can think of many new ways to maintain biodiversity if we use broader perspectives and construct our policy instruments in a multidisciplinary way, instead of thinking in never meeting parallels.

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Sammanfattning

Att många skogslevande arter är hotade har uppmärksammats i Sverige, liksom i många andra länder. Det största hotet är det moderna, intensiva skogsbruket. De hotade arterna behöver ofta stora träd, död ved, gammelskog eller lövskog. Ett tydligt exempel är vitryggig hackspett som både är beroende av larver i död ved och av att det finns stora lövträd, gärna aspar, att göra bohål i. När skogsbruket har minskat tillgången på både död ved och asp har även hackspettarnas livsmöjligheter minskat och de har dött ut lokalt.

I Bergslagen, där jag har genomfört studierna för avhandlingen, är dessa förhållanden speciellt tydliga. Här rådde brist på skog redan på 1500-talet, då mycket skogsråvara användes inom bergsbruket. För att utvinna järn, koppar och silver gick det åt enorma mängder träd, bl a till kolning. Träkol användes i flera stadier i utvinningen av malmen. I början på 1900-talet var de flesta gruvor och hyttor nedlagda, då inleddes istället det regelrätta skogsbruket. I de skogar som fanns då var lövträd vanligare än nu. En orsak var svedjebruket där ett första successionsstadium av löv kom upp på övergivna svedjor. Efter skogsvårdslagen 1903, när det bestämdes att återplantering alltid skulle ske efter avverkning, producerade svenska staten flera miljarder granplantor för utsättning. Redan då sjönk lövträdsandelen. I mitten av 1900-talet började man bekämpa lövet, först med röjning, sedan med kemiska medel. Därefter har lövinslaget i produktionsskogarna norr om Götaland varit mycket lågt.

En viss, svag, lagreglering av naturvårdshänsyn kom 1975, men man fortsatte att göra stora kalhyggen där inga träd lämnades kvar. Efter att hotet mot skogsarterna blivit uppmärksammat på internationell nivå, och den svenska miljörörelsen propagerat för större hänsyn, ändrades lagen. I den senaste skogsvårdslagen, från 1993, blev produktionsmålet jämställt med miljömålet; båda målen är nu lika viktiga. Skogen skall brukas på ett uthålligt sätt som tillåter arternas fortlevnad. En del andra förändringar genomfördes vid lagändringen. Jag har studerat några aspekter av tre av de nyinförda metoderna.

1, *Indikatorarter*. Skogsstyrelsen inledde 1993 en inventering av skogarna med avseende på nyckelbiotoper, dvs områden som kunde innehålla hotade arter eller ha bra förutsättningar för att innehålla sådana. Vid inventeringen används sk signalarter, som skall indikera bra förhållanden för andra arter. Signalarterna utgörs av ca 500 lavar, mossor, kärlväxter, svampar och insekter. Frågan var om signalarterna verkligen indikerade det de var utvalda att indikera. Av ett utvalt set med 33 lavarter, varav 20 var signalarter, fann jag endast 6 signalarter, men dessa var knutna till äldre träd eller lövträd. Förekomst av signalarter var också relaterad till förekomst av andra arter, dvs de funna arterna var funktionella som indikatorer på goda förhållanden. Det fanns fler lavarter i obrukad gammal barrskog och blandskog än i brukad barrskog. I en jämförelse med fågelarter visade sig dessa skilja sig åt i förekomst bara mellan barr- och blandskog; desto högre lövandel, desto fler fågelarter. Troligen var den gamla barrskogen för fragmenterad och ytorna för små för att hålla fågelarter som kräver gammelskog. Detta kan tyda på att fåglar och lavar skulle kunna användas som indikatorer på olika skalor; lavar kan finnas kvar längre på små ytor, medan fåglar kunde vara bra att använda på landskapsnivå. I en enkätstudie visade sig småskogsägare ha låg kunskap om ett antal listade signalarter. Däremot kände fler än hälften till alla fyra fåglar på listan. I indikatorartssystem utformade för småskogsägare och allmänhet bör man alltså använda ett fåtal stora och lättigenkännliga arter med bra indikatorvärde.

2, *Rapporteringen av naturvårdshänsyn på avverkningsanmälan* På avverkningsanmälan som skogsägaren lämnar in till skogsvårdsstyrelsen, skall sedan 1994 anges vilken naturvårdshänsyn som skall visas vid avverkning. Detta kan betraktas som skogsägarens intentioner, vilka skulle kunna tänkas öka med tiden då informationen om naturvård ökat. Jag undersökte intentionerna, särskilt gällande hänsyn till enskilda träd, men kunde inte finna att det förekommit en generell höjning under de sex studerade åren (1995-2000). Visserligen syntes en ökning men anledningen var troligtvis att man 1998 lagt till tre typer av hänsyn, dvs gett tre ytterligare möjligheter att markera. Mängderna lämnade hänsyn på undersökta hyggen var relativt små jämfört med gällande rekommendationer. Intressant, då relationen intention-praktik annars är svårstuderad, var att det fanns en överensstämmelse mellan intentionerna på blanketten och den tagna naturvårdshänsynen. Detta antyder att intentionerna på blanketten skulle kunna använda som indikatorer på verklig naturvårdshänsyn. Blanketten bör dock förändras för att bättre kunna användas i naturvårdsövervakningen, men mer forskning behövs kring detta.

3, *Effekten av den ökade utbildningen av skogsägare i naturvårdsfrågor*. Sedan början på 1990-talet har skogsvårdsstyrelserna erbjudit skogsägare kurser om skogsbruk och naturvård. Kurserna kan tänkas påverka skogsägarnas kunskap om, och attityd till, naturvård, vilket också visades i en enkätundersökning. De som var mest positiva till naturvård var dock yngre kvinnor med hög akademisk utbildning, medan de som yrkesmässigt arbetade med skogs- och lantbruk var de minst positiva, trots att de hade mest både av skoglig utbildning och av kunskap om naturvård. De starkast attitydpåverkande faktorerna verkade alltså vara andra än kurserna; möjligen egna värderingar. Ett starkt beroende av inkomsten från skogen och högre ålder på skogsägaren var också kopplade till en mindre positiv attityd. Kvinnor var mindre aktiva i skogsbruket och ägde mindre arealer än män. Att besöka den egna skogen ofta ledde till att man kunde fler skogsarter och till en positiv attityd. En klar majoritet kunde varken tänka sig att miljöcertifiera sitt skogsbruk eller betala mer skatt för fler naturreservat. För uppnåendet av skogsvårdslagens miljömål är det alltså viktigt att kurser betonar vikten av naturvård. De ägare som redan har en positiv attityd kan också erbjudas specialiserade utbildningar, som hur man gynnar vissa 'målarter' i ens region.

Sammanfattningsvis fungerade de olika undersökta metoderna relativt bra, men förbättringar är både möjliga och önskvärda. Förslag på sådana kan vara att indikatorartssystem med få och lättigenkännliga arter utformas för bruk av skogsägare, att avverkningsblanketten ändras och det inrapporterade används som information och att skogstyrelsen utformar utbildningar olika med tanke på olika skogsägargruppers attityder och behov.

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