Conservation Measures in Swedish Forests

The debate, implementation and outcomes

Per Simonsson
Faculty of Forest Sciences
Department of Forest Ecology and Management
Umeå

Doctoral Thesis
Swedish University of Agricultural Sciences
Umeå 2016

Acta Universitatis agriculturae Sueciae
2016:103

Cover: Examples of retention forestry in boreal Sweden today.
(Illustration: Martin Holmer)

ISSN 1652-6880
ISBN (print version) 978-91-576-8709-8
ISBN (electronic version) 978-91-576-8710-4

Print: SLU Service/Repro, Uppsala 2016

Conservation Measures in Swedish Forests. The debate, implementation and outcomes

Abstract

In Sweden, a multi-scaled model for conservation of biodiversity in forests has been developed since the early 1990s. This model can be divided conceptually into three different levels; (i) retention forestry in the production forests; (ii) voluntary forest set-asides; and (iii) formally protected forests. This thesis explores the debate, implementation and outcomes in the forest of these conservation measures.

From being absent from public debate, forestry became heavily criticised during the early 1970s due to aerial spraying of herbicides to control deciduous trees on clear-cuts. The criticism of forestry and increased awareness of the problems concerned with forestry from a conservation perspective put strong pressure on the forestry sector. As a result, Swedish forestry and conservation policy was changed fundamentally during the 1990s and many new conservation measures were implemented. I have identified a number of driving forces behind this development which include the compilation of Red Lists, demands from foreign customers and forest certification.

I present, in a paper from 1997, management options which mimic natural forest disturbance regimes better than traditional forestry and I reflect on the implementation of these ideas. One important outcome of the new ideas during the 1990s is the practical application of retention forestry in Sweden. My results clearly show that young forests have become structurally richer since the introduction of the retention approach. The number of retention trees and amount of dead wood in young stands increased between 1997 and 2007.

I also compared the area extent, structural diversity of importance to biodiversity and stand characteristics between voluntary set-asides, formally state-protected nature reserves and managed production forests. My analysis shows that voluntary set-asides are an important complement to traditional reserves in terms of geographical location, size and structural factors important to biodiversity.

In conclusion a combination of historical perspective and landscape-level data give us the opportunity both to understand complex developments and to develop tools for future successful conservation measures in the Swedish forests.

Keywords: driving forces, forest history, retention forestry, natural forest dynamics, conservation, voluntary set-asides, forest certification, dead wood

Author's address: Per Simonsson, SLU, Department of Forest Ecology and Management, SE-901 83, Umeå, Sweden
E-mail: per.simonsson@sca.com

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Simonsson, P., Gustafsson, L. & Östlund, L. (2015) Retention forestry in Sweden: driving forces, debate and implementation 1968–2003. *Scandinavian Journal of Forest Research,* 30, 154-173.

II Fries, C., Johansson, O., Pettersson, B. & Simonsson, P. (1997) Silvicultural models to maintain and restore natural stand structures in Swedish boreal forests. *Forest Ecology and Management*, 94, 89-103.

III Kruys, N., Fridman, J., Götmark, F., Simonsson, P., Gustafsson, L. (2013) Retaining trees for conservation at clearcutting has increased structural diversity in young Swedish production forests. *Forest Ecology and Management,* 304, 312-321.

IV Simonsson, P., Östlund, L. & Gustafsson, L. (2016) Conservation values of certified-driven voluntary forest set-asides. *Forest Ecology and Management*, 375, 249-258.

Papers I-IV are reproduced with the permission of the publishers.

The contribution of Per Simonsson to the papers included in this thesis was as follows:

I Responsible for the research idea and for designing the study through discussions with Lars Östlund and Lena Gustafsson, analyzed the historical records, main responsible for writing the article and for revising the article after comments by editors and reviewers.

II Discussed the design of the study with co-authors, contributed through discussions with ideas on natural forest dynamics and silvicultural models, participated in the writing and the revision of the article.

III Discussed the idea and design of the study with co-authors, contributed through discussions with the data-analysis and participated in the writing and the revision of the article.

IV Responsible for the research idea and for designing the study through discussions with Lena Gustafsson and Lars Östlund, analyzed the data from the Swedish National forest inventory, main responsible for writing the article and for revising the article after comments by editors and reviewers.

Abbreviations and definitions

Abbreviations are used without the plural s

ASIO-model	A model indicating different fire frequencies; Absent, Seldom, Infrequent and Often
ENGO	Environmental Non-Governmental Organization(s)
EPA	The Environmental Protection Agency
FSC	Forest Stewardship Council
FURA	Fjällnära Urskogars Räddnings Aktion [ENGO engaged in the protection of high altitude forests]
GIS	Geographic Information System
High altitude forests	Forests along the Scandinavian mountain range. Until 1982 it relates to forests beyond the border for economic forestry established by the Forest service (skogsodlingsgränsen). Later it relates to forests beyond a border established by the Forest Agency inserted in the Forestry Act (fjällnära skog).
MoDo	A major Swedish forestry company
NFI	The (Swedish) National Forest Inventory
PEFC	Programme for the Endorsement of Forest Certification
PF	Production Forest(s)
R	Formally state-protected nature reserve(s) and National Park(s)
RF	Retention forestry
SCA	A major Swedish forestry company
SLU	Sveriges Lantbruksuniversitet (Swedish University of Agricultural Sciences)
The State Forests	In Swedish: Domänverket, today called Sveaskog AB and the Property Board of Sweden
State Forest reserves	In Swedish: Domänreservat
SSNC	Swedish Society for Nature Conservation
VSA	Voluntary forest set-aside(s)
WKH	Woodland Key Habitat(s)

1 Introduction

1.1 “The Swedish model” of forest biodiversity management

Forest protection and nature conservation in forestry were not big environmental issues until the early 1970s. Forestry in northern Sweden had undergone major changes during the 1950s and 1960s: from predominately manual felling, through selective logging without extensive forestry measures, clear-cutting was introduced large-scale with active silviculture in order to create rapid-growing new forests (Östlund et al. 1997; Josefsson & Östlund 2011). Many new forestry methods were introduced in the 1960s, such as forest fertilisation using nitrogen, radical scarification methods, aerial spraying of deciduous scrub with phenoxylic acids and the introduction of alien tree species. Extensive mechanisation occurred during the 1950s to 1970s, when tractors replaced horses and manual felling with chainsaws was replaced by large harvesters (Eriksson 2016). This led to a considerable decrease in the numbers of people employed in forestry and the depopulation of many small villages in forested areas. As a result of the mechanisation process, clear-cuts in the north of Sweden were often hundreds of hectares in size (Jordbruksdepartementet 1974).

From being absent from public debate, forestry became heavily criticised during the early 1970s due to aerial spraying of herbicides in young stands (Paper I). The criticism of forestry and increased awareness of the problems concerned with forestry from a conservation perspective put strong pressure on the forestry sector. As a result, Swedish forestry and conservation policy was changed fundamentally during the 1990s and many new conservation measures were implemented. The result was the development of a multi-scaled model for conservation of biodiversity in forests (Gustafsson & Perhans 2010) sometimes called *“the Swedish model”* of forest biodiversity management (de Jong 1998; Angelstam 2003).

This model can be divided conceptually into three different levels, illustrated by a pyramid (Fig.1) (e.g. Naturvårdsverket 1990). The broad base of the pyramid consists of the large area of ordinary production forest, where nature conservation should be undertaken in association with normal forestry measures, such as final-felling, pre-commercial thinning and thinning. This involves the retention of individual trees, protection and creation of small care-demanding habitats and buffer zones adjacent to water and wetlands. This includes small patches from an individual tree up to areas of 0.5 – 1 ha, and is referred to as conservation on the small-scale level. By implementing this on all forest land, the total area will be large despite the fact that each individual unit of retention is small. The responsibility and cost of implementation lies entirely with the forest owner.

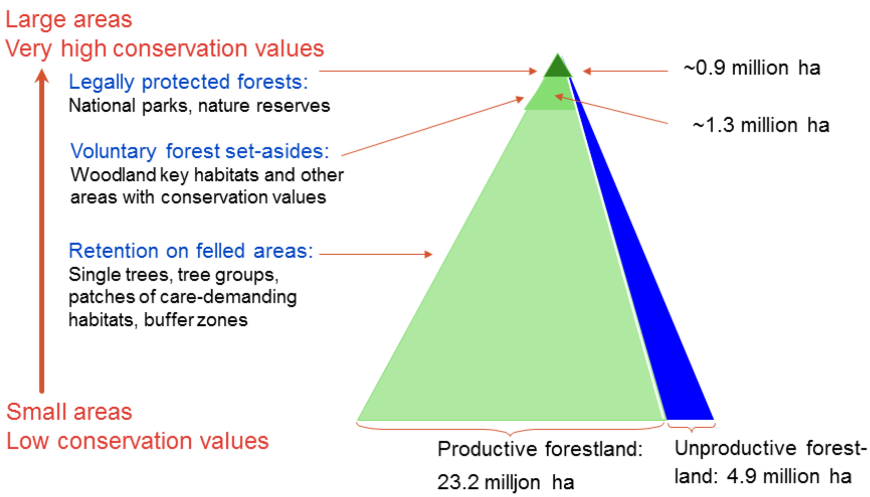

Figure 1. "The Swedish model" of forest biodiversity management.

The next section of the pyramid contains areas from 0.5-20 ha in size, the medium-scale level. These areas have considerable conservation value, for example being woodland key habitats and differing from ordinary forestland. Some of these areas are not subject to forestry at all, whilst others might require conservation management or modified forest management. Forest owners and the government share the responsibility for these areas. The government protects some areas by creating habitat protection areas within privately owned forests, but most areas are protected as voluntary set-asides.

The top of the pyramid contains larger areas, the large-scale level, and consists mainly of areas of high natural value. The protection of these forests is mainly the responsibility of the government, and they are mostly designated nature reserves or National Parks.

In addition to protection and conservation on productive forestland, all unproductive forestland is protected under the Swedish Forestry Act. This is forestland according to the international definition (Skogsstyrelsen 2014a), but which produces less than 1 m^3 ha^{-1} $year^{-1}$. This amounts to about 5 million hectares.

1.1.1 The small scale – retention forestry

Nature conservation during felling is common practice in current Swedish forestry. Diverse terminology is used to describe this, such as *variable retention* (Franklin et al. 1997) and *green-tree retention* (Rosenvald & Lõhmus 2008). In this thesis I use the term retention forestry (RF). Examples of RF are the retention of individual trees, tree groups and dead wood, the retention of care-demanding habitats such as herb-rich swamp-forests and buffer zones around streams, lakes and wetlands (Fig. 2). Calculations by the Swedish Forest Agency show that, on average, 7.8% of the cut area is retained for nature conservation (Skogsstyrelsen 2015). All felling is generally preceded by planning in the field by a forester based on a practical manual developed by forest owners' associations or forest companies (e.g. SCA 2012). Typically, retention patches are marked using plastic tape, so that they can be clearly seen by the harvester even if the logging takes place during winter conditions. Retention patches are also marked on a GIS layer that the machine operator can see on his computer whilst driving the machine. In addition to the nature conservation planned by the forester, the machine operators also have the responsibility of retaining individual trees and tree groups.

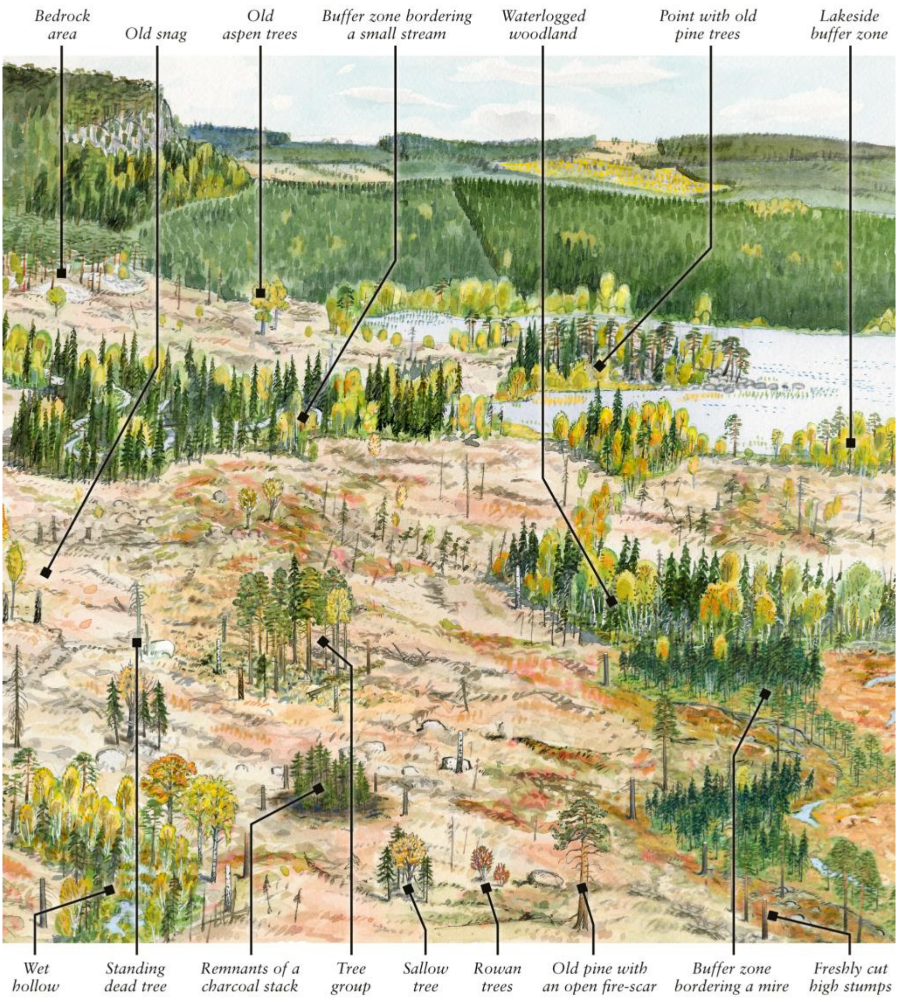

Figure 2. Examples of retention forestry in boreal Sweden today. The figure is taken from the SCA (2012) instruction manual on retention forestry. Illustration: Martin Holmer.

The idea behind today's nature conservation is to retain trees or areas that are of particular biodiversity value. Based on ideas from the 1990s about imitating natural disturbance regimes (e.g. Paper II, Angelstam 1998), moist and wet areas are overrepresented as retention patches (Fig. 3).

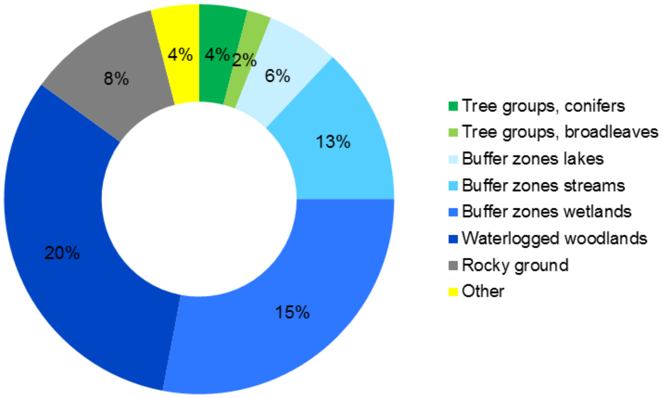

Figure 3. The distribution of different types of retention patches on final felled areas at the forestry company SCA (unpublished figures).

RF has many purposes (Gustafsson et al. 2012), such as: (i) "life-boating" – providing conditions for species that depend on old-growth forests, e.g. old trees, (ii) increasing the amount of substrate in the new stand in order to support species dependant on early-successional stages, (iii) enhancing connectivity in the forest landscape, (iv) maintaining different ecosystem functions like mycorrhizal processes, (v) decreasing the impact on surrounding environments, e.g. watercourses, and also (vi) making cut areas more aesthetically appealing.

Clauses related to retention forestry have been included in the Swedish Forestry Act since 1975, when a key paragraph was added with a clause stating that conservation should be incorporated into forest management (SFS 1974). In 1979 a new, separate section on nature conservation was added for the first time, §21 (SFS 1979). Most regulations in this paragraph stipulated that aesthetic values and recreational interests should be considered. In 1993 a revised Forestry Act was passed, enshrining a major change in forest policy (which is still valid), stipulating that environmental and production values should be regarded as equally important. Now the key paragraph, §1, states: "*The forest is a national resource that shall be managed in such a way as to provide sustainable good yield while maintaining biological diversity. Forest management should also take into account other public interests*" (SFS 1993). In the new Forestry Act, the clauses on nature conservation are in §30, which provides regulations stipulating that appropriate measures shall be taken regarding care-demanding habitats, plant and animal species, buffer zones, trees and groups of trees and the size of clear-cuts. Most of the regulations in §30 concern biodiversity, unlike the corresponding section in the previous legislation of 1979.

All the measures intended to foster implementation of retention forestry in Swedish forestry policies have always been “soft”, including the provision of substantial resources for relevant education and advice, while legal regulation has been weak (Hysing & Olsson 2005; Götmark et al. 2009). The law is based largely on “*freedom under responsibility*” (Bush 2010), which means that the government expects landowners to take great responsibility, without the need for state-controlled details. The regulations in the legislation are mandatory, but if a forest-owner does not follow them no sanctions can be imposed unless the Swedish Forest Agency has previously issued an injunction stating which specific retention action(s) must be applied. Another major limitation of the law is that the conservation requirements must not be *“so extensive as to severely handicap current land use”* (Bush 2010).

1.1.2 The medium scale – voluntary set-asides and woodland key habitats

Today’s voluntary set-asides (VSA) are, to a large extent, the result of the certification of forest owners according to one of the international certification standards, FSC (Forest Stewardship Council) or PEFC (Programme for the Endorsement of Forest Certification). In 1998 FSC International approved the Swedish national FSC-standard and this was the first voluntarily negotiated national standard for forest certification. The Swedish forest owners’ associations were initially part of the FSC negotiations, but left and started PEFC, which had its first standard approved in 2000. Currently, the two international certification systems, FSC and PEFC cover approximately equal areas (12 million ha), and many forest properties are certified under both systems.

According to the Swedish national FSC standard, a minimum of 5% of the productive forestland should be set aside “from measures other than management required to maintain or promote biodiversity conditioned by natural processes or traditional land use practices” (FSC 2010). The same requirement is also part of the national standard of PEFC (PEFC 2012). Forest certification has therefore been an important driving force for VSA and these “certification-driven” set-asides are currently an important part of “the Swedish model” to maintain biodiversity in the forest landscape.

Even prior to the arrival of certification systems, there were of course forests that landowners had excluded from forestry voluntarily. Through the certification systems, the process of VSA became more systematic, with clear targets. There were also requirements that these areas be defined in forest management plans. According to the Swedish FSC standard, large forest owners must make information on their VSA publicly available. This is done using maps published on a website (http://protectedforests.com/). Smaller FSC certified forest-owners and PEFC certified forest owners are not required to make their VSA public, but must show them to an auditor in connection with an external review.

The Swedish Forest Agency has estimated the extent of VSA several times. A VSA is defined as being "*at least 0.5 ha area of coherent productive forest land, where the owner has voluntarily decided to avoid measures that damage its natural, cultural or social values. The area must be registered in a plan or other document.*" (Skogsstyrelsen 2012). The word "voluntarily" implies that the landowner has made the decision to protect the area without any obligation to the government or municipality. The latest estimate showed that there are 1.33 million hectares of VSA. The increase was rapid after the turn of the millennium, due to forest certification (Fig 4) (Skogsstyrelsen 2015).

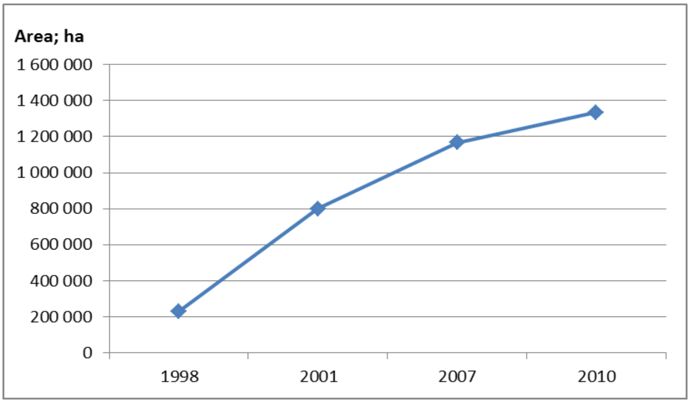

Figure 4. The total area of voluntary forest set-asides 1998-2010.(Skogsstyrelsen 2002; Skogsstyrelsen 2008; Skogsstyrelsen 2012a; Skogsstyrelsen 2015)

Woodland key habitats

The term woodland key habitat (WKH) was coined by the Swedish Forest Agency, and refers to habitats where red-listed species could be expected (see section 3.3.3.) (Nitare & Noren 1992). The coining of the new term, along with the extensive surveys conducted during subsequent years lay the foundation for forest-owners' more systematic attempts to protect forests as voluntary forest set-asides. Today both the FSC and PEFC certification standards require that WKH be excluded from forestry or that they be managed to promote biodiversity. Moreover, all FSC-certified forestry companies are committed to avoiding purchasing timber from WKH, which implies that forest owners who are not certified can have difficulties in finding a buyer for timber from WKH. The Environmental Code stipulates that all felling of WKH must be preceded by consultation with the Swedish Forest Agency. Thus, WKH do not have any formal protection today, but instead have a strong informal protection through certification, and they form the basis of the current pool of voluntary set-asides in Swedish forests.

The Swedish Forest Agency manages a database of all WKH in the country and these are available on a website (https://skogskartan.skogsstyrelsen.se/skogskartan/). At present, ca 100 000 WKH are registered, covering ca 460 000 ha (Skogsstyrelsen 2016). WKH on private land have an average size of 3.4 ha, whilst WKH on land owned by large forestry companies are on average 8.0 ha.

1.1.3 The large scale – formally protected reserves and National Parks

Forests can be formally protected as National Parks, nature reserves, habitat protection areas or under nature conservation agreements (Naturvårdsverket 2009). The government decides National Park status, whilst nature reserves are designated by county and local administration. The Swedish Forest Agency designates habitat protection areas and nature conservation agreements. A new National Park or nature reserve requires a description of the purpose of protection as well as a management plan for the area. A nature reserve that includes forestland does not necessarily imply that forestry is prohibited in the reserve.

At present there are 849 700 ha of National Parks and nature reserves on productive forest land, with restrictions on forestry (Sveriges officiella statistik 2016b). Of these, 432 000 ha are high altitude forests. In addition, there are 56 000 ha of forests that are habitat protection areas or under nature conservation agreements (Sveriges officiella statistik 2016a). This means that 3.9 % of the productive forest area is formally protected with restrictions on forestry.

1.2 Swedish boreal forests and forestry

Sweden has 23 million ha of productive forestland (>1m^3 growth ha^{-1} year^{-1}), mostly within the boreal zone, apart from the southernmost part, which is in the temperate zone. The boreal zone is usually divided into a southern part, the hemiboreal zone hosting temperate broadleaved tree species, and followed by south, central and north boreal zones towards the north (Nordiska ministerrådet

1984). Apart from Paper III, the studies described herein cover the south, central and north boreal zones (see Paper IV for a map). This area spans a distance of 1100 km from south to north and exhibits large variation in productivity primarily as a consequence of the increasingly colder climate to the north, with a mean annual volume increment of 6.4 m^3 ha^{-1} $year^{-1}$ in the southernmost county (Värmland) and 2.9 m^3 ha^{-1} $year^{-1}$ in the northernmost county (Norrbotten) (Forest Statistics 2014). Along the east–west gradient, from the Baltic sea to the Scandinavian mountain chain, the altitude increases, leading to a harsher climate in the west where the productive forestland ends toward the tree line. The forests are dominated by Norway spruce *Picea abies* and Scots pine *Pinus sylvestris*, which comprise about 80% of the standing volume in the region (Forest statistics 2014). Privately owned companies own about 30% of the forestland, the state and other public owners (including the state-owned forestry company Sveaskog) own about 30%, and private individuals about 40% (Forest Statistics 2014).

Industrial forestry has been conducted in the region since the 17th century, starting in the south, primarily for the production of charcoal for mining and iron production. Northwards expansion of large-scale forestry exploitation commenced during the second half of the 19th century, when forests were selectively cut for large diameter pine wood (Josefsson & Östlund 2011). The saw-mill industry grew rapidly during this period and large volumes of sawn timber were exported (Björklund 1984; Lundgren 2011). During the early 20^{th} century pulp industries appeared along the coast, and with these came a demand for small diameter wood as well. Both clear-cutting and selective cutting were practiced. During the slump of the 1930s and the following war years, selective cutting took over almost completely. The standing volume of forests decreased and large areas of "left-over stands" covered the land, with low wood volumes and poor growth (Ebeling 1959). During the 1950s and 1960s The State Forest (Domänverket) and the private forestry companies abandoned selective cutting in favour of clear-cutting. Lundmark et al. (2013) describe the change as follows; *"From being extensive and exploitative, the forest management became more intensive and reconstructive*". A starting point for this "restoration period" in Norrland was the State Forest circular No.1/50 from 1950, in which selective cutting was prohibited, stipulating that cut areas must be regenerated (Ebeling 1959). Clear-cutting was however not a new method, but had been in practice since the early 1900s, and was widely regarded as the best harvesting method. However, selective cutting became common in the 1930s – 1940s, due to economic reasons (Lundmark et al. 2013).

As well as the large-scale transition to clear-cutting, another change to forestry occurred during the 1950s – 1970s, namely mechanisation. Tractors replaced horses and chainsaws were replaced by various harvesting machines (Eriksson 2016) (Fig.5). Mechanisation in the 1960s led to clear-cuts that were several hundred hectares in size. New forestry methods were introduced in the 1960s such as mechanised scarification, forest fertilisation and aerial spraying of herbicides to control brushwood in clear-cuts (Sveriges Skogsvårdsförbund 1978; Leastander 2015).

Normal measures today after final-felling are scarification and planting within three years, pre-commercial thinning when the stand is 10-15 years old and then 1-3 thinnings before final felling. Rotation times vary between 60 and 120 years. The forestry practiced during the last 150 years has resulted in structurally simplified production forests with well-delineated stands of equal age and small quantities of dead wood (Östlund 1993; Linder & Östlund 1998) and other forest structures when compared to intact forests. This has led to decreasing populations of many forest species (ArtDatabanken 2015).

Figure 5. During the 1970s, harvesting with large forestry machines started, following earlier practices with chainsaw harvest. Photo SCA

1.3 Aim of the thesis

The overall research questions addressed in this thesis refer to the debate, implementation and outcomes on the ground of different conservation measures in the Swedish forest landscape. My main aim is to depict the historical development and current situation of *"the Swedish model"* of forest biodiversity management in forests and forestry. My hope is that this will lead to an improved understanding of the drivers behind our current way of working with different conservation measures in the forest.

More specifically I aim to: (i) analyse the forestry debate and identify the key driving forces behind the development of conservation measures in production forestry in general and of retention forestry in particular; (ii) present and discuss management options in boreal Sweden which mimic natural dynamics; (iii) quantify the development over time of retained living trees and dead trees after final harvest, with a focus on young forests (0–10 years old); and (iv) evaluate how certification-driven voluntary forest set-asides contribute to forest protection and important forest structures. Based on these questions I want then to broaden the discussion and contextualise the development of conservation in Swedish forestry during the last 50 years and also to some extent, to make comparisons within the international perspective.

2 Methods and data used

The studies comprising this thesis build on a variety of historical records. I have combined a predominantly qualitative approach in paper I with more quantitative data in papers III and IV. Paper II is more of a discussion paper with suggestions about management options for maintaining and restoring natural stand structures and processes.

2.1 Analysis of historical sources

The study in Paper I is based on a thorough, systematic analysis of articles published between 1968 and 2003 in journals issued by two non-profit associations in Sweden representing key interest groups (cf. Anshelm 2004; Lindkvist et al. 2011; Lundmark et al. 2013). One is *Skogen* (“*The Forest*”), the Swedish Forestry Association’s magazine, and the others are the Swedish Society for Nature Conservation’s (SSNC) magazine *Sveriges Natur* (“*Nature of Sweden*”) and annual *Sveriges Naturs årsbok* (*“The Yearbook of Nature in Sweden*”). Both of these are umbrella organisations and their journals are regarded as providing representative views of the forestry sector (including forestry industries) and Swedish non-governmental conservationists, respectively. Much of the public debate on forestry and forest conservation issues in Sweden during the last 50 years (including views of the foremost protagonists) has been expressed in these journals.

We scrutinised all issues of each journal published during the period 1968-2003, following recommendations that the time period for such analysis should cover all major changes in the study system (c.f. Bürgi et al. 2004). The starting year of 1968 was chosen because a pilot study indicated that retention forestry was not discussed before then and the end year of 2003 because international forest certification efforts and retention forestry were well established by then.

In a first step, 2191 standard articles, reviews, editors' comments, letters to editors and announcements, all with some relevance to the subject, were chosen. The subject content of each article was summarised in one sentence and each article was categorised according to a three-point scale of relevance for this study. In a second step, 899 of the most relevant articles were chosen for thorough analysis. Each of these articles was categorised according to type (e.g. editorial, article, letter to the editor), subject relevance (using a 4-point scale) and subject type. All articles related to retention forestry and our questions were more deeply analysed and both summaries and quotes were compiled. In addition, many more general articles on forestry/conservation were examined to place the retention forestry discussion in a broader conservation context.

2.2 Disturbance types

In Paper II we divided the boreal forests into three site (disturbance) types. For each of the three types, we described processes, structures and composition which characterise the natural forest state. We identified and described systematically how a uniform clear felling system affects these characteristics and discussed how forestry could be modified to enhance biodiversity.

2.3 National Forest Inventory

The studies in Papers III and IV were based on data from the National Forest Inventory (NFI). The NFI was started in 1923 and contains annual inventories of all land in Sweden, providing data at national and regional levels, with a focus on forest and other wooded land. The present design was introduced in 1983 (Ranneby et al. 1987). Data on trees, forests and management history are recorded by field teams in a stratified random systematic cluster design with partial replacement and in plots with a radius of 7 m, 10 m or 20 m depending on the variable. Permanent plots are surveyed every 5 to 10 years, and at least 5 years of data are usually needed for reliable estimates (Axelsson et al. 2010). The list of recorded variables in the NFI is extensive, covering both forestry and environmental aspects.

2.4 Voluntary set-asides, production forests and formally protected reserves and National Parks

For the study in Paper IV, databases containing information on voluntary set-asides (627 000 ha) and production forests (6.1 million ha) for 2013 were used from forestland owned by the private forestry companies Bergvik Skog, Holmen and SCA, and the state-owned forestry company Sveaskog. Analyses were separated into categories of all forest ages, and forests >100 years old (27% of total analysed forest area). We focused on the whole boreal zone of Sweden, except the hemiboreal zone, and divided the data into three subzones – north, central and south boreal zones – when estimating the area. However, the data resolution did not allow us to analyse these subzones separately for the variables relating to structures and stand characteristics.

For formally protected areas we used databases from the Environmental Protection Agency for 2013 including formally protected productive forestland designated as nature reserves or National Parks under the Environmental Code where forestry is not permitted unless biodiversity is promoted. Reserves with no restrictions on forestry were excluded.

3 Historical background of “the Swedish model” of forest biodiversity management

This chapter provides a brief description of the history of Swedish conservation and the development of “the Swedish model” of forest biodiversity management. The aim is to elucidate the driving forces behind today’s conservation work. The description is not intended to be comprehensive, but rather to provide an overview of the debates and development of forest conservation. The period 1968 – 2003 is the focus because it was eventful; it starts when forestry was not regarded as an environmental issue and stretches through to the time when international forest certification schemes became widespread (Paper I).

3.1 1880–1970 – conservation is not a big issue

3.1.1 Formal protection

The idea of protecting nature in Sweden is more than 130 years old. As early as 1880 the polar explorer Adolf Erik Nordenskiöld suggested that National Parks be introduced “*where forest and land and lake be left undisturbed, where trees should not be felled, bushes not cleared, grass not cut, and where all animals, except pests, should be safe from hunters*” (Grönberg 1911). Nordenskiöld was probably inspired by the USA, where the world’s first National Park, Yellowstone, was established in 1872. During the early 1900s the academic discussion about nature protection legislation intensified and an investigation was opened in 1907. This lead to the introduction of nature protection legislation in 1909, allowing parliament to form National Parks and protect smaller natural monuments such as outstanding trees and boulders (Ödman et al. 1982). Sweden became the first country in Europe to designate a number of

National Parks. Several of these consisted only of mountain areas, but two were forested – Gotska Sandön and Hamra. Gotska Sandön National Park was initially only 368 ha, but was increased in 1963 to cover the entire island area of 3 600 ha. Despite the new legislation of 1909, very few new parks were created until the 1980s when a more systematic effort started. One exception is Muddus National Park, one of Sweden's largest protected areas, formed in 1942 and covering 20 000 ha of productive forest. In 1960 there were 341 areas protected as natural monuments, covering only 3000 ha, in addition to the 16 National Parks (Frisén 2001).

Conservation undertaken by public bodies grew during the 1960s as a result of a government investigation, "Naturen och samhället", in 1962 (SOU 1962). The investigation concluded that protection of the most valuable areas in the country was of the highest priority. Various industries that might harm nature were discussed in the investigation, but it is interesting to note that forestry was not mentioned. Neither was the need to protect forested areas. The most important outcome of the investigation was new conservation legislation as well as the formation of a new central government conservation board in 1963 – Statens naturvårdsnämnd. This board was given a broader remit in 1967 and was merged with the new governmental agency, the Environmental Protection Agency (Statens Naturvårdsverk), which remains the central agency for conservation issues in Sweden today. In addition, county administration boards were given the regional responsibility for conservation, and several counties introduced special positions to address conservation issues from the mid 1960s. An important task for the county administration boards was to survey valuable areas for conservation and recreation and to form so-called county conservation plans (Frisén 2001).

The new conservation legislation that came in 1964 introduced a new conservation tool, nature reserves, that county administrations could use to protect areas. County administration plans written in the 1960s and 1970s were the basis for designating nature reserves. Permanent finances to cover land purchase and compensation payments were introduced to the state budget. However, the state finances available for this were very limited, so nature reserves that limited forestry activities were very few. The new conservation legislation also gave the state the right to expropriate land for nature reserves if an agreement could not be reached with the land-owner regarding compensation payments. One additional effect of the new legislation was that natural monuments larger than 1 ha were transformed into nature reserves.

I interpret the very limited area of formally protected forests in the 1960s as an effect of a lack of interest from the public or conservation organisations in the protection of ordinary conifer forests. This is confirmed by the following from the book “Naturvård av idag” (Brink 1962): “*When the common Swede imagines protection of forests or forest remnants it is not a coniferous forest that comes to mind, but a deciduous one, preferably a group of ancient oaks. The luscious herb-rich groves appeal to many Nordic people with their openness, in contrast to the dark and dismal coniferous forests.”*

3.1.2 Swedish Society for Nature Conservation and forestry

Swedish Society for Nature Conservation (SSNC) was formed in 1909, i.e. the same year as the new conservation legislation. For a long time the society was an academic organisation, in which professors played a central part, often as expert advisors to the government. It wasn’t until the government conservation organisation expanded in the 1960s that the SSNC gained broader public recognition and started to work in the field of opinion-making (Anshelm 2004). The SSNC also mainly focused on conservation of mountain areas and small odd features such as large trees, tall junipers, oddly-shaped trees or geological formations. When SSNC chairman Sten Selander suggested in 1936 that nature conservation should permeate all work in forestry and agriculture, this was regarded as a new idea (Wramner & Nygård 2010). It is interesting to note that Selander argued that *“conservation is for the benefit of man, not the benefit of nature”* (Selander 1936). During the 1940s the protection of threatened animals, particularly predators, was the main issue for the SSNC (Anshelm 2004). Forest protection was not a major issue at this time but there were concerns that technical and economic development was devastating forests and waterways (Anshelm 2004). That conservation was generally not a concern for society during the 1930s and 1940s is made clear in the following description by Dahlbeck (1987) who was active in SSNC at the time: *“One almost had to apologise for working with conservation, as it was practically irrelevant according to the view of the establishment. Very few people joined the voluntary movement, which was also split by fundamental differences of opinion. The state organisation was almost completely absent.”*

Apart from the fight to protect threatened animals, the most important issues for the SSNC during the 1950s were objections to the use of chemical pesticides, protection of undisturbed waterways, and the need to protect characteristic aspects of the Swedish landscape. Specific protection of forests did not, however, stand out as a prominent issue. The society successively shifted its efforts from the protection of individual objects to issues concerning long-term management of nature’s values. The 1960s were the decade of environmental alarm, when biocide poisoning of birds and pollution of air and water were major issues for society. The prominent forest issues in the 1960s were spruce plantations on old fields and meadows, which changed the old cultural landscape, as well as the felling of beech woodlands in Southern Sweden.

3.1.3 Voluntary forest set-asides and retention forestry

Foresters had promoted the ideas of protecting small remnants of old-growth forests and areas with special vegetation in the early 1900s. The Forest Service (Domänverket) started to set aside State Forest reserves (Domänreservat) as early as 1913. Initially this was only done to a limited extent, but increased during the 1930s when 111 areas, covering almost 4 000 ha, became State forest reserves. By 1950 there were 362 State Forest Reserves covering 11767 ha of which 9553 were classed as "*coniferous forest of virgin forest type*" (Domänverket 1951).

In 1938 the Swedish Society for Nature Conservation took the initiative in a collaboration with forestry company SCA to survey and protect remnant old-growth forests. The response from SCA was positive. A long article on the front page of one of Sweden's largest newspapers had the headline *"The largest private initiative for Swedish conservation – Large forest reserves created"* (Svenska Dagbladet 1938). The forest administrative offices reported valuable old-growth forests to the main office, but the planned surveys with staff from SSNC could not be undertaken due to the onset of the Second World War. The company perspective on forming "company reserves" was that these would be scientific reference areas to relate to managed forests.

A further example of early voluntary forest set-asides is from the forestry company MoDo, which set aside some large areas of old-growth forest in Ångermanland as "company reserves" during the 1950s (e.g. Andrén 1992). The company silviculture register clearly stated that these areas were protected. There are several examples of foresters setting aside old-growth forests as "company reserves" (e.g. Holmgren & Malmström 1958; Axelsson 1995). Apart from the Forest Service's more systematic protection of State Forest reserves, it does not appear that voluntary forest set-asides covered any significant area until the woodland key habitat concept was introduced in the 1990s.

Instructions for leaving individual trees, odd looking trees or for leaving trees on non-productive forest land have existed for a long time. In 1924 there was a suggestion that nature conservation be included in the Forest Service instructions. The conservation paragraph in the instructions was rewritten in 1955, stating that "*forests, tree groups or individual trees on rock, bogs or other impediment"* should generally be retained (Oldertz 1959). The retention at this time was primarily for aesthetic reasons and covered trees on non-productive land. During the late 1950s MoDo conducted a survey to find out how much timber originated from non-productive forest land. The results showed that the amounts were very low, and a decision was made in the early 1960s to stop clear-cutting non-productive forest land (Andrén 1992).

3.2 The 1970s and 1980s – a stormy debate about forestry

3.2.1 The forestry debate

From being a minor environmental issue, the forestry debate heat up and became very lively in the 1970s, when the forestry received a lot of criticism (Höjer 1973). The debate started with mass protests against aerial spraying of herbicides to control deciduous growth in young stands (Fig.6) (Laestander 2015). Criticism broadened to cover other forestry measures such as forest fertilisation, scarification, the use of DDT, alien tree species and clear-cutting as a forestry method (e.g. Fältbiologerna 1973). Criticism did not only stem from the ENGOs but also from the general public and from tabloid columnists who demanded legislation outlawing clear-cutting (Enander 2007).

The forestry industry could not accept the harsh criticism from the general public and ENGOs. They felt unjustly criticised when forestry was labelled a "*serious environmental hazard*" or when accused of "*vandalism*". Common arguments for clear-cutting forestry were (Paper I): (i) – Clear-cutting is ecologically appropriate as it imitates forest fires, a natural disturbance; (ii) – Foresters have chosen our profession because we love nature, trust us to do the right thing for nature; (iii) –Forestry is so important for Sweden's economy that we have to clear-cut; and (iv) – Forestry is de facto conservation. Felling of over-aged and slow-growing forests with dead trees and replacing these with healthy growing plantations was regarded as conservation work.

The forestry industry interpreted the criticism of forestry in general and of clear-cutting in particular as an information problem. They believed that conservation demands were vague and mostly "*general opinions*", whilst the forest industry provided the facts (Paper I). They thought that if only the general public was informed about forestry methods and understood that new forests would replace the old ones, clear-cutting would be accepted. This led to the formation of a working group for information issues, that e.g. arranged meetings for journalists in order to explain forestry methods (Hagner 2005). To soften the criticism of "*ugly*" clear-cuts, foresters started to retain individual trees and tree groups to decrease the treeless impression that large clear-cuts gave. Retention forestry that evolved during the 1970s was therefore primarily based on aesthetic considerations (Paper I).

Figure 6. A widespread debate and criticism of Swedish forestry started in the beginning of the 1970s. The criticism was primarily triggered by massive protests against aerial spraying of herbicides to control deciduous growth in young stands. Photo: SKOGENbild.

By 1973 the forestry debate had been going on for a few years, when several books on forestry and conservation were published. The Environmental Protection Agency issued a book on forestry and conservation (Statens naturvårdsverk 1973), The Swedish Society for Nature Conservation's yearbook had forestry and conservation as a theme (Svenska naturskyddsföreningen 1973), and the youth organisation "Fältbiologerna" published a book on forestry and ecology (Fältbiologerna 1973). The Environmental Protection Agency's book was a collection of facts, mainly describing different forestry methods, but without stating their own position. Even the Swedish Society for Nature Conservation's book had many descriptive articles on forestry and it is interesting to note that seven of the book's authors were professional foresters. The authors provided their own opinions, which varied considerably. One article suggested a model of work that is similar to "the Swedish model" of today (Rydberg 1973), whilst others argued that radical scarification was legitimate, as it imitated fire disturbance (Sirén 1973). Fältbiologerna's book differs from the others as this organisation demanded that forestry put an end to practices such as fertilisation, radical scarification, the use of chemical pesticides and herbicides, and that clear-cutting be regulated by law (Fältbiologerna 1973).

The widespread criticism of clear-cuts led to petitions to the Swedish parliament demanding that this practice be forbidden (Fig 7). The result was that the Ministry for Agriculture established a working group to investigate the impact of clear-cuts on the environment. The group presented a report in 1974, clarifying the official standpoint as being that clear-cutting was the most appropriate harvesting method on most forestland (Jordbruksdepartementet 1974). Furthermore, incorporation of mandatory reporting of planned clear-cuts and a general precautionary rule about nature conservation in the forestry legislation was recommended. The report's recommendations primarily focused on aesthetic retention. The recommendations were passed in parliament, leading to changes in the Forestry Act from 1975-07-01. The clause "*Consideration must be shown towards conservation interests*" was included with mandatory reporting introduced for clear-cuts larger than 0.5 hectares. The change in legislation meant that forest-owners had to submit to a certain amount of intrusion with respect to conservation interests and that this ought to be a normal part of forestry operation.

During the 1970s knowledge increased about how forestry was disadvantageous to forest-dwelling plants and animals. At Skogshögskolan (the Royal College of Forestry) a working group was established in 1974 in order to map the threats to different species groups and to provide conservation recommendations for forestry and its associated agencies (2008). The first Swedish Red List was presented in 1975 and covered vertebrates, the best-known species group (Ahlén et al. 1975). This work resulted in the issuing of seven different books on retention actions targeted at different species groups (e. g. Ahlén et al. 1979; Ehnström & Waldén 1986). The work on red-listed species continued through a pilot project partly financed by the WWF, involving establishment of a dedicated Threatened Species Unit based at SLU. However, in 1991 the Unit was formally integrated into SLU, one of its most important tasks being to spread knowledge about the occurrence of red-listed species. For the Swedish Society for Nature Conservation, species conservation has always been a major issue, and many articles in its magazine have focused on the topic.

Figure 7. Mechanisation in the 1960s led to clear-cuts that were several hundred hectares in size and were highly criticized by the public. Photo:SCA

Foresters and conservation groups apparently did not understand each other, as there was a clear absence of constructive dialogue in the 1970s and early 1980s (Lisberg Jensen 2002). One reason for this was probably that foresters axiomatically regarded forestry as sustainable from a timber production perspective, and therefore also “ecologically correct”. Carl-Olof Tamm, an internationally renowned professor at Skogshögskolan, wanted to puncture that myth and maintained that there were forestry methods that certainly were dubious and that “*irreversible depletive change can hardly be compatible with ecological principles”*(Tamm 1979).

In 1978 a new forestry report was presented, recommending a substantial increase in forest production by fertilisation, ditching, the use of alien tree species, and including various suggestions for a new Forestry Act (SOU 1978). The Swedish Society for Nature Conservation was highly critical of the report, stating that issues related to flora and fauna had not been sufficiently addressed. A new Forestry Act came into force in 1980, which for the first time included a separate section on nature conservation, §21, including detailed regulations written by the Swedish Forest Agency. A scientific assessment of the quality of the retention actions stipulations in §21 of the Forestry Act was presented 1985 and the results showed considerable deficiencies regarding, for instance, the retention of dead trees (Eckerberg 1985; Eckerberg 1986). More training, better planning and more conservation specialists in forestry were recommended to improve quality.

During the 1980s forestry underwent a mental change as insight was gained into the built-in conflict between forestry and conservation, which had previously been denied. In 1985, in the magazine *”Skogen”,* the director of the Swedish Forest Agency, Björn Hägglund, urged forestry representatives to “*Change their attitude”*, because they had not shown that they were capable of participating in a constructive debate with conservationists. He wrote that: “*We demand that conservationists listen to forestry …. But then we must also listen to them”* (Hägglund 1985). Bush (2010) highlights this as an important event. Red-listed species came more into focus and foresters could not deny that there were many species that were threatened by forestry. With the Red List, it could be argued that the criticism was more scientifically based (Fig.8). Forestry was more inclined to listen to scientifically based critique than more vague claims that clear-cuts are ugly, and old forests are beautiful. During the late 1980s, instead of regarding conservation issues only as an information problem, forestry companies started producing instructions for their employees to improve conservation efforts and training their staff accordingly. For instance, the Iggesund Company’s instructions stated that all snags and high-stumps should be retained, if present, and if neither were present at least one large living tree per three hectares should be retained.

3.2.2 Formal protection

During the late 1970s discussion increased about the need to create more nature reserves, as the remaining old-growth forests were being felled at an increasing rate. An article in Sveriges Natur in 1976 claimed that there were, at most, 100 000 ha of protected forest land in Sweden, of which 90 000 ha was in State Forest reserves and in the Muddus National Park. The author suggested that a reasonable goal would be to at least double that area (Holmstedt 1976). He suggested establishing a network of reserves of at least 1500 ha each, evenly distributed across the country. The Swedish Society for Nature Conservation (SSNC) also wrote to the Environmental Protection Agency (EPA) in 1976 requesting interim protection for the remaining old-growth forests in the country (Sveriges Natur 1976). Even the EPA wanted a moratorium on felling in old-growth and high altitude forests until a proper investigation could be conducted, examining how these could be protected and who would be responsible for protection (Skogen 1978)

Figure 8. Usnea longissima is a red-listed species, and was in the 1980s an important symbol for threatened species in old-growth spruce forests. Photo Per Simonsson

In 1978 the SSNC published the book "Levande Skog" presenting the society's view on forestry, but the need for reserves was not emphasised. Instead the book set out clear demands that many forestry methods should be changed or forbidden, e.g. fertilisation, herbicide application, planting alien species and radical scarification, as well as a limit on clear-cut areas to 5-20 ha (Svenska Naturskyddsföreningen 1978).

The need to protect the remaining old-growth forests was one of the most discussed issues during the forestry debate of the 1980s. The SSNC's yearbook of 1981 had the theme *"Old-growth*", and includes SSNC's demands for old-growth protection. It states that "*at least*" 1 % of the Swedish productive forests must be protected and that this must be in reserves that are "*large enough*" with a "*better distribution across the country*" (Segnestam 1981). This would provide a further 150 000 ha of protected forest. The book stated clearly that the government's *"phrases about an ecological view are worthless* *if society cannot provide the money for land purchase and compensation payment"* (ibid). A rough estimate indicated that 3 billion SEK would be needed to protect these 150 000 ha, which was put in relation to the 10 million SEK that was annually available at the time for creating reserves. In another article in the yearbook, Professor Olle Zackrisson, from the forestry faculty at SLU, presented a new idea for the time – that many old-growth forests actually need management in order to develop in an ecologically sound way. Old-growth reserves with fire dynamics need fire management (Zackrisson 1981).

The first more systematic attempt to survey valuable forests was initiated by the Environmental Protection Agency during the mid-1970s. First a questionnaire survey was conducted regarding valuable old-growth and deciduous forests (Statens naturvårdsverk 1976). Then a national old-growth forest survey was undertaken together with the county administration and forest agencies during the period 1978 – 1981. The survey identified 314 locations with an area of ca 45 000 ha outside the montane areas and Norrbotten county (Naturvårdsverket & Skogsstyrelsen 1982). The results of the survey provided the first basis for planning and prioritisation of forest protection in Sweden. Funding for purchasing valuable forests had been very limited for a long time, but was doubled in 1985 to 40 million SEK per year, which enabled the first organised protection of forests (Naturvårdsverket 1997). A major event occurred when the Environmental Protection Agency reached an agreement with six large forestry companies to purchase 26 old-growth forests covering 16 000 ha at a price of 172 million SEK (Frisén 2001). There was subsequent protection of 33 800 ha of old-growth and wetlands around Blaikfjället in Västerbotten, despite protests from the County administration and local municipalities.

The government presented an environmental bill in 1988, emphasising the importance of general nature conservation and the forestry sector's responsibility for this. Another point emphasised was that old-growth forests need to be protected, but no new funding was provided for this (Wramner 2010). The Environmental Protection Agency presented a new National Parks plan in 1989, suggesting the creation of 20 new National Parks (Naturvårdsverket 1989).

3.2.3 High altitude forests and the limit for economic forestry

Today, more than half of the formally protected forests are high altitude forests, where many voluntary forest set-asides are also located. Management of high altitude forests was a contentious issue during the 1980s, and is therefore described in more detail below.

As a result of the Forest Services' reorganisation of forestry in 1950, shifting towards clear-cutting, a limit for economic forestry was defined along the mountain chain, beyond which clear-cutting was not allowed. This was a provisional boundary, mainly including forests with low standing volume in harsh environments. The border was biologically motivated as it was not certain that regeneration was possible beyond it and it was also an economic boundary, beyond which investments in new stands were not deemed profitable. There was also an awareness of the forests' natural value when the limit was defined (Linder 1987). The border lead to 740 000 ha of productive forests on state land being excluded from forestry (Höjer 1954). The location was moved several times and the area covered was 550 000 ha when it was removed in 1982 (Hedén 1983).

The foresters at the Forest Service regarded the border as a pure regeneration threshold and maintained as early as 1975 that new scarification methods and the introduction of the north American lodgepole pine *Pinus contorta* provided hope that the forests beyond it could be managed for commercial production (Öhrn 1978). Concerns about fellings of the high altitude forests led to a poster campaign by the Swedish Society for Nature Conservation (SSNC) in 1978 against the Forest Services' plans for felling (Segerström 1978). Even the Environmental Protection Agency was concerned about the high altitude forests and suggested a 10 year felling moratorium from 1978, whilst cost liability for protecting the forests was investigated (Skogen 1978). The SSNC continued with a postcard campaign directed at politicians in 1981 warning about the fellings (Fig.9). It is interesting to note that the SSNC warned about regeneration, reindeer husbandry, game and recreation, but did not mention species conservation as a reason for protecting the forests (Hjelm 1981).

The Forest Service replied to the forest policy report in 1978 that they did not intend to clear cut beyond the defined boundary nor to make any major changes to its location in the foreseeable future. ENGOs regarded the removal of the boundary in 1982 together with planned fellings of 80 000 ha as a betrayal (Olsson 1983). Even the Royal Swedish Academy of Sciences wrote to the government and demanded that the Forest Service's plans to harvest in the high altitude forest be stopped (Skogen 1982). Criticism of the Forest Service from ENGOs as well as from the Environmental Protection Agency was extensive and SSNC demanded that all the old-growth high altitude forests be exempt from logging. The Forest Services tried to soften the criticism by forming large State Forest reserves but ENGOs perceived it only as a way to *"falsely reassure public opinion"* (Oldhammer 1984).

Figure 9. A postcard which the Swedish Society for Nature Conservation sent to politicians in 1981, warning about the effects of clear-cutting in high altitude forests in Sweden.

Initially much of the high altitude forest debate focused on whether it was possible to regenerate these forests. Even SSNC had concerns about whether it was possible to regenerate forests as one of the major criticisms of the fellings. A group of scientists concluded after a long excursion in 1984 that it probably was possible to regenerate on some land, but that it required extensive silvicultural management such as radical scarification in order to succeed (Skogen 1984b). Gradually during the 1980s the issue of reforestation became less central and ENGOs focused instead on the importance of forests for wildlife, recreation and reindeer herding as the main arguments for forest protection. Focus was also put on the long continuity of high altitude forests as a value in itself and that new forests would be much poorer in species diversity than the forests that were felled (Wramner 1986). The Forest Service claimed in turn that the felling was important to provide employment in rural areas.

The Environmental Protection Agency and County Administrations broadened the ongoing surveys of old-growth forests in 1981 to also cover the high altitude forests. A further 64 locations were identified, covering 150 000 ha of productive forests of high natural value. Of these, 33 000 ha were areas that the Forest service wanted to manage despite their high natural value

(Skogen 1984a). During negotiations between the two state organisations, the Environmental Protection Agency and the Forest Service, there were three main areas about which agreement could not be reached, e.g. Kirjesålandet in Västerbotten. The government was therefore given the task of solving the matter. The three areas was protected – a victory for conservation. The result of the overall negotiations was that 55 new nature reserves were created and the Forest service agreed to protect 70 areas as State reserves (Löfgren 1987). The SSNC was not content just to discuss the protection of individual areas, but wanted a permanent conservation boundary to be established, beyond which forestry should not be allowed. They argued that the high altitude forests were a unique contiguous unit of undisturbed forests (Wramner & Hjelm 1987). Felling "*parts of the high altitude forest is like knocking a tooth out of someone's mouth"* (Lindevall 1984) was one argument used. There was also criticism of state funding being used to finance forest roads into the high altitude forests (Hjelm 1985).

In 1988 the Swedish Society for Nature Conservation (SSNC) presented a suggested conservation boundary that was 3 800 km long and ran along the entire mountain chain, beyond which large-scale forestry should not be allowed (Svenska Naturskyddsföreningen 1988). This was based on aerial photographs and was mainly west of the old border. The area delimited covered all land, including private land, which was not included in the old border. In 1989, the SSNC suggested that parliament should declare a temporary cessation of felling until a more permanent decision could be made about the high altitude forests. They did not succeed in getting a permanent moratorium, and in 1990 parliament decided to introduce two new boundaries in the high altitude forests. Beyond one, the size of clear-cuts was limited to a maximum of 20 ha, alien tree species were not permitted and radical scarification was not allowed. In all, the SSNC was very involved in issues concerning the high altitude forests during the 1980s and were in close contact with politicians (Hjelm 1987).

The failure to establish a permanent limit was a great disappointment for the ENGOs. A new organisation called FURA (Fjällnära Urskogars Räddnings Aktion) had been established in 1984 with the sole task of protecting the high altitude forests (Frängmyr 1993). When the political approach failed, an attempt was made to use consumer power to stop the fellings. FURAs chairman wrote in 1991: *"We have now realised that we cannot continue to waste our energy on political games, but must move on and speak a language that forestry companies understand. A keyword in their language is money. Everything they produce will be bought by consumers like you and me. In other words, you have the POWER as a consumer"* (Johansson 1991). After this, FURA wrote to forestry companies, threatening to boycott their products if they did not stop felling high altitude forests. The threat was taken seriously, and all forestry companies stopped such felling, so the boycott did not need to be put into action.

The fight for the high altitude forests continued on common land, and was especially harsh around the commonly-owned Njakafjäll in Västerbotten, covering 6200 ha of high altitude forests. Forestry companies were sensitive to pressure about boycotts from foreign buyers, whilst common land was owned by a large number of private land-owners who were not afraid to get into conflicts with ENGOs. The discussions in Njakafjäll started in 1984, when there was a proposal to construct a forest road, using state funding. This lead to much toing and froing, with a lot of involvement from ENGOs who wanted the forests to be protected. The conflict culminated in January 1997, when Greenpeace blocked some felling under dramatic circumstances. A solution was found in 1998, when the government presented extra funding to compensate the common, thus ending a 14-year long conflict. Scientists criticised funding to protect Njakafjäll, suggesting that it would be a better use of money to protect forests in Southern Sweden, where there were few protected areas (Ek 1998).

When the Swedish FSC standard was developed in the mid 1990s, the SSNC's boundary from 1988 was incorporated into the standard, according to which clear-cutting is prohibited beyond this limit. As all large forestry companies and the Property Board of Sweden are FSC certified this practically meant an end to all felling beyond the border on company and state-owned land.

3.3 The 1990s – threats of boycotts and a breakthrough for conservation

3.3.1 The forestry debate

The Forest Agency had issued a number of handbooks during the 1980s on nature conservation. This knowledge was summarised in a more popular book and education campaign called "A Richer Forest" (The National Board of Forestry1992). This was a large campaign, reaching out to forest-owners, forestry officers and forestry machine operators. As many as 100 000 individuals took part in the programme. The ideas of retention forestry had a broad impact on many stakeholders as a result of this campaign.

The focus on red-listed species in conservation grew during the 1990s. The Swedish Species Information Centre (previously called the Threatened Species Unit) became formally integrated into SLU in 1991, one of its most important tasks being to spread knowledge about the occurrence of red-listed species. An extensive debate started when one author criticised the way the Red List was used and interpreted for conservation purposes (Sjöberg 1993).

A committee was appointed in 1990 to investigate forestry policy and it presented a report in 1992 (SOU.1992). The report recommended extensive changes in forestry policy and forestry legislation. Parliament had already issued a statement in 1991 citing the following overall target: *"The biological and genetic diversity shall be secured. Plant and animal communities shall be preserved so that naturally occurring species shall be provided the conditions to survive in viable populations"* (Regeringens proposition 1990/91). Before the target and associated clauses were incorporated in revisions to the Forestry Act, the Swedish Society for Nature Conservation suggested that stricter and more biologically functional general regulations about retention forestry should be included. Furthermore, there were demands for conservation regulations with penalties, and changes in compensation rules for forest-owners. A new Forestry Act came into force in 1994, giving environmental and production goals equal importance. Many of the detailed regulations concerning timber production were removed, and regulations concerning retention forestry were given a clear orientation towards preservation of plants and animals (Paper I). It is interesting to note that all stipulations concerning aesthetic retention were removed from the new legislation, where they were previously dominant.

Inspired by the success of the consumer boycott threat to forestry companies that felled high altitude forests, Swedish ENGOs started to cooperate internationally, with each other and with buyers of forest products. In 1993, Greenpeace Germany demanded "*clear-cut free paper*" backed up by Axel Springer Verlag and three other major paper buyers. The subsequent discussions between forestry companies and German paper buyers led to some of the latter withdrawing demands for clear-cut free forestry "*provided that forest diversity of plants and animals is not affected*" (Sveriges Natur 1994). But Springer's environmental director said "*In the future we will support the suppliers who care for species protection and biodiversity*" (Lindevall 1994).

In 1992 the Taiga Rescue Network was established, an international network of ENGOs. Their aim was to spread knowledge about valuable forests in the coniferous belt around the northern hemisphere and to put pressure on land-owners and politicians to protect these forests. The Taiga Rescue Network hosted their first international conference in Jokkmokk in 1992 (Skogen 1992).

3.3.2 Introduction of disturbance regimes

It has long been known by foresters that fire is an important disturbance factor in boreal forests (e.g. Tirén 1937; Högbom 1934). Fire scars on living trees and burnt dead wood were common in forests up until the late 20th century, despite the fact that fires decreased drastically from the mid 1800s and onwards (Zackrisson 1977). During the early 1900s prescribed burning was used under seed trees as a regeneration method, and Joel Wretlind's fellings with seed trees and burning in Malå, Västerbotten were well-known and often resulted in successful regeneration (Ebeling 1959). When clear-cutting and scarification became standard in the 1970s, and this approach was questioned, the response was often that the methods imitated natural forest fires and were thus ecologically valid (e.g. Sirén 1973; Statens Naturvårdsverk 1973, Tamm 1979). By this, foresters imagined large-scale stand-replacing fires with a fire interval of about 100 years and the aim of creating homogenous, even-aged stands with an even age distribution between stands.

The acknowledgement that forest fires vary in intensity, frequency and severity developed successively during the 1990s and had great impact on thinking and practical implementation of different conservation measures. Pioneering work was done by Zackrisson (1977) on fire frequency in Västerbotten, showing that it varied considerably depending on physiographic and biotic factors. Exposure was one important factor, where south-facing slopes had burned more often than north-facing slopes, and dry vegetation types had burned more often than moist ones. The so-called ASIO model was developed during the 1990s as a conceptual tool for foresters to use in conservation work. The model differentiates between four different fire frequencies. The model is called ASIO after the words Absent, Seldom, Infrequent and Often indicating different fire frequencies (Angelstam 1998). Underlying the ASIO model was the suggestion that different fire frequencies should be regarded and treated in different ways when taking conservation actions during e.g. felling, choice of regeneration method and ecological landscape planning. Suggestions for different conservation measures adapted to different disturbance regimes are discussed in Paper II and in chapter 4.2.

3.3.3 Woodland key habitats

With increased knowledge about the occurrence of different red-listed species, forestry needed improved planning to take these species into account. Forestry was criticised for presenting colourful publications stating that they took account of red-listed species, whilst the ENGO´s felt that the reality was somewhat different (Lindahl 1990). The Swedish Society for Nature Conservation (SSNC) undertook several systematic studies during the 1980s examining how forestry companies lived up to their environmental policies; the results were poor according to the SSNC (Olsson 1988). In 1990 the Forest Agency coined the term "woodland key habitat" (WKH) to describe habitats where red-listed species could be expected to occur. Previously conservation had been focused on old-growth forests and undisturbed areas, but focus now shifted towards red-listed species (Nitare 2011). Long continuity, rare stand characteristics and abundant occurrences of key elements such as dead wood and old trees were important characteristics for identifying WKH (Nitare & Norén 1992) (Fig. 10). In 1993 the Forest Agency started large-scale surveys of WKH. Apart from a short gap, these went on until 2006. The large forestry companies performed their own WKH surveys, which were controlled by the Forest Agency.

Figure 10. Example of a woodland key habitat with an abundance of key elements such as dead wood and old trees. Photo Olle Hedvall.

3.3.4 Ecological landscape planning

The woodland key habitat surveys provided a good basis for planning and the large forestry companies started to work with conservation issues on a landscape scale during the 1990s. Ecological landscape plans were developed (Angelstam & Pettersson 1997; Angelstam 1997). Different pilot studies were performed in order to test how the plans could be put into practice. One issue was whether core areas should be connected by corridors (Gustafsson & Hansson 1997). Landscape planning was such a hot topic at the time that the autumn conference of the forestry faculty at SLU had it as a theme in 1994 (Sveriges lantbruksuniversitet 1994). Two main approaches to ecological landscape planning were developed in boreal Sweden, the species approach and the naturalness approach (Fries et al. 1998). The main theoretical background to the species approach was island biogeography (MacArthur & Wilson 1967) and landscape ecology (Forman & Gordon 1986). The naturalness approaches were derived from theories of natural disturbance and natural succession and one practical application was the ASIO model (Angelstam 1998). Practical implementation of ecological landscape planning was a mix of the two approaches. The woodland key habitats were always the basis for areas that were exempted from forestry activities (e.g. Bratt et al. 1993).

3.3.5 Forest certification

Work towards international forestry certification commenced in the early 1990s. The initiatives from the ENGOs *"were partly motivated by their view that state regulatory processes and frameworks have failed to take care of environmental problems"* (Boström 2003). In 1993 a working group was commissioned by the WWF to formulate a Swedish FSC standard and in 1995 the Swedish Society for Nature Conservation (SSNC) and WWF presented an outline for a Swedish standard (Paper I). A broad working group was established in 1996, including representatives of private forest-owners, forestry companies, the wood-processing industry, unions, the indigenous Sami people and various ENGOs. A draft for a Swedish FSC standard was completed in 1997 and an SSNC representative said *"We have certainly had to compromise on some issues, but we have still received more than we have given away"* (Liljenström 1997). Some of the most important achievements of the SSNC were the incorporation of more comprehensive retention forestry requirements in the FSC standard than the forest owners wanted and the protection of all WKH. The Forest Owners' Association withdrew from the FSC process in 1997 as they regarded the requirements as too high. They accused the FSC of being appropriate for tropical conditions, but not relevant for Nordic conditions. Together with other European private forestry actors, but without the participation of ENGOs, they subsequently established the competing environmental certification system PEFC (Paper I).

The SSNC scrutinised some of the first FSC-certified clear-cuts and was critical of several aspects, especially the small numbers of field controls during audits. In 2001 a member of the SSNC claimed that the FSC restrained the

Society "*But if the forest has gained somewhat from FSC, we within SSNC have made a great loss. A weapon has been removed from our hands. As SSNC supports the FSC, we cannot criticise the FSC-labelled forest owners openly any more*" (Olsson 2001). An informal network outside the SSNC was formed to protect old-growth forests, as the SSNC was regarded as not free to criticise FSC certified forests (ibid). This network has developed into a member organisation still active under the name Protect The Forests (http://www.skyddaskogen.se/).

3.3.6 Formal protection

In 1990 the Environmental Protection Agency was assigned by the government to produce an action programme for conservation, containing the foundations of "the Swedish model" of forest biodiversity management with measures on three levels depending on each area's natural value, size and cost liability (Naturvårdsverket 1990). A strategy for formal protection of nature was produced in connection with the action programme (Naturvårdsverket 1991). This specified a target of protecting 106 000 ha of forest, of which 70 000 ha was high altitude forest. The Environmental Protection Agency considered that 100-200 million SEK per year was needed during the 1990s for the continued protection of the country's most valuable forests. This was a request made by the agency, but there was no political decision about target levels. The idea that conservation work should be undertaken on three different levels returned in the government's Environmental Bill in 1991 (Regeringens proposition 1990/91) and a new tool for protection was introduced, namely the "habitat protection area" as discussed by Bush (2010).

The Environmental Protection Agency compiled data on the area of formally protected and Forest Service reserves on productive forest land in 1997, concluding that there were 173 000 ha, equalling about 0.81 % of the productive forests below the mountain forest region. The equivalent figure in the mountain forest region was ca 670 000 ha, representing 43% (Naturvårdsverket 1997).

The remaining natural forests were declining rapidly and increased fragmentation of forests (e.g. Andrén1994; Andrén 1997) as well as threshold values were central issues in the conservation debate (e.g. Carlson & Stenberg 1995; Naturvårdsverket 1997). A government investigation was ordered to suggest levels for future forest protection, and results were presented in 1997 (SOU 1997a; SOU 1997b). The short-term goal was to protect a further 900 000 ha of forest below the high altitude forests within 10-20 years. As a long-term goal 9-16 % of the forest land was to be protected within 40 years, varying according to geographic region.

3.4 The 2000s – forest certification and extensive formal protection

3.4.1 The forestry debate

After the major changes that occurred in forestry in the 1990s and because of forest certification, the forest debate calmed down somewhat in the early 2000s. The large forestry companies were busy developing ecological landscape plans and private forest owners produced "green forestry plans", with voluntary protection of woodland key habitats. Forestry companies' voluntary set-asides (VSA) were initially not revealed to the public, but after being accused of keeping them "secret" a common website was developed where VSA of the large forest companies, the Property Board of Sweden and the Swedish church are presented together with all areas that are formally protected (http://protectedforests.com/). As VSA are part of Swedish forestry policy and parliament has made decisions about their quantity and quality (Regeringens proposition 2000/01), the Forest Agency has evaluated VSA several times. The most recent evaluation showed that there are 1.33 million hectares of VSA (Skogsstyrelsen 2015). In order to evaluate the benefits of VSA and reserves there is often a call for better knowledge about their quality (Elbakidze et al. 2011; Angelstam et al. 2011) which the results of Paper IV can provide to a great extent.

An on-going discussion during the 2000s has been about retention forestry quality. The Forest Agency has followed up retention forestry quality in its so-called Polytax surveys, which showed flaws during 2010-2012 with respect to care-demanding habitats in 36% of the fellings where these were present (Skogsstyrelsen 2014a). The forestry sector did not share the view that these were flaws and in order to agree on what constituted good retention actions, the Forest Agency initiated a dialogue project together with the forestry sector, other agencies and ENGOs. The aim was to draw up common targets for retention forestry (Skogsstyrelsen 2014b). The Forest Agency was very active in the development of retention forestry during the 1980s and 1990s, with various education campaigns, but lost its leading role when this was taken over by the certification organisations. The certification standards are often more precise about retention forestry than the law is. Through the dialogue project, the Forest Agency has once again become an important part of retention forestry development.

Criticism from the Swedish Society for Nature Conservation (SSNC) about FSC increased during the 2000s. Certified companies' fellings were scrutinised, revealing that woodland key habitats were still being felled (Naturskyddsföreningen 2013). The SSNC was critical of the fact that no certified forest-owner had had their certificate withdrawn despite breaking the requirements of the relevant scheme several times. Because of this the SSNC left the board of FSC in 2008 and terminated its Swedish membership in 2008. The SSNC remains, however, a member of the international FSC.

The SSNC presented a new forest policy in 2011. They stated the need for 20 % of the productive forest land below the high altitude forests to be given permanent protection (Naturskyddsföreningen 2011). This 20 % could even include voluntary forest set-asides, but not retention patches and buffer zones. Furthermore, the SSNC demanded that the state funding for forest protection should be increased so that the area targets of 20 % could be reached by 2020, and that the area of clear-cut free forestry should cover 30 % of the productive forest land.

The SSNC proposed an entirely new forest policy and legislation in 2014 (Naturskyddsföreningen 2014). They stated that current forest policy was developed 20 years ago and therefore does not consider new knowledge or national environmental targets. The SSNC wanted the Forestry Act to be incorporated into the Environmental Code. A central criticism from the SSNC has been that forest policies are too soft and that the conservation requirements according to the Forestry Act must not be so extensive as to severely handicap current land use (Olsson 1992). The new Forestry Act proposed by the SSNC includes absolute figures for conservation not liable to compensation payments, and includes leaving buffer strips, dead wood and 10 "eternity trees" per ha during felling.

3.4.2 Formal protection

Parliament set sectoral environmental targets in the late 1990s, introducing a new tool for environmental work (Regeringens proposition 1997/98). One of the 15 targets was "Living forests", with one milestone decided in 2001 being the protection of a further 900 000 ha of productive forests by 2010 (Regeringens proposition 2000/01). This was the first political decision about the extent of future forest protection. Of the 900 000 ha to be protected, the aim was for 320 000 ha to be reserves, 30 000 ha to be habitat protection areas and 30 000 ha to be covered by nature conservation agreements. Apart from formal protection, it was intended that a further 500 000 ha should be protected as voluntary forest set-asides.

Based on clear political targets for further formal protection of forests, the Environmental Protection Agency and Forest Agency were given the task of developing a "National strategy for the formal protection of forest" which was presented in 2005 (Naturvårdsverket & Skogsstyrelsen 2005). The strategy took a value-based approach and prioritised areas with high conservation value at the stand level along with areas which, because of their size or position, have a good chance of maintaining their nature conservation value. The strategy included a model for prioritising site selection and highlighted forest types with special conservation values. The national strategy also specified county-based area targets.

Many forestry companies did not want to sell land for nature reserves, but wanted to receive land to compensate for the areas that were designated. Therefore, the government decided in 2010 that 100 000 ha of forest from the state-owned forestry company Sveaskog should be transferred to the Environmental Protection Agency to be used for compensation (Regeringens proposition 2009/10:169). The following exchange deals led to the creation of 450 new nature reserves, covering 60 000 ha of productive forest land (Naturvårdsverket 2015a).

New milestone targets for forest protection were decided by parliament in 2014: by 2020 a further 150 000 ha should be protected as nature reserves and 200 000 ha as voluntary set-asides (Regeringens proposition 2013/14). The government concluded that previous targets had been reached and that a new strategy for formal protection of forests needed to be developed; this will be done in 2016.

4 The studies

In this chapter I summarise the individual studies included in this thesis.

4.1 Paper I – Retention forestry in Sweden: driving forces, debate and implementation 1968–2003.

In this paper we sought to identify forces driving the conceptual development, acceptance and implementation of retention forestry in Sweden by describing and investigating the forestry debate among foresters and ENGOs from 1968 to 2003. The debate and development is partly described in chapter 3. In our search for explanations for the development of retention forestry in Sweden, we identified six possible national and international driving forces: (i) widespread criticism of clear-cutting from ENGOs and the public during the 1970s; (ii) lists of threatened species; (iii) the forestry sector's concern about severe political restrictions on forestry; (iv) demands from foreign customers initiated by ENGOs; (v) influences of "New Forestry"; and (vi) forestry certification (Fig. 11).

4.1.1 Widespread criticism from ENGOs and the public

The initial driving force was the widespread criticism of clear-cuts, which were perceived as large and ugly by the public and ENGOs in the 1970s. Foresters and conservation groups clearly did not understand each other. Foresters were hurt by the harsh criticism, and regarded themselves as successful men of the modern age, as they turned sparse old forests into dense fast-growing plantations. Lisberg Jensen (2011) notes that "*Clear-felling became an expression of modernity*". Thus, forestry forced its opponents to argue for the opposite, i.e. to defend the "old". During the 1970s various forms of retention forestry were proposed, mainly to increase the aesthetic value of clear-cuts. In addition, scientific research on the perception of clear-cuts was initiated, one

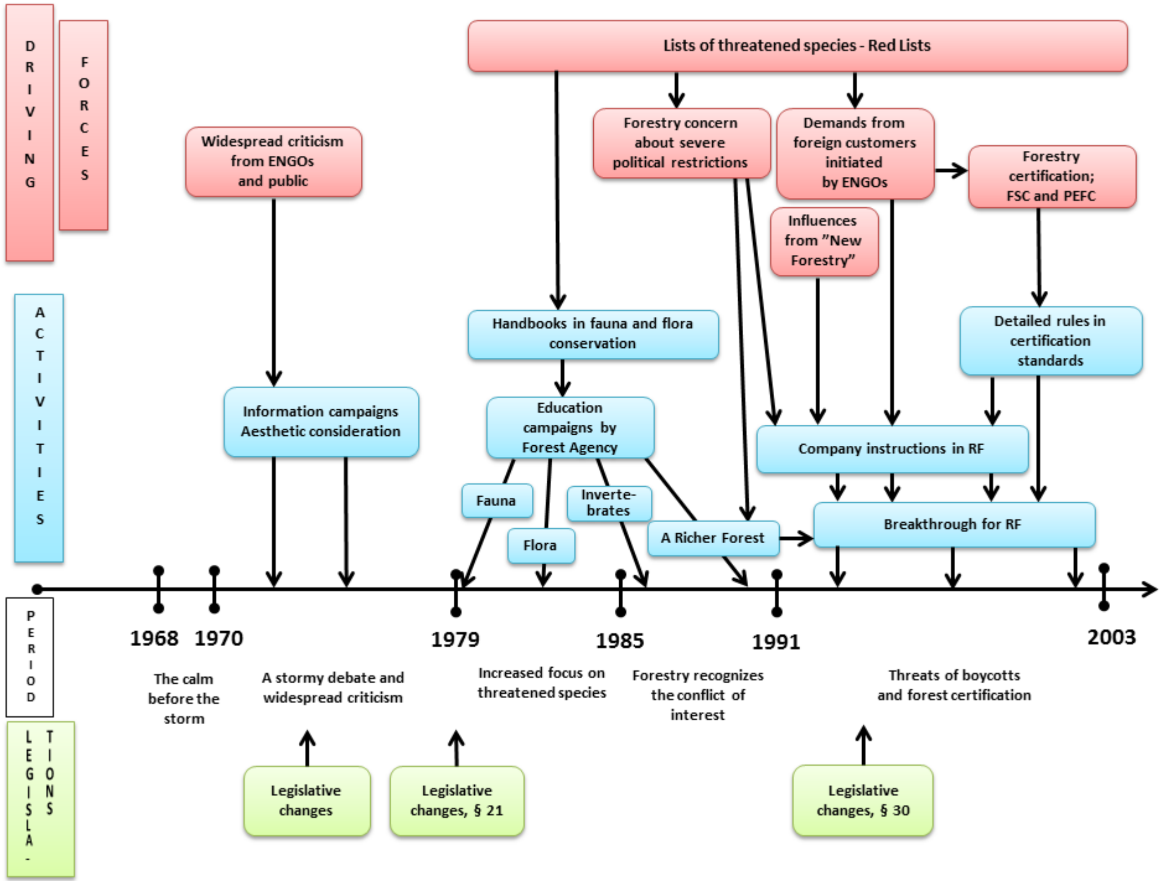

Figure 11. Diagram depicting the driving forces and the following activities for the development of retention forestry. The study period has been divided into different periods and legislative changes are marked

conclusion being that simple measures, like seed tree retention and smaller clear-cuts, could make them "*less deterrent*".

4.1.2 Lists of threatened species

The second driver was the compilation of Red Lists. During the 1970s foresters perceived the criticism of clear-cut forestry to be diffuse, with mixed arguments, many of which they considered based on sentiment rather than logic. Then suddenly, conservationists started providing detailed lists of threatened species and pointing out actual occurrences in the forest. This was a new, and uncomfortable, experience for the foresters. The focus of the debate shifted from the previous aesthetic concerns during the 1970s (and in the 1979 Forestry Act), towards flora and fauna conservation and threatened species. A basis for this development was the systematic mapping of threatened species and compilation of Red Lists, mostly by SLU researchers, who also produced several handbooks on flora and fauna conservation, issued by the Forest Agency (e.g. Ingelög 1981; Ehnström & Waldén 1986). The lists of threatened species became important drivers and effective tools for the criticism of forestry from the early 1980s until the end of the study period, and led to demands for more extensive retention forestry, more voluntary set-asides and more nature reserves (Lindahl 1990).

4.1.3 Forestry sector concerns about severe political restrictions

The third main driver we have identified is the forestry sector's concern about severe political restrictions. The sector could not ignore scientific arguments against clear-cutting based on red-listed species (see also Elliot & Schlaepfer 2001). When, in the late 1980s, foresters gradually recognised the problem that clear-cut forestry negatively affected flora and fauna, we conclude that they made a conscious decision to introduce retention forestry on a larger scale. They hoped that this would avoid severe forestry restrictions based on political forces that might insist on other management systems or obligations to sell large forest areas as nature reserves. The director of the Swedish Forest Agency, Björn Hägglund, clearly stated in 1985 that retention forestry was considerably better for forestry than exempting large areas from forest management, which would impose considerably more restrictions and incur considerably greater costs for both the forestry industry and the state. He also reacted in 1985 to the harsh debate by urging foresters to change their attitude towards conservation and listen to conservationists' criticisms.

4.1.4 Demands from foreign customers initiated by ENGOs

The fourth main driver was the strident demand, initiated by ENGOs, from European customers in the early 1990s for more environmentally-friendly forestry, especially clear-cut free harvesting systems. Simply threatening to boycott Swedish products resulted in complete cessation of harvesting high altitude forests. This was a major achievement for the ENGOs, which then started to work with one of Europe's largest paper purchasers, Springer Verlag. Seeing one of their major clients sit next to Greenpeace representatives at a press conference and demand "*clear-cut free paper"* was a completely new, and uncomfortable, experience for the forestry industry.

4.1.5 Influences of "New Forestry"

The developments in Sweden occurred in parallel to similar developments in the Pacific Northwest region of the USA. During the early 1990s debate in the USA focused on the cutting of old-growth forests, and the introduction of retention forestry was advocated as one part of a solution to this, and associated problems, as part of the "New forestry" concept. "New forestry" received great attention in Sweden and several Swedish foresters visited the Pacific Northwest region and were impressed by what they saw. We therefore consider that the "New Forestry" concept inspired both scientists and foresters to develop retention forestry in Sweden, thus it can also be considered a driving force, though weak.

4.1.6 Forest certification: FSC and PEFC

The sixth and final driving force identified in our analysis is forest certification, which is strongly linked to the fourth driver "Demands from foreign customers initiated by the ENGOs". Market demands were major reasons why Swedish forestry organisations joined the two international forestry certification systems, FSC and PEFC (whose standards clearly state requirements for retention forestry) in the late 1990s. Overall, forest certification in Sweden was strongly influenced by international processes like the Convention on Biological Diversity in 1992, which put biodiversity on the global agenda (Boström 2003). Certification is usually regarded as a market-driven system, but underlying the certification demands from the forest product customers there were often demands from various ENGOs, e.g. the WWF (Cashore et al. 2004; Gulbrandsen 2005; Johansson 2013).

4.2 Paper II – Silvicultural models to maintain and restore natural stand structures in Swedish boreal forests.

This is a discussion paper published in 1997, presenting ideas on management options which mimic natural forest disturbance regimes. I have included it in my thesis as it gives perspectives on conservation paradigms and approaches taken two decades ago.

The main idea behind the various conservation measures in Swedish forestry in the 1990s and in the "New Forestry" concept in the United States was that natural biodiversity can be maintained, or even restored, if forest management mimics natural processes, blends natural structures and includes natural composition in the production forest (Franklin 1992; Haila 1994). In boreal Sweden this means, for example, that fire (as an important process), living large-diameter trees (as important structures) and a higher proportion of deciduous trees in conifer stands (as important for composition) should be more frequent than in forests entirely used for timber production. A new idea was that it is necessary to undertake different measures in forests with different disturbance regimes. Paper II presents management options for three major site types in boreal Sweden which mimic natural forest disturbance regimes better than traditional forestry. These three site types reflect three different disturbance regimes and are: (i) Scots pine forests on dry and mesic sites subjected to frequent low-intensity fires; (ii) deciduous or Norway spruce dominated forest on mesic sites with large scale stand-replacing disturbances, mainly fire; and (iii) Norway spruce forest on moist and wet sites regenerated though so-called gap dynamics.

Table 1-3 present natural and important processes, structure and composition for the three site types together with suggested modifications in order to maintain and restore these features.

Table 1. *Natural features (processes, structures and composition) in Scots pine forests on dry or mesic sites, traditional management and suggested modifications in order to maintain and restore these features*

Natural feature		Related silvicultural measures	
		Traditional management	Suggested modifications
Processes			
Fire with relatively low intensity and high frequency		Clear-felling at dominant age 80-140 years	Use of the clear-felling system with green tree retention and more varied rotation period (e.g. 50-200 years)
Leading to:	Burned ground	(Efficient fire suppression and no use of fire)	Prescribed burning
	Warmed up ground	Removal of trees; scarification	Prescribed burning
	Exposed mineral soil (at severe fire)	Scarification exposing 10-30% of the mineral soil	Prescribed burning, or better, slight or moderate mechanical disturbance of ground vegetation, e.g. by scarification
	Nutrient release	Removal of trees; scarification	Removal of trees; prescribed burning; mechanical disturbance of ground vegetation, e.g. by slight or moderate scarification
	Tree death (except for most thick-barked trees, primarily pines)	Clear-felling and retention of pine seed trees for 5–15 years	Green tree retention followed by prescribed burning; leave trees as relicts; omit, vary or modify the traditional low thinning to generate self-thinning; girdle, push over or fell selected trees
	Natural regeneration	Natural regeneration from seed trees and surrounding stands	Natural regeneration, e.g. by means of seed trees or shelterwood, or seeding
	Reduced allelopathic effects on pine	(Efficient fire suppression and no use of fire)	Prescribed burning
Structures			
Several centuries old pines		(Final felling at dominant age 80-120 years)	Leave single or groups of large pines at final felling.
Snags and downed logs, also large ones		(Formation of dead trees heavily reduced by thinning)	Tree retention followed by prescribed burning; leave trees as relicts; omit, vary of modify the traditional low thinning to generate self-thinning; girdle, push over or fell selected trees
		(Harvesting of wind-thrown trees)	
Fire-scarred living and dead trees		(No use of fire)	Tree retention followed by prescribed burning
Composition			
Uneven-aged stand structure		One age class emanating from from seed tree regeneration	Omit, vary or modify the traditional low thinning, and accept self-thinning; leave trees or gropus of trees at final felling
All-sized stand structure		An aim for small height scarification by means of thinning	
A fraction of deciduous trees, primarily white birch		Deciduous trees present are normally kept in the stands	Favour other species than pine, above all, deciduous trees

Table 2. *Natural features (processes, structures and composition) in deciduous or Norway spruce dominated forests on mesic sites, traditional management and suggested modifications in order to maintain and restore these features*

Natural feature		Related silvicultural measures	
		Traditional management	Suggested modifications
Processes			
Fire. probably more intense and less frequent than on pine sites		Clear-felling at dominant age 80-120 years	Use of the clear-felling system with green tree retention and more varied rotation period (e.g. 100-200 years)
Leading to:	Burned ground	(Efficient fire suppression and no use of fire)	Prescribed burning
	Warmed up ground	Removal of trees; scarification	Prescribed burning
	Exposed mineral soil (at severe fire)	Scarification exposing 10-30% of the mineral soil	Prescribed burning or better, slight or moderate mechanical disturbance of ground vegetation, e.g. by scarification
	Nutrient release	Removal of trees; scarification	Removal of trees; prescribed burning; mechanical disturbance of ground vegetation, e.g. by slight or moderate scarification
	Tree death (except for some thick-barked trees, primarily pines)	Clear-felling and cleaning	Green tree retention followed by prescribed burning; leave trees as relicts; omit, vary or modify the traditional low thinning to generate self-thinning; girdle, push over or fell selected trees
	Natural regeneration	Planting, following scarification	Use of natural regeneration or seeding (after scarification) as a complement to planting
Structures			
Old, dying or dead deciduous trees in late successional phase		Deciduous trees present are normally thinned out	Promote a portion of deciduous trees at thinning; no thinning (and accept self-thinning)
Scattered centuries-old pines		(Final felling at dominant age 80-120 years)	Leave single or groups of large pines at felling
Snags and downed logs, also large ones		(Formation of dead trees heavily reduced by thinning) (Harvesting of wind-thrown trees)	Tree retention followed by prescribed burning; leave trees as relicts; omit, vary or modify the traditional low thinning to generate self-thinning; girdle, push over or fell selected trees
Fire-scarred living and dead trees		(No use of fire)	Tree retention followed by prescribed burning
Composition			
Minor age distribution		An aim for small differences in tree size by means of thinning	Use of modified clear-felling system
Deciduous tree dominated succession after fire disturbance		Deciduous trees present are normally cleaned or thinned out	Designate certain areas for deciduous succession; use of modified clear felling system; promote deciduous trees at cleaning and thinning; no thinning (and accept self-thinning)
On patches that escaped fire all-sized spruce dominated forests might have developed		Clear-felling and cleaning	Leave patches from around one-tenth to some hectares on the clear felling uncut

Table 3. *Natural features (processes, structures and composition) in uneven-aged Norway spruce forests regenerated by so-called gap dynamics, traditional management, and suggested modifications to maintain and restore these natural features*

Natural feature		Related silvicultural measures	
		Traditional management[a]	Suggested modifications
Processes			
Gap dynamics including:		Clear-felling and cleaning at dominant age 80-120 years	Use of selection systems that assure tree continuity; leave (parts of) selected stands uncut
	Tree felling by storm, snow or as a result of insect infestation	(Formation of dead trees heavily reduced, partly as a result of thinning)	(Accept those processes)
	Uprooting with sometimes exposed mineral soil	(Formation of uprooted trees heavily reduced by thinning)	Leave trees as relicts and accept that some of them die by, e.g. upprooting
	Regeneration on down logs, stumps and tussocks	Scarification and planting; (this natural type of regeneration is largely impeded on cleared sites)	Leave parts of selectively cut stands uncut, to promote this natural type of regeneration; leave wind-thrown trees on the site Natural regeneration, or planting if necessary
	Low fire frequency (intervals of about 200 years and more)	Clear-felling and cleaning at dominant age 80-120 years	Use prescribed burning on a portion of this site type (preferably combined with green tree retention)
Structures			
Snags and logs including large ones		(Formation of dead trees heavily reduced by thinning) (Harvesting of wind-thrown trees)	Retain living and dead trees; vary the intensity in removed trees to generate self-thinning; girdle, push over or fell selected trees
A minor portion of old, dying or dead deciduous trees (primarily hairy birch)		Deciduous trees present are normally kept in the stands	Favour species other than spruce, above all, deciduous trees
Composition			
Occurrence of gaps		Clear-felling and cleaning	Use of selection systems
Uneven-aged stand structure		One age class emanating from planting	Use of selection systems
All-sized stand structure		An aim for small height scarification by means of thinning	Use of selection systems
A fraction of deciduous trees, primarily hairy birch		Occuring deciduous trees are normally kept in the stands	Promote at least a portion of deciduous trees
Other caracteristics			
Relatively thick humus layer, occasionally disturbed by uprooting		Clear-felling and scarification exposing about 50% of the soil	Use of selection systems and accept some uprooting
Stable hydrology		Clear-felling and sometimes draining by ditching	No cutting or selection of shelterwood systems; no ditching
Stable micoclimatic conditions		Clear-felling	No cutting or selective cutting
Stable nutrient conditions		Clear-felling and sometimes draining by ditching	No cutting or selective cutting; no ditching

[a]Clear-felling, scarification and planting has long been the normal silvicultural system used in this type of stand but natural regeneration without scarification under shelterwood has now become more common. Selection systems are occasionally used.

4.3 Paper III – Retaining trees for conservation during clear-cutting has increased structural diversity in young Swedish production forests.

The retention approach appeared in the early 1990s (Paper I) and in Paper III we describe our investigation of whether large-scale effects of this can be observed in the young forests. We studied whether important structures such as dead trees and retained living trees have increased since the retention approach was introduced. We used data from the National Forest Inventory (NFI) for the whole country, and subdivided it into geographical regions. Using NFI plots we were able to analyse single dead and living trees and trees in patches <0.02 ha in the young stands. Tree patches >0.02 ha and buffer zones around streams and wetlands were not included as these are not classified as the same age as the surrounding young forest.

4.3.1 Dead wood volume

Trends in dead wood volume (dbh ≥ 100 mm) in young forests (0–10 years old) using five-year averages show that the volume ha^{-1} had increased significantly by about 70% in Sweden during the period 1997–2007 (Table 4). The most pronounced increase (>250%) was observed for Götaland, and was especially evident during the period 2003–2007 (storm Gudrun occurred in 2005). There was also a large increase over time in Svealand (>80%). Northern Sweden exhibited more moderate changes, with an increase of about 50% in S Norrland and only about 10% in N Norrland. All changes in the regions were significant except for that in N Norrland. For the whole country, and for the regions N Norrland and S Norrland amounts had stabilised between 2005 and 2007, while a similar flattening out was seen for Götaland only between 2006 and 2007. The dead wood volume in the young forest (0–10 years old) varied between 9 m^3 ha^{-1} and 6 m^3 ha^{-1} depending on region, with the highest levels in S Norrland, and the lowest in N Norrland.

Table 4. *Dead wood volume (m^3ha^{-1}; dbh ≥100 mm and height/length ≥1.3 m) in young forests (0-10 years) during 1997-2007 using five-year averages, by region. 95% confidence intervals are given for 1997 and 2007, respectively. For regions, see Paper III.*

	1997	1999	2001	2003	2005	2007
Götaland	2.56+0.41	3.29	3.83	6.19	8.14	9.02+0.57
Svealand	3.56+0.46	4.81	5.64	5.58	6.31	6.59+1.49
Southern Norrland	6.20+0.59	6.90	7.74	8.86	9.44	9.39+0.87
Northern Norrland	5.21+0.80	5.34	5.62	5.69	5.94	5.60+1.16
Sweden total	4.56+0.92	5.24	5.84	6.67	7.49	7.66+0.84

Hard dead wood, i.e. recently killed trees, increased significantly from 2.0 m^3 ha^{-1} to about 5 m^3ha^{-1} from 1997 to 2007 for the whole country. Thus, this decay class contributed greatly to the observed total increase, since soft dead wood volumes ha^{-1} displayed a much smaller and non-significant increase. Dead tree volume in the largest class (dbh ≥ 400 mm) as well as finer diameter dead trees (dbh ≥100 mm and ≤400 mm) both increased significantly in forests aged 0–10 years during 1997–2007.

"Forestry companies" was the owner category that left the most dead wood per hectare in young forest (0–10 years old) calculated for the whole country, and with a significant increase from about 6 $m3ha^{-1}$ in 1997 to almost 10 $m3ha^{-1}$ in 2007. The increase from 1997 to 2007 was also significant for small private forest owners, from about 3.5 m^3ha^{-1} to about 7 m^3ha^{-1}.

4.3.2 Number of living trees

Evaluating the number of living retention trees using NFI data is difficult as it is impossible to differentiate retention trees from seed trees. Scots pine *Pinus sylvestris* is the predominate seed tree, but is also a common retention tree as it withstands storms well. Our study therefore presented results both with and without *P. sylvestris*. Including *P. sylvestris* overestimates the number of retention trees, whilst excluding Scots pine underestimates it. However the trends over time are more interesting than absolute values.

When young forests (0–10 years old) in 1955, 1989 and 2007 are compared, the number of living trees ha^{-1} (dbh > 150 mm) varies between 6 and 14 (without *P. sylvestris*) (Table 5) and the increase between 1989 and 2007 was 147 %. In 2007, the average number of living trees ha^{-1} in young forests (0–10 years old) (excluding *P. sylvestris*) was about 14, with large variations between regions: Götaland had the most, about 25 ha^{-1}, and S Norrland and N Norrland had the fewest, both about 9 ha^{-1} (Table 5).

Including *P. sylvestris*, the number was about 25 ha^{-1} for the whole country, most for Götaland with about 34 ha^{-1}, and fewest for S Norrland with about 18 ha^{-1}. *P. sylvestris* was the most common tree species in young forests (0–10 years old) for the whole of Sweden, with an average total of about 11 trees ha^{-1}, and was especially common in N Norrland (about 15 ha^{-1}). Excluding this tree species, the most common tree taxa in young forests was *Betula* spp. (about 6 trees ha^{-1}), followed by *Picea abies* (about 4 trees ha^{-1}), and ''other deciduous tree species'' (about 3 trees ha^{-1}). *Betula* spp., *P. abies*, and ''other deciduous tree species'' were especially common in Götaland.

Table 5. Number of all living trees ha^{-1} (dbh $\geq$150 mm) for forests aged 0-10 years for the whole of Sweden and for different regions during 1955-2007, excluding Pinus sylvestris. 95% confidence intervals are given for 1955, 1989 and 2007, respectively. For regions, see Paper III.

	YEAR					
	1955	1970	1980	1989	1995	2007
Sweden total	14.18±0.97	8.19	8.51	5.58±0.71	8.15	13.77±1.43
Götaland	22.00±1.77	13.06	14.28	10.34±1.80	13.80	24.65±3.96
Svealand	12.03±1.27	6.29	5.32	4.94±1.14	7.54	12.86±2.22
Southern Norrland	16.06±2.42	9.24	8.07	4.39±1.44	6.86	9.05±2.13
Northern Norrland	10.57±1.18	5.75	7.88	4.33±1.32	5.81	8.80±2.57

4.4 Paper IV – Conservation values of certification-driven voluntary forest set-asides.

Voluntary set-asides (VSA) were established more systematically from the mid 1990s, parallel to the development of the woodland key habitat (WKH) survey. Further, the introduction of the two international forest certification systems FSC and PEFC around the turn of the millennium required certified forest owners to retain all WKH, and to set aside at least 5 % of their productive forest land. The international certification systems and the WKH concept have thus been the main driving forces behind VSA in Sweden. In Paper IV, we compared the area extent, structural diversity of importance to biodiversity and stand characteristics of VSA, formally state-protected nature reserves (R) and managed production forest (PF). We used data from the National Forest Inventory (NFI) and focused on forestry company land in boreal Sweden, amounting to about 7 million ha. We used data for the time period 2009-2013 from a total of 7993 (639 VSA, 553 R, 6801 PF) NFI plots. The plots were selected from the whole NFI sample using maps (polygon layers) of VSA, R, and PF in a Geographic Information System (GIS). For most variables, analyses were separated into categories of all forest ages and forests >100 years old, because old forests have been shown to be important to species that need long continuity and forest-interior conditions.

4.4.1 Area and size distribution

Company owned VSA and R covered approximately the same area in boreal Sweden, almost 650 000 ha. There were large differences in their geographical distribution, with 65% of the area of VSA found in the south and central boreal regions compared to 35% of R. The proportion of VSA of total forest company land varied between 18% and 6% depending on region, with the highest proportion in the north. The very uneven distribution of reserves implies that, outside the north boreal region, there are only 230 000 ha of R but 408 000 ha of VSA.

VSA were more numerous in all size classes except for >10 000 ha, where there were 15 R but only one VSA. A striking difference in the number was detected for sizes <10 ha, with 25 222 VSA but only 252 R. The total number of VSA was >35 000 compared to 1661 R.

The high area percentage of R in the north boreal region (65%) is due to the establishment of numerous large reserves in the mountain region in the 1980s and 90s. Most of the VSA area is instead found in the central and southern regions (65%) because they are more evenly distributed in relation to the area of company land.

4.4.2 Structural variables

There was a clear pattern for the two structural variables dead wood (>100 mm diameter) and large-diameter trees (>400 mm diameter), with the highest values obtained for R (for all forest ages: 24.5 m^3 ha^{-1} for dead wood and 12.1 for large-diameter trees ha^{-1}), intermediate values for VSA (17.6 m^3 ha^{-1}, 8.6 ha^{-1}) and the lowest values for PF (7.0 m^3 ha^{-1}, 2.0 ha^{-1}). The pattern was similar when dead wood was separated on the basis of diameter, e.g., dead wood >300 mm constituted 43% of all dead wood in R, 31% in VSA and 22% in PF of all dead wood >100 mm for forests >100 years. The amount of dead wood in forests >100 years old was about 25 m^3 ha^{-1} for R and about 20 m^3 ha^{-1} for VSA, and considerably less than commonly reported for old growth forests in boreal Fennoscandia. VSA had a significantly higher volume of the important broadleaved tree species aspen, rowan and sallow, i.e., 3.9 m^3 ha^{-1} compared to 1.8 m^3 ha^{-1} for R and 1.1 m^3 ha^{-1} for PF, for all forest ages.

4.4.3 Stand characteristics

VSA and R were considerably older than PF. The percentage of forest >100 years old was 74% for VSA, 82% for R but only 16% for PF. R were characterised by a high percentage of forests >160 years old, i.e., 39% (Fig. 12a). Spruce forests were most common in VSA (41%) and R (48%), whereas pine forests were most common in PF (51%) (Fig.12b). Coniferous–broadleaved forests were significantly more common in VSA than in R and PF, with the lowest percentage in R. The bilberry type was the most common ground vegetation type for all forest categories, and significantly more common in VSA (47%) than in R (39%) and PF (33%).

VSA and R had lower site productivity than PF, e.g., 50% of VSA and 70% of R had a productivity <3 m^3 ha^{-1} $year^{-1}$ compared to 28% for PF (Fig 12c). Site productivity in R was especially low: 28% of R had a productivity <2 m^3 ha-[1] $year^{-1}$ (Fig. 12c). VSA contained a higher percentage of forests with high standing volume per hectare than the other two categories: 30% of the area had standing volumes >200 m^3 ha^{-1} compared to 17% for R and 15% for PF (Fig. 12d). For forests >100 years, R had an especially large share of low volumes: 43% of the area of this forest category had volumes <100 m^3 ha^{-1}.

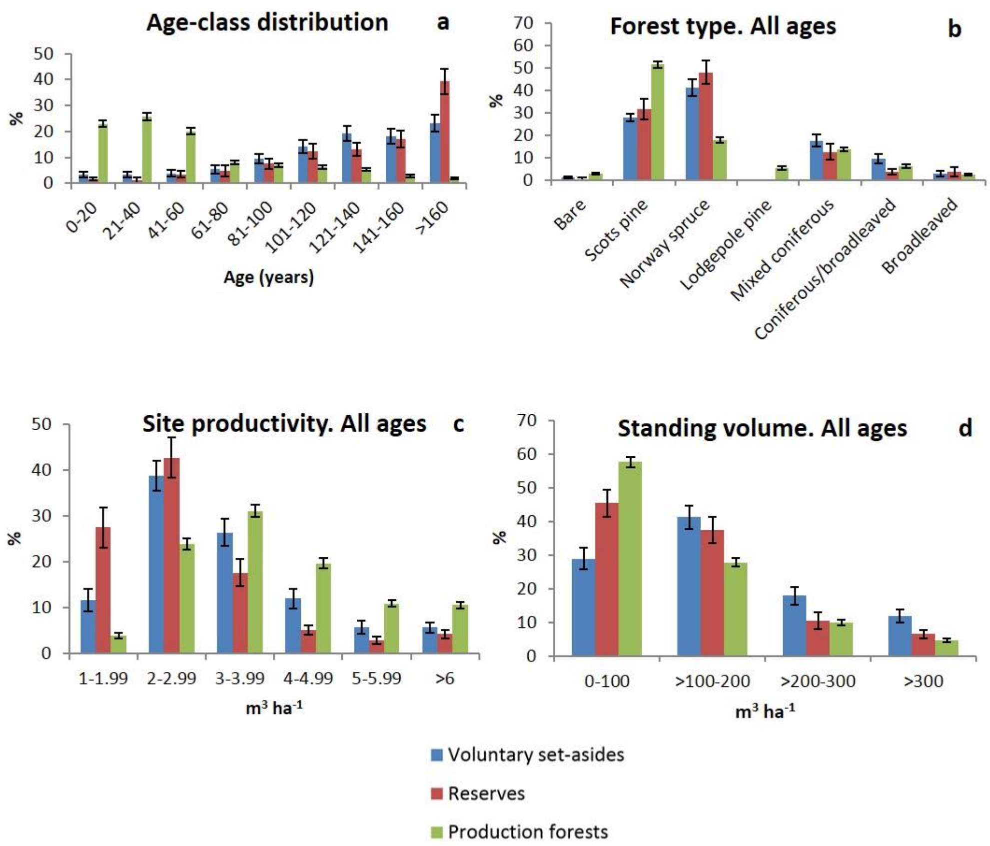

Figure 12. Percentages of total area for different forest categories (voluntary set-asides, reserves, production forests) distributed by age class (a), forest type (b), site productivity (c) and standing volume (d).

5 Discussion

5.1 Reflections and conclusions from the studies

5.1.1 Driving forces

We identified six main driving forces for retention forestry development in Sweden (Fig. 11). The debate about clear-cuts started suddenly in the early 1970s, after previously being a non-issue. The origin of retention forestry lies in attempts to mitigate this criticism of clear-cuts and increase public acceptance by retaining trees and tree groups. In the mid-1970s scientists and environmental organisations provided increasing evidence that clear-cuts had negative effects on certain plants and animals, thereby advocating retention forestry from a conservation perspective. The reason for choosing retention forestry as a tool for forest conservation rather than creating large forest reserves was probably that the cost of improving conservation could be distributed among numerous land-owners instead of being borne solely by the Swedish state.

Despite a lack of systematic methodology for assessing the relative importance of the driving forces (Hersperger & Bürgi 2009), in our case we found strong support for the hypothesis that the main one was concern for threatened species. This is because the compilation of Red Lists offered a new instrument for environmentally-oriented actors to demonstrate concrete effects of forestry on biodiversity, from national to stand level. These lists strongly affected both the public debate and the drivers “forestry sector concerns about severe restrictions on forestry” and “demands from foreign customers”.

5.1.2 Management options for different site types

In Paper II we suggested different management options for different site types and here I reflect on the implementation of these ideas and on the development of alternative approaches since the paper was published.

Suggested modifications in table 1-3 (from 1997) are given in bold type below. i, ii and iii refer to the different site types:

(i) Scots pine forests on dry and mesic sites subjected to frequent low-intensity fires.
(ii) Deciduous or Norway spruce dominated forest on mesic sites with large scale stand-replacing disturbances, mainly fire.
(iii) Norway spruce forest on moist and wet sites regenerated by so-called gap dynamics.

Use of the clear-felling system with retention of single or groups of trees [i,ii]

Has been implemented to a great extent, see Papers I and III.

Prescribed burning, Tree retention followed by prescribed burning [i,ii]

Has been implemented, but on a limited scale (Fig.13). The Swedish FSC standard states that *"Managers of major holdings shall take all reasonable measures to burn an area equivalent to at least 5 % of the regeneration area on dry and mesic forest land over a five-year period"* (FSC 2010). If burned forest is left to develop naturally, the burnt area is multiplied by a factor 3. The PEFC standard does not require burning. However, there are no comprehensive statistics on annual prescribed burning, but I estimate that about 2000 ha are burned annually in Sweden.

Slight or moderate soil scarification [i,ii]

Has been implemented, as soil scarification today is a normal measure and more gentle methods that have a less negative impact have been developed.

More varied rotation periods (e.g. 50–200 years) [i,ii]

Has not been implemented. Final-felling ages have generally decreased. The Forestry Act states a minimum age for final-felling. Requests have been made by the forestry industry to reduce this further. Not felling production forests at an optimal age is regarded as a high cost that does not correspond to the conservation benefit.

Girdle, push over or fell selected trees [i,ii]

Has been implemented, but on a very small scale (Skogsindustrierna 2015). The forestry company Bergvik Skog has allocated ca 10 000 ha of voluntary set-asides for conservation of the threatened white-backed woodpecker (*Dendrocopos leucotos*). Some of the measures taken are girdling of deciduous trees or creation of high stumps in order to generate dead wood (http://www.bergvikskog.se/en/sustainability/environment-biodiversity/endangered-species/). In Sveaskog's ecoparks and SCA's conservation parks, active conservation measures are taken to damage and kill trees (e.g. Sveaskog 2012).

Figure 13. Prescribed burning under seed trees (*Pinus sylvestris*) is a management option which mimics a natural forest process. Photo Per Simonsson.

More natural regeneration [i,ii,iii]

Has not been implemented. Instead the proportion of natural generation, based on reports pertaining to final felling, decreased from ca 35% during the mid-nineties to about 10% in 2012 (Skogsstyrelsen 2014b). The reason for this is that natural regeneration is a less predictable method than planting; seed trees are often blown down and natural regeneration does not involve improved seedlings that grow quicker.

Omit, vary or modify the traditional low thinning to generate self-thinning [i,ii]

Has not been implemented to any great extent. Some modification of thinning has been implemented, for instance when retaining certain biotopes during thinning (e.g. SCA 2011). Leaving large areas to self-thin is not happening at present.

Favour species other than conifers, above all, deciduous trees [i,ii]

Has partly been implemented. The total volume of deciduous trees has increased by ca 40 % from 1995 to 2013 which means that the proportion of deciduous trees has increased from 15 % to 18 % during the same period (Sveriges lantbruksuniversitet 2016). The standing volume of broadleaves ≥ 30cm dbh has increased by 75 % during the same period (Sveriges lantbruksuniversitet 2016).

Designate certain areas for deciduous succession [ii]

Has partly been implemented. The proportion of productive forest land dominated by broadleaved trees has increased from ca 7.5% in 1995 to 8.5% in 2013 (Sveriges lantbruksuniversitet 2016). In northernmost Sweden, however, there has been a decrease during the same period from 6.5% to ca 6%. According to the Swedish FSC standard there should be 5 % of deciduous-dominated stands on forest land (FSC 2010).

Promote a portion of deciduous trees at thinning [ii]

Has been implemented, as deciduous trees are retained to a greater extent during thinning, especially biologically important species like Aspen *Populus tremula,* Sallow *Salix caprea* and Rowan *Sorbus aucuparia*.

Use of selection cutting systems that assure tree continuity: leave parts of selected stands uncut [iii]

Selection cutting systems have not been introduced to any great extent in production forests. However, moist and wet sites are often left as retention areas during final-felling, when they form a small part of a larger felling site. As shown in Fig. 3, a large proportion of conservation areas retained during final-felling are moist and wet sites, i.e. where selection cutting often is relevant.

No cutting or selection cutting or shelterwood systems; no ditching [iii]

"No cutting" has been partly implemented as shown by the analysis of voluntary set-asides presented in Paper IV. Results clearly show that spruce forests and the soil moisture classes "mesic-moist" and "moist-wet" are overrepresented among voluntary set-asides. Neither selection cutting nor use of shelterwood systems is implemented to any extent today. During the 1990s there were great hopes that forestry could use shelterwood systems in moist Norway spruce stands. Later studies have shown high mortality among shelterwood trees with poor regeneration results (Sikström & Pettersson 2005). Therefore the use of shelterwood systems has mostly been abandoned. The notified area of protective ditching has increased since the mid 1990s. (Skogsstyrelsen 2014a).

Many of our suggested management options from 1997 have been implemented in modern forestry and several of them are included in the PEFC and FSC standards. The extent of the measures can, however, be questioned in relation to long-term preservation of biodiversity in all landscapes. Angelstam et al. (2013) maintain that several of today's FSC indicators do not satisfy the SMART criteria (Specific, Measurable, Accurate, Realistic and Timebound) and that quantitative standard levels do not originate from evidence-based research, but are the result of a negotiation process. Our suggestion in 1997 to increase the use of selective cutting or shelterwood systems in Norway spruce forest on moist sites and to increase the area of natural regeneration has, however, not been implemented. Bilberry *Vaccinum myrtillus* L. is a common and important species in the boreal forests (Esseen et al. 1997) and its abundance seems to decrease linearly with increased logging intensity (Bergstedt & Milberg 2001). Selective felling seems to be an option where bilberry maintenance is required, for example in edge zones along wetlands. Here bilberry is a key species for many birds that eat insect larvae which feed on bilberry (Atlegrim & Sjöberg 1995).

5.1.3 Young forests have become structurally richer

Our study clearly shows that young forests have become structurally richer since the introduction of the retention approach in forestry. We interpret the large increase between 1997 and 2007 in the amount of dead wood (ca 70%) in stands aged 0-10 years as an effect of increased nature conservation actions at final felling. A more recent study of dead wood in managed Swedish forests shows that the increase has slowed down in recent years and that a balance between input (natural mortality) and loss of dead wood due to decay will eventually be reached (Jonsson et al. 2016).

The information on dead wood amounts from the National Forest Inventory-data raises questions about the turnover between age classes. The amount in the oldest age classes >100 years and >60–100 years, i.e., those that are mature for final felling, is much higher than that of the youngest forests. If all dead wood from the old forest was retained at harvest, the amounts should be fairly equal in the youngest and oldest forests. That this is not the case has previously been shown by Fridman & Walheim (2000), and is also clear in our data. The disappearance of dead wood could be due to damage from heavy machinery (harvesters, forwarders, tractors) during logging and soil scarification (Hautala et al. 2004), natural decomposition of soft wood (e.g. of birch) after harvest, and possibly by harvest of wind-thrown retention trees by forest owners, as indicated by some studies (e.g. Liungman 2000). The increasing extraction of tops and branches for bioenergy use may also reduce the dead wood resource (Rudolphi & Gustafsson 2005).

5.1.4 Voluntary set-asides are an important complement to traditional reserves

Our analysis showed that voluntary set-asides (VSA) are an important complement to traditional reserves in terms of geographical location, size and structural factors important to biodiversity. Reserves (R) are located mainly in the north boreal region whilst VSA are located mainly in the south and central boreal regions. Generally R are older and have more dead wood and large-diameter trees but are considerably less productive and have lower standing volume than VSA. The main reason for the higher amount of dead wood and large-diameter trees in R is their location in the north boreal region. This part of the country has a shorter history of industrial logging compared to areas further south (Östlund 1993) and consequently has more natural forest legacies. In past studies, forest reserves in Sweden have been found to occur on land with considerably lower productivity than the average (e.g. Fridman 2000). In our data, site productivity was, indeed, lower in R than in production forests (PF), but VSA also had comparatively low productivity (3.3 m3 ha^{-1} $year^{-1}$ for VSA, 2.7 m3 ha^{-1} $year^{-1}$ for R, 3.9 m3 ha^{-1} $year^{-1}$ for PF). One reason for the differences in productivity between the forest categories could be that low-productivity forests have lower economic value than high-productivity forests, and thus advantageous to set aside from an economic point of view, as also reflected in the large share of R and VSA in the cold and low-productivity north boreal region. It may also be that low-productivity forests have been managed less intensively, leading to higher structural diversity, and thus have been predominantly selected as VSA and R. On the other hand, the data suggest that in the selection of VSA, low wood volume, (i.e. forests with low economic value) was not important: for forests >100 years old, volumes were similar between VSA and PF. For R, 43% of forests >100 years old had volumes <100 m^3 ha^{-1} compared with only about 20% for VSA and PF, indicating a selection bias towards R.

The higher structural diversity in VSA compared to PF was expected. The industrial, large-scale forestry during the last century in Sweden has resulted in forests primarily consisting of young, structurally homogenous stands: 49% of all PF are younger than 40 years old (Fig. 12a).

5.2 International perspectives

In order to understand the internal Swedish situation it is necessary to contextualise and look abroad. Both international conventions and exposure to an international market for wood products have had a strong impact on Swedish forestry. Various international conventions have, of course, had an overall impact on the development of conservation work in Sweden. However, this has often occurred in a more indirect way. The Convention on Biological Diversity that was agreed in 1992 (CBD 1992) was one of the overall drivers of changes in Swedish forestry policy in the early 1990s (Angelstam et al. 2011) and provided some weight to the criticism from ENGOs that forestry was a threat to many red-listed species (Paper I). Generally, however, I consider that international forestry policy processes have had limited impact on the development of national forest policy in Sweden (Lindstad & Solberg 2012). Nevertheless, the Aichi targets, adopted within the CBD framework in Nagoya 2010, have had great impact on the Swedish government's new strategy for biodiversity and ecosystem services, in which new targets for both formal protection and voluntary set-asides have been specified (Regeringens proposition 2013/14). One of the Aichi targets is that 17 % of the land and freshwater area should be protected by 2020, especially areas of special importance for biodiversity and ecosystem services. Sweden has also adopted several EU policies and directives such as the EU Birds, Habitat and Water Framework Directives (European Commission 1979; 1992; 2000). For forest owners, however, I maintain that *"Demands from foreign customers initiated by ENGOs"* and *"Forest certification"* are the major driving forces that have lead to changes in forestry (Paper I).

We talk about "the Swedish model" with its three levels, retention forestry, voluntary forest set-asides and legally protected forests (chapter 1.1), but a relevant question is – how Swedish is "the Swedish model"?

A global review of the use of retention forestry (RF) is presented in Gustafsson et al. (2012). RF is applied on all forest land in Finland, Norway and Sweden and on more than 50% of the forests in the Baltic states, Germany and in the Canadian provinces of Alberta, British Columbia and Ontario. In the United States RF is applied to varying degrees on all federal lands, but also on other land-owner categories in the eastern USA. In Latin America, RF is only applied by a few forestry companies in southern Argentina, whilst Australia requires all states to retain habitat trees in different forest types. The amount that is retained varies between and within different countries, with less than 10 % in northern Europe and as much as 30% in Tasmania, Australia. RF is therefore not unique to Sweden, but it is unusual that RF is implemented on all forest land, irrespective of land-owner categories, which is the case in Sweden according to the legislation. RF is often described as having been developed in north-western America during the late 1980s (Gustafsson et al. 2012), but as described in Paper I, Sweden introduced and implemented the practice of RF even earlier (Ahlén et al. 1979).

When it comes to voluntary set-asides (VSA) and their extent in Sweden, they are largely a result of forest certification (Paper IV). The standards of both FSC and PEFC require that at least 5% of productive forest land be set aside, irrespective of whether there are areas of high conservation value or not. The contents of different countries' national standards vary considerably. The forests in Finland and Norway are mainly owned by small private forest owners, certified according to PEFC. Their national PEFC-standards do not contain quantitative requirements specifying how much should be set aside, only that certain valuable biotopes must be protected.

Canada has 52 million hectares of forest certified by FSC whilst Russia has 40 million hectares. These are the two countries with the most FSC certified forests in the world. They also lack specific targets specifying how much forest should be set aside according to their standards. The Canadian standard, however, requires "*a protected areas network, which includes areas set aside to provide for sufficient ecosystem representation, to conserve enduring features, to maintain locally/regionally rare ecosystems, and to serve as scientific reference areas*" (FSC 2004). According to the Russian standard, forest owners must "*establish a net-work of representative samples of existing ecosystems within the forest area being certified, which provides preservation of the diversity of landscapes, ecosystems, habitat types and local flora and fauna*" (FSC 2012). Elbakidze et al. (2011) compared two FSC certified forestry units in Sweden and in the Russian republic of Komi, showing that the area of VSA was similar in the two countries. However, the Swedish VSA are more fragmented and considerably smaller, which implies that the core area of VSA in Sweden is less than that in Russia. My interpretation is that the FSC-agreements in Canada and Russia are comparable to the Swedish FSC-standards and thus that VSA are also created in those countries. In Canada and Russia the forests are, to a large extent, owned by the state and therefore the costs of VSA are not carried by private companies logging these forests on short- or long-term contracts.

Regarding formal protection of nature, National Parks and nature reserves have been the traditional ways of protecting different habitats against various forms of exploitation and they are designated in most countries (Geldmann et al. 2013). In 2014, 15.4% of the world's terrestrial and inland water areas were protected (Juffe-Bignoli 2014). In Sweden, 15.5% of terrestrial and inland water areas are protected, which is a low figure in the European context

(European Environment Agency 2015). It is very difficult to compare the extent of formally protected forests between different countries as both protection and forests are defined in different ways. The two Swedish government agencies, the Environmental Protection Agency and the Forest Agency, have not been able to agree about how much protected forest land there is in Sweden, but have instead shown that there are different ways to calculate the figures (Naturvårdsverket & Skogsstyrelsen 2012). It is important to consider what land is defined as forest land when comparing protection between countries, but it is also important to consider what the aim of protection is and which restrictions are linked to the protection status.

In summary, "the Swedish model" does not appear unique or particularly "Swedish". What separates Sweden from other forested boreal countries of the world is the large extent of voluntary set-asides on non-public land together with the fact that retention forestry is implemented on all land. May these facts should be considered the real content of the Swedish forestry model and maybe also the latter one is in line with the Swedish aptness, in many areas, to apply general solutions for all rather than treating different landowners differently.

5.3 Personal reflections on current and future conservation in Swedish forests

Based on my research and professional experience, I present here some highly personal reflections on how the Swedish model works and also present some ideas on how conservation approaches could be developed.

5.3.1 Future possibilities for formal protection of forests in Sweden

At present about 900 000 ha of productive forest land are formally protected as National Parks, nature reserves, habitat protection areas or through nature conservation agreements (Sveriges Officiella Statistik 2016a;b). This means that 3.9 % of the productive forest area is formally protected. Of this area, 51% is high altitude forests (Sveriges Officiella Statistik 2016b). These high altitude forests are very valuable for nature conservation, but are mostly low-productivity forests with very low timber volumes (Paper IV). The large proportion of protected high altitude forests indicates the uneven geographical as well as ecological distribution of the protected areas; this has been a subject of discussion for some time (e.g. Nilsson & Götmark 1992; Fridman 2000).

Formal protection of forests is internationally the most common measure to protect biodiversity in forests (Geldmann et al. 2013), and also one of the cornerstones of "the Swedish model". I think it is questionable that only 2 % of the productive forest outside the mountain region is formally protected.

Consequently, I believe that the government should take more responsibility for “the Swedish model” and allocate more money to the formal protection of forests.

One problem, however, is the huge cost involved in purchasing land and paying compensation to land owners. The Environmental Protection Agency estimates costs of ca 84 000 SEK per hectare when forests are formally protected under the Environmental Code (Naturvårdsverket 2015a). Several government investigations have looked at the formal protection of forests (e.g. SOU 1997a; b), and it is clear that politicians wince at the costs and would rather put the responsibility on the land-owners instead. The most recent environmental proposition presented by the government suggests that voluntary protection should increase by 200 000 ha between 2014 and 2020 despite the fact that voluntary protection is more extensive than formal protection (Regeringens proposition 2013/14).

One way of increasing the area of formally protected forests is to use land owned by the state company Sveaskog for land exchange with owners whose forests become protected. This type of land exchange has already been implemented since the government decided to use 100 000 ha of Sveaskog’s land for land exchange with the major forestry companies, the church, commons etc. The exchange provided a further 450 nature reserves, and 60 000 ha of productive forest land will be permanently protected.

The Environmental Protection Agency regards the land exchange deals to be a success and a cost efficient way of protecting forests (Naturvårdsverket 2015a). I share this opinion and believe the government should continue with this type of land exchange with Sveaskog in order to take more responsibility for the formal protection of forests. This type of land exchange has benefits in the form of simpler transactions between forest owners and the Swedish government and also reduces the antagonism of forest owners towards the creation of new forest reserves.

5.3.2 The focus on red-listed species

When studying the conservation debate in journal articles published in the 1960s and 1970s (Paper I) I sometimes laughed at how they reasoned back then. Therefore it might be good to reflect on how people some 50 years from now will regard our conservation work and how they will assess our methods. One informed guess might be that we will be astounded by how we were so focused on red-listed species. Today, occurrences of red-listed species directly or indirectly control the selection of areas for protection. This applies both to formally and voluntarily protected areas. The development of the importance of Red Lists for protected areas is described in Paper I.

I think that the occurrence of red-listed species has too great an influence on conservation work today. Many red-listed species are naturally rare and are redundant in supporting the various functions of the forest ecosystem. Ecosystem services are frequently discussed today (e.g. Regeringens proposition 2013/14) but the term has not had an impact on practical conservation yet. As an example, it may be a greater problem that both the cover of reindeer lichens on the ground and pendulous lichens in the trees are decreasing in our boreal young stands than that a number of localities for red-listed species may disappear. Reindeer lichens and pendulous lichens are important for the ecosystem service "reindeer grazing". A simple measure to increase lichen cover on the ground is to have less dense young stands. The cover of pendulous lichens can be increased by leaving more patches of trees with lichens during final-felling, so that the lichens can disperse to surrounding trees in the young stands. I think we should discuss moving from the implementation of conservation measures per se towards measures that strengthen important ecosystem functions rather than strictly focusing on the protection of red-listed species.

In this context I also wonder whether we have forgotten the human perspective in our focus on red-listed species. Today, many of the areas with formal or voluntary protection will more or less never be visited by humans. We assume that the protection of red-listed species has such an intrinsic value that it does not matter whether anyone ever experiences the biodiversity of the area. For a long time the main objective of conservation was rather to preserve undisturbed areas so that humans could experience wilderness and conservation had an anthropocentric perspective (Anshelm 2004). When ENGOs wanted to protect forests from felling in the 1970s and 1980s using "emotional" arguments about beautiful pristine forests, they received little sympathy from forest-owners or the forestry industry. However, when occurrences of red-listed species could not be contested in the same way, the Red Lists became an important tool for forest conservation (Lindahl 1990, Paper I). One method for identifying valuable boreal forests using red-listed species was developed by the ”One step ahead” group in Jokkmokk during the late 1980s (Karström 1992; Naturvårdsverket 1993). The survey method became widespread in Sweden and was adapted by many forestry companies and authorities. Everyone who surveyed woodland key habitat in northern Sweden learned to recognise the most important indicator species. The focus on red-listed species increased successively and has continued to increase (Paper I). However, today even the most eager species' advocates, maintain that red-listed species are mainly a tool for protecting more forests. "*The only way to receive recognition for anything is through numbers and tables. It is* *certainly sad. Maybe even unworthy. The carpenter does not need to love his hammer, it is his tool. And I do not have better tools than the red-listed species. They are irrefutable, quantifiable, an objective fact that cannot be questioned. That is how I take responsibility. I might have wished to do things another way. But I have no choice. Beauty does not translate into tables."* (Zaremba 2012). The conflict in a local community between a strict scientific and species approach vis-a-vis an anthropocentric approach to the protection of forests is described by Beland Lindahl (2008).

My belief is that conservation work in our forests should take on a more anthropocentric perspective. Important questions to address then are: What type of reserves and set-asides do Swedish people want to protect? What type of retention during felling does the general public wish to see?

5.3.3 The challenge of creating a green infrastructure including both formal and voluntary protected areas

The importance of increasing connectivity in fragmented forest landscapes by using protected areas, and thus strengthening green infrastructure, is a topic of discussion today (Elbakidze et al. 2013; European Commission 2012; European Environment Agency 2014). Each County Administration Board has the task of presenting regional action plans for green infrastructure (Naturvårdsverket 2015b). As shown in Paper IV, company-owned voluntary set-asides (VSA) in south and central boreal regions constitute a considerably larger area than nature reserves, and often exhibit similar qualities to reserves. VSA, particularly those on company-owned land are therefore an important component of the County Administration's work with green infrastructure (Länsstyrelsen Västerbotten 2016). Small, certified land-owners cannot relocate their VSA because they have small properties, whilst large land-owners can do this if they want to enhance landscape connectivity in conjunction with nature reserves. A major challenge lies in coordinating formally protected areas and VSA from a green infrastructure perspective, and on deciding which principles coordination should be based on (e.g. Andersson et al. 2013; Snäll et al. 2016).

A key approach for the County Administration's work on green infrastructure is to identify "core regions" (Länsstyrelsen Västerbotten 2016). "Core regions" are areas that have particularly high concentrations of key sites for fauna and flora, as well as biologically important structures, functions and processes, compared to the wider landscape. In these areas the aim is to achieve higher proportions of protected areas. I believe that conservation efforts should be more aggregated at the landscape level. I therefore think that large forest companies should cooperate with the County Administrations in their work with green infrastructure. This means that new voluntary set-asides must be established in “core regions” at the same time as other VSA are removed. I suggest that, in the same way that we identify “core regions”, we should also identify “non-core regions”, where we must accept that we cannot maintain all biodiversity. “Non-core region” should have lower levels of retention and fewer VSA, as long as these are relocated to “core regions”. This type of conservation zoning is one of the ideas behind so-called triad forestry (e.g. Tittler et al. 2012). It is essential in the future to develop planning models in which both reserves and voluntary set-asides and their spatial configuration are considered. This will require integration of non-state and state governance processes.

6 Concluding remarks

In Paper I we showed that editorial texts, articles and letters to the editor in two relevant magazines, can be used to track the development and drivers of major changes in an industry such as forestry. The articles clearly show that foresters and conservation groups did not understand each other, as there was a clear absence of constructive dialogue in the 1970s and early 1980s. In contrast to conservation groups, foresters viewed the clear-cutting of old, slow-growing forests and replacement with vital plantations to represent a form of active conservation. Conservation groups regarded it as vandalism. Our study also showed that different drivers can combine into a chain of events. The establishment of the Red List allowed conservation groups to criticise Swedish forestry, urging foreign forest-product buyers to put pressure on the Swedish forestry sector. This in turn led to forest certification and detailed rules within the certification standards. For a deeper understanding of the decisive factors affecting the development of Swedish forestry, in-depth interviews with key people would be valuable.

Many of the ideas proposed in Paper II to adapt forestry in order to enhance biodiversity have since been introduced into Swedish forestry practice. We stated clearly, when written, that Paper II should be considered a working document open to revision as research progressed. More recent research has shown that many of the suggestions we made in 1997 have proved to be valid, and that one can get far with “intelligent guesses”, not always having to wait for scientific evidence. Unfortunately, I believe that much of the evidence-based research regarding retention forestry is far too focused on getting publishable results instead of providing answers to practitioners’ questions. For example, there are many studies that show the benefits of creating high-stumps, but hardly any that focus on the effects of retaining buffer strips along wetlands (Gustafsson et al. 2010). The costs of creating high-stumps are very marginal, whilst forestry incurs high costs in saving timber volumes as buffer zones to wetlands. I believe that practical forestry should have greater influence on modern conservation research, so that relevant questions are addressed.

In Paper III we showed that the number of retention trees and amount of dead wood in young stands increased between 1997 and 2007. Our interpretation was that this is an effect of new forestry policy and e.g. certification standards introduced in the early 2000s. It is important to follow-up the development of retention trees and dead wood over time. A recent study shows, for instance, that the amounts of dead wood are decreasing in northernmost Sweden (Jonsson et al. 2016). We used data from the National Forest Inventory (NFI), making it possible to continue the type of analyses performed in Paper III. A major weakness in data from the NFI is the inability to differentiate *Pinus sylvestris* retention trees from seed trees. It would be valuable if the NFI could add an assessment of this classification to their future data collection.

Voluntary forest set-asides (VSA) are a corner stone of Swedish forestry policy and “the Swedish model”. VSA amount to a greater area than formally protected forests. It has often been remarked that the quality and composition of VSA is unknown. In Paper IV we filled in a large gap by presenting the first objective description of important structural variables and stand characteristics for company-owned VSA in boreal Sweden. The study showed that VSA represent an important complement to current reserves in the Central and South boreal zones in terms of size and structural factors important to biodiversity. As expected, our analysis showed that the majority of VSA are small, but that there are also a fairly large number of bigger VSA. Lack of information on VSA on small private land makes it difficult to get an overall picture of their status in Sweden and it would be desirable if these could be made available. There is also a need to study the connectivity between VSA as well as between VSA and reserves, in order to provide input to work on green infrastructure.

Finally, a historical perspective and landscape-level data give us the opportunity both to understand complex developments and to develop tools for future successful conservation measures in the Swedish forests. The history of the Swedish model of forest biodiversity management reveals a lot of complexity but also some clear answers. Comprehensive and precise data sets from the National Forest Inventory and other sources give flavor and detail to this story. I sincerely hope that we will intensify and deepen this important discussion in the future.

References

Ahlén, I., Enström, B., Ingelög, T. (1975). Bevarande av vilda djur och växter – forskning om hotade och missgynnade arter i skogsmark. In: *Svenska Naturskyddsföreningens årsbok 1975*.

Ahlén, I., Boström, U., Ehnström, B. & Pettersson, B. (1979). *Faunavård i skogsbruket.* Jönköping: Skogsstyrelsen.

Andersson, K., Angelstam, P., Elbakidze, M., Axelsson, R. & Degerman, E. (2013). Green infrastructures and intensive forestry: Need and opportunity for spatial planning in a Swedish rural–urban gradient. *Scandinavian Journal of Forest Research*, 28, pp. 143-165.

Andrén, T. (1992). *Från naturskog till kulturskog*. Bjästa: CEWE-förlaget.

Andrén, H. (1994). Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos*, pp. 355-366.

Andrén, H. (1997). Habitat fragmentation and changes in biodiversity. *Ecological Bulletins*, pp. 171-181.

Angelstam, P. & Pettersson, B. (1997). Principles of present Swedish forest biodiversity management. *Ecological Bulletins*, pp. 191-203.

Angelstam, P. (1997). Landscape analysis as a tool for the scientific management of biodiversity. *Ecological Bulletins*, pp. 140-170.

Angelstam, P. K. (1998). Maintaining and restoring biodiversity in European boreal forests by developing natural disturbance regimes. *Journal of Vegetation Science*, 9, pp. 593-602.

Angelstam, P. (2003). Forest biodiversity management – the Swedish model. In: Lindenmayer, D. & Franklin, J.F. (eds), *Towards Forest Sustainability*. Collingwood, Vic.: CSIRO Publishing, pp.143-166.

Angelstam, P., Andersson, K., Axelsson, R., Elbakidze, M., Jonsson, B. G. & Roberge, J. M. (2011). Protecting forest areas for biodiversity in Sweden 1991–2010: Policy implementation process and outcomes on the ground. *Silva Fennica*, 45, pp. 1111-1133.

Angelstam, P., Roberge, J. M., Axelsson, R., Elbakidze, M., Bergman, K. O., Dahlberg, A. & Johansson, T. (2013). Evidence-based knowledge versus negotiated indicators for assessment of ecological sustainability: The Swedish Forest Stewardship Council standard as a case study. *Ambio*, 42, pp. 229-240.

Anshelm, J. (2004). *Det vilda, det vackra och det ekologiskt hållbara. Om opinionsbildningen i Svenska Naturskyddsföreningens tidskrift Sveriges Natur 1943-2002.* Skrifter från forskningsprogrammet landskapet som arena. Umeå: Umeå universitet.

ArtDatabanken. (2015). *Rödlistade arter i Sverige 2015*. Uppsala: ArtDatabanken. SLU.

Atlegrim, O. & Sjöberg, K. (1995). Effects of clear-cutting and selective felling in Swedish Boreal coniferous forest: Response of invertebrate taxa eaten by birds. *Entomologica Fennica,* 6, pp. 79-90.

Axelsson, A-L. 1995. *O.E. Berggrens reservat i Ljungå*. Sveriges Lantbruksuniversitet. Inst. för skoglig vegetationsekologi. Rapporter och uppsatser Nr 7.

Axelsson, A.-L., Ståhl, G., Söderberg, U., Peterson, H., et al. (2010). National Forest Inventories reports: Sweden. In: Tomppo, E., Gschwantner, T., Lawrence M. & McRoberts R.E. (eds), *National Forest Inventories - Pathways for Common Reporting*. Heidelberg: Springer, pp. 541-553.

Beland Lindahl, K. (2008). *Frame analysis, place perceptions and the politics of natural resource management: exploring a forest policy controversy in Sweden*. Diss. Uppsala: Swedish University of Agricultural Sciences.

Bergstedt, J., & Milberg, P. (2001). The impact of logging intensity on field-layer vegetation in Swedish boreal forests. *Forest Ecology and Management*, 154, pp. 105-115.

Björklund, J. (1984). From the Gulf of Bothnia to the White sea - Swedish direct investments in the sawmill industry of Tsarist russia. *Scandinavian Economic History Review*, 32, pp. 18-41.

Boström, M. (2003). How State-Dependent is a Non-State-Driven Rule-Making Project? The Case of Forest Certification in Sweden. *Journal of Environmental Policy & Planning*, 5, pp. 165-180.

Bratt, L., Cederberg, B., Hermansson, J., Lundqvist, R. Nordin, A. & Oldhammer, B. (1993). *Särnaprojektet. Inventeringsrapport från en landskapsekologisk planering*. Dalanatur (5). Naturskyddsföreningen i Dalarna.

Brink, P. (1962). *Svensk naturvård av i dag*. Lund: Bibliotekstjänst.

Bürgi, M., Hersperger, A.M. & Schneeberger, N. (2004). Driving forces of landscape change – current and new directions. *Landscape Ecology*. 19, pp. 857-868.

Bush, T. (2010). Biodiversity and sectoral responsibility in the development of Swedish forestry policy, 1988–1993. *Scandinavian Journal of History*. 35, pp. 471-498.

Carlson, A. & Stenberg, I. (1995). *Vitryggig hackspett (Dendrocopos leucotos): biotopval och sårbarhetsanalys*. Uppsala: Swedish University of Agricultural Sciences, Department of Wildlife Ecology.

Cashore, B., Auld, G. & Newsom, D. (2004). *Governing through Markets – Forest Certification and the Emergence of Non-State Authority*. New Haven CT: Yale University Press.

CBD. (1992). *The Convention on Biological Diversity*. United Nations.

Dahlbeck, N. (1987). Människan och naturvårdaren Sten Selander. Supplement in: Selander,S. (1987). *Det levande landskapet i Sverige*: 3:e edition. Göteborg: Bokskogen.

Domänverket. (1951). *Naturvård i statens skogar*. Stockholm: Domänverket.

Ebeling, F. (1959). Domänverket och Norrlandsfrågorna. In: Arpi, G. (ed), *Sveriges skogar under 100 år.* Part II. Stockholm: Kungl. Domänstyrelsen, pp. 612-638.

Eckerberg, K. (1985). Ej godkänt för skogsbrukets naturvård – så här kan vi bli bättre! *Skogen*. (2). pp. 52-55.

Eckerberg, K. (1986). *Tillämpningen av skogsvårdslagens § 21*. Slutrapport från fältundersökning. Umeå: Sveriges lantbruksuniversitet, Institutionen för skogsekonomi, Rapport.

Ehnström. B. & Waldén, H. (1986). *Faunavård i skogsbruket. Del 2 – Den lägre faunan.* Jönköping: Skogsstyrelsen.

Ek, B. (1998). Lägg hellre pengarna i Småland än i Njakafjäll. *Skogen*. (9), pp. 24-26.

Elbakidze, M., Angelstam, P., Andersson, K., Nordberg, M. & Pautov, Y. (2011) How does forest certification contribute to boreal biodiversity conservation? Standards and outcomes in Sweden and NW Russia? *Forest Ecology and Management*. 262, pp. 1983–1995.

Elbakidze, M., Angelstam, P., Sobolev, N., Degerman, E., Andersson, K., Axelsson, R., ... & Wennberg, S. (2013). Protected area as an indicator of ecological sustainability? A century of development in Europe's boreal forest. *Ambio,* 42, pp. 201-214.

Elliott, C., & Schlaepfer, R. (2001). The advocacy coalition framework: application to the policy process for the development of forest certification in Sweden. *Journal of European Public Policy,* 8, pp. 642-661.

Enander, K-G. (2007). *Skogsbruk på samhällets villkor.* Umeå: Sveriges lantbruksuniversitet, Institutionen för skogens ekologi och skötsel.

Eriksson, M. (2016). *Developing client-supplier alignment in Swedish wood supply*. Diss. Umeå: Swedish University of Agricultural Sciences.

Esseen, P. A., Ehnström, B., Ericson, L. & Sjöberg, K. (1997). Boreal forests. *Ecological bulletins,* pp. 16-47.

European Commission. (1979). *Council directive 79/409/EEC of 2 April 1979 on the conservation of wild birds*. Council of the European Communities, European Centre for Nature Conservation.

European Commission. (1992). *Council directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora*. Council of the European Communities, European Centre for Nature Conservation.

European Commission. (2000). *Directive, 2000/60/EC of the European parliament and of the council of 23rd October 2000.* Establishing a framework for community action in the field of water policy.

European Commission. (2012*). Our life insurance, our natural capital: an EU biodiversity strategy to 2020.*

European Environment Agency. (2014). *Spatial analysis of green infrastructure in Europe.* Technical report 2. Luxembourg: Publications Office of the European Union.

European Environment Agency. (2015). *Cross-country comparisons. Biodiversity - protected areas.* http://www.eea.europa.eu/soer-2015/countries-comparison/biodiversity

Forest Statistics. (2014). *Official Statistics of Sweden*. Umeå: Swedish University of Agricultural Sciences.

Forman, R. & Godron, M. (1986). *Landscape ecology*. New York: Wiley.

Franklin, J.F. (1992). Scientific basis for new perspectives in forests and streams. In: Naiman, R.J. (ed). *Watershed Management: Balancing Sustainability and Environmental Change*. New York: Springer-Verlag, pp. 25-72.

Franklin, J.F., Berg, D.R., Thornburgh, D.A. & Tappeiner, J.C. (1997). Alternative silvicultural approaches to timber harvesting: Variable retention systems. In: Kohm, K.A. & Franklin, J.F. (eds). *Creating a Forestry for the 21st Century: The Science of Forest Management.* Washington D.C: Island Press. pp. 111-139.

Fridman, J. (2000). Conservation of forest in Sweden: a strategic ecological analysis. *Biological Conservation,* 96, pp. 95-103.

Fridman, J. & Walheim, M. (2000). Amount, structure, and dynamics of dead wood on managed forestland in Sweden. *Forest Ecology and Management*, 131, pp. 23-36.

Fries, C., Carlsson, M., Dahlin, B., Lämås, T. & Sallnäs, O. (1998). A review of conceptual landscape planning models for multiobjective forestry in Sweden. *Canadian Journal of Forest Research*. 28, pp. 159-167.

Frisén, R. (2001). Skogsbruk och naturvård under ett halvt sekel, 1950-2000. In: Eklund, H & Hamilton, G. (eds). *Skogspolitisk historia*. Skogsstyrelsen, Rapport 8A. Jönköping: Skogsstyrelsens förlag,

Frängsmyr, Tore (ed) (1993). *Norrländsk uppslagsbok*: ett uppslagsverk på vetenskaplig grund om den norrländska regionen. Bd 1, [A-Gästg]. Höganäs: Bra böcker.

FSC. (2004). *Forest Stewardship Council Canada Working Group. National Boreal Standard*.

FSC. (2010) *Swedish FSC Standard for Forest Certification including SLIMF indicators. FSC-STD-SWE-02-02-2010*.

FSC. (2012). *FSC Russian National Office. Forest Stewardship Council Standard For Russian Federation.*

Fältbiologerna. (1973). *Skogsbruk och ekologi*. Fakta om skogen och skogsbrukets miljöeffekter. Stockholm: Fältbiologerna.

Geldmann, J., Barnes, M., Coad, L., Craigie, I. D., Hockings, M. & Burgess, N. D. (2013). Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. *Biological Conservation*, 161, pp. 230-238.

Grönberg, G. (1911). A.E. Nordensköld – en föregångsman för naturskyddssaken i norden. In: *Svenska Naturskyddsföreningens Årsskrift 1911*.

Gulbrandsen, L. H. (2005). Explaining different approaches to voluntary standards: A study of forest certification choices in Norway and Sweden. *Journal of Environmental Policy and Planning*, 7, pp. 43-59.

Gustafsson, L. & Hansson, L. (1997). Corridors as a conservation tool. *Ecological Bulletins,* pp. 182-190.

Gustafsson, L. & Perhans, K. (2010). Biodiversity conservation in Swedish forests: ways forward for a 30-year-old multi-scaled approach. *Ambio*, 39, pp. 546-554.

Gustafsson, L., Kouki, J. & Sverdrup-Thygeson, A. (2010). Tree retention as a conservation measure in clear-cut forests of northern Europe: a review of ecological consequences. *Scandinavian Journal of Forest Research*, 25, pp. 295-308.

Gustafsson, L., Baker, S.C., Bauhus, J., Beese W.J., Brodie, A., Kouki, J., Lindenmayer, D.B., Lõhmus, A., Martínez, Pastur, G., Messier, C. at al. (2012). Retention forestry to maintain multifunctional forests: a world perspective. *BioScience*, 62, pp. 633-645.

Götmark, F., Fridman, J. & Kempe, G. (2009). Education and advice contribute to increased density of broadleaved conservation trees, but not saplings, in young forest in Sweden. *Journal of Environmental Management.* 90, pp. 1081-1088.

Hagner, S. (2005). Skog i förändring. Stockholm: Kungl. Skogs- och lantbruksakademien.

Haila, Y. (1994). Preserving ecological diversity in boreal forests: ecological background, research, and management. *Annales Zoologici Fennici*, 31, pp. 203-217.

Hautala, H., Jalonen, J., Laaka-Lindberg, S. & Vanha-Majamaa, I. (2004). Impacts of retention felling on coarse woody debris (CWD) in mature boreal spruce forests in Finland. *Biodiversity & Conservation*, 13, pp. 1541-1554.

Hedén, E. (1983). Helt fel Kullman – så här ligger det till. S*kogen*. (10), p. 53.

Hersperger, A. M. & Bürgi, M. (2009). Going beyond landscape change description: quantifying the importance of driving forces of landscape change in a Central Europe case study. *Land Use Policy*, 26, pp. 640-648.

Hjelm, K. (1981). Hjälp till att rädda fjällskogarna. *Sveriges Natur*. (6), pp. 251-252.

Hjelm, K. (1985). Vinst genom statsbidrag. *Sveriges Natur*. (5), p. 45.

Hjelm, K. (1987). SNF och fjällskogsfrågan. In: *Svenska Naturskyddsföreningens årsbok 1987*.

Holmgren, A. & Malmström, C. (1958). Urskogen å hemmanet Stenbittjärn i Skorpeds socken, Ångermanland. *Norrlands skogsvårdsförbunds Tidskrift*, pp. 225-240.

Holmstedt, S. (1976). Fler skogsreservat! *Sveriges Natur*. (5), pp. 205-209.

Hysing, E. & Olsson, J. (2005). Sustainability through good advice? Assessing the governance of Swedish forest biodiversity. *Environmental Politics*. 14, pp. 510-526.

Hägglund, B. (1985). Ändra attityd. *Skogen*. (7), p. 42.

Högbom, A. G. (1934). *Om skogseldar förr och nu och deras roll i skogarnas utvecklingshistoria.* Uppsala: Almqvist & Wiksell.

Höjer, E. (1954). Skogodlingsgränsen på kronomarkerna i Norrland. *Norrlands Skogsvårdsförbunds Tidskrift.* pp. 233-253.

Höjer, E. (1973). Två decennier och ett tredje – från 50-tal till 70-tal i skogen. In: *Svenska Naturskyddsföreningens årsbok 1973.*

Ingelög, T. (1981). *Floravård i skogsbruket. Del 1 - Allmän del*. Jönköping: Skogsstyrelsen.

Ingelög, T. (2008). Artdatabanken – en resa från 70-talets kalhyggesdebatt till dagens Nationalnyckel. In: Ramberg, G (ed). *SLU – Tre decennier mitt i samhällsutvecklingen.* Uppsala: Sveriges lantbruksuniversitet. pp. 257-269.

Johansson, J. (2013). *Constructing and Contesting the Legitimacy of Private Forest Governance: The Case of Forest Certification in Sweden*. Diss. Umeå: Umeå University.

Johansson, O. (1991). Samförstånd bar ingen frukt, nu tar vi till bojkottvapnet! *Furan* (2) pp. 3-4.

de Jong, J. (1998). Mer hänsyn krävs vid avverkning. *Skog&Forskning*. (1), pp. 41-47.

Jonsson, B. G., Ekström, M., Esseen, P. A., Grafström, A., Ståhl, G. & Westerlund, B. (2016). Dead wood availability in managed Swedish forests – Policy outcomes and implications for biodiversity. *Forest Ecology and Management*, 376, pp. 174-182.

Jordbruksdepartementet. (1974). *Kalhyggen.* Ds Jo. 1974:2. Stockholm: rapport.

Josefsson, T .& Östlund, L. (2011). Increased production and depletion: the impact of forestry on northern Sweden's forest landscape. In: Antonson, H. & Jansson, U. (eds.) *Agriculture and* *forestry in Sweden since 1900*. Stockholm: The Royal Swedish Academy of Agriculture and Forestry.

Juffe-Bignoli, D., Burgess, N.D., Bingham, H., Belle, E.M.S., de Lima, M.G., Deguignet, M., Bertzky, B., Milam, A.N., Martinez-Lopez, J., Lewis, E. et al. (2014*). Protected Planet Report 2014.* UNEP-WCMC: Cambridge, UK.

Karström, M. (1992). Steget före – en presentation. *Svensk Botanisk Tidskrift.* (3), pp. 103-114.

Laestander, S. (2015). *Den kemiska bekämpningen av skadlig lövskog har öppnat helt nya vyer för skogsbruket – flygbesprutning med herbicider i Arjeplog 1953-1978*. Examensarbete i biologi. Umeå, Sveriges lantbruksuniversitet.

Liljenström, S. (1997). Stort steg mot miljömärk skogsbruk. *Sveriges Natur.* (5), p. 16.

Lindahl, K. (1990). *De sista naturskogarna. Om svensk naturvård i teori och verklighet*. Stockholm: Naturskyddsföreningen.

Linder, P. (1987). Om upprättandet av Domänverkets skogsodlingsgräns. *Sveriges Skogsvårdsförbunds Tidskrift.* (4), pp. 31-39.

Linder, P. & Östlund, L. (1998). Structural changes in three mid-boreal Swedish forest landscapes, 1885–1996. *Biological Conservation.* 85, pp. 9-19.

Lindevall, B. (1984). Kärnfrågan i Jokkmokk – Naturskydd eller sysselsättning? *Skogen.* (5-6), pp. 59-61.

Lindevall, B. (1994). ”Kaklhyggesfritt pappper”. *Skogen.* (1), pp. 6-8.

Lindkvist, A., Kardell, Ö. & Nordlund, C. (2011). Intensive forestry as progress or decay? An analysis of the debate about forest fertilization in Sweden, 1960–2010. *Forests*. 2, pp. 112-146.

Lindstad, B. H. & Solberg, B. (2012). Influences of international forest policy processes on national forest policies in Finland, Norway and Sweden. *Scandinavian Journal of Forest Research*, 27, pp. 210-220.

Lisberg Jensen, E. (2002). *Som man ropar i skogen: Modernitet, makt och mångfald i kampen om Njakafjäll och i den svenska skogsbruksdebatten 1970-2000*. (In Swedish with English summary). Diss. Lund: Lund University.

Lisberg Jensen, E. (2011). Modern clear-felling: from success story to negotiated solution. In: Antonson, H. & Jansson, U. (eds) *Agriculture and forestry in Sweden since 1900*. Stockholm: The Royal Swedish Academy of Agriculture and Forestry. pp. 338-353.

Liungman, M. (2000). *Monitoring Retention of Trees and CWD on Clearcuts in South-Western Sweden.* Honour’s thesis. Gothenburg: University of Gothenburg, Department of Zoology.

Lundgren, N-G. (2011). Norrbotten frontier: forestry work, technology and incomes. In: Antonson, H. & Jansson, U. (eds) *Agriculture and forestry in Sweden since 1900*. Stockholm: The Royal Swedish Academy of Agriculture and Forestry. pp. 354-371.

Lundmark, H., Josefsson, T. & Östlund, L. (2013). The history of clear-cutting in northern Sweden – driving forces and myths in boreal silviculture. *Forest Ecology and Management*, 307, pp. 112-122.

Länsstyrelsen Västerbotten. (2016*). Grön infrastruktur i det boreala skogslandskapet*. Umeå: Länsstyrelsen Västerbotten, Naturvårdenheten.

Löfgren, R. (1987). Att rädda fjällskog. In: *Svenska Naturskyddsföreningens årsbok 1987*.

MacArthur, R. H. & Wilson, E. O. (1967). *The theory of island biogeography*. Princeton, N.J.: Princeton Univ. Press.
The National Board of Forestry. (1992). *A Richer Forest*. Jönköping: Skogsstyrelsen.
Naturskyddsföreningen. (2011). *Policy. Skogen.*
Naturskyddsföreningen. (2013). *Trovärdighet på spel – Frivilligheten i skogen fungerar inte*.
Naturskyddsföreningen. (2014*). Ny vår för skogen – Naturskyddsföreningens förslag till ny skogspolitik och rättsliga förstärkningar*.
Naturvårdsverket & Skogsstyrelsen. (1982). *Urskogar – Inventering av urskogsartade områden i Sverige.* Allmän del. SNV PM 1507. Jönköping: Skogsstyrelsens förlag.
Naturvårdsverket. (1989). *Nationalparksplan för Sverige*. Stockholm: Naturvårdsverkets förlag.
Naturvårdsverket. (1990). *Natur ´90 - Aktionsprogram för naturvård*. Stockholm: Naturvårdsverket Informerar.
Naturvårdsverket. (1991). *Naturvårdsplan för Sverige.* Stockholm: Naturvårdsverket Informerar.
Naturvårdsverket. (1993). *Indikatorarter för identifiering av naturskogar i Norrbotten*. Stockholm: Naturvårdsverkets förlag. Rapport 4276.
Naturvårdsverket. (1997). *Skogsreservat i Sverige*. Stockholm: Naturvårdsverkets förlag. Rapport 4707.
Naturvårdsverket & Skogsstyrelsen. (2005*). Nationell strategi för formellt skydd av skog*. (In Swedish with English summary). Stockholm: Naturvårdsverket.
Naturvårdsverket. (2009). *Swedish nature conservation 100 years*. Stockholm: Naturvårdsverket.
Naturvårdsverket & Skogsstyrelsen. (2012). *Bevarande av biologisk mångfald – instrument och omfattning.* Naturvårdsverket. Kompletterande redovisning till Miljödepartementet och Landsbygdsdepartementet (M2012/71/Nm).
Naturvårdsverket. (2015a). *Ersättningsmark för skydd av natur – en bra affär*. Stockholm: Naturvårdsverket.
Naturvårdsverket. (2015b). *Riktlinjer för grön infrastruktur*. Stockholm: Naturvårdsverket.
Nilsson, C. & Götmark, F. (1992). Protected areas in Sweden: is natural variety adequately represented? *Conservation Biology*, 6, pp. 232-242.
Nitare, J. & Norén, M. (1992). Nyckelbiotoper kartläggs i nytt projekt vid Skogsstyrelsen. *Svensk Botanisk Tidskrift.* 86, pp. 219-226.
Nitare, J. (2011). *Barrskogar - Nyckelbiotoper i Sverige*. Jönköping: Skogsstyrelsen.
Nordiska ministerrådet. (1984). *Naturgeografisk regionindelning av Norden*. 2:e edition. Oslo: Nordiska ministerrådet.
Ödmann, E., Bucht, E. & Nordström, M. (1982). *Vildmarken och välfärden: om naturskyddslagstiftningens tillkomst*. Stockholm: LiberFörlag.
Oldertz, C. (1959). Naturskydd och landskapsvård. In: Arpi, G. (ed). *Sveriges skogar under 100 år.* Part II. Stockholm: Kungl. Domänstyrelsen. pp. 649-658.
Oldhammer, B. (1984). Stoppa skövlingen av fjällskogarna! *Sveriges Natur.(*4), pp. 14-19.
Olsson, R. (1983). Det finns absolut ingen anledning till lugn. *Sveriges Natur.* (1), pp. 8-10.
Olsson, R. (1988). Bristande vilja till naturvård. *Sveriges Natur.* (3), pp. 27-30.
Olsson, R. (1992). *Levande skog: skogsbruket och den biologiska mångfalden*. Stockholm: Naturskyddsföreningen.
Olsson, R. (2001). Nätverk för gammelskogarna. *Sveriges Natur.* (3-4), p. 96.

Öhrn, I. (1978). Nej – fjällskogen är inte i farozonen. *Sveriges Natur.* (4), pp. 311-312.

Östlund, L. (1993). *Exploitation and structural changes in the northern Swedish boreal forest 1800-1992*. Diss. Umeå: Swedish University of Agricultural Sciences.

Östlund, L., Zackrisson, O. & Axelsson, A.-L. (1997). The history and transformation of a Scandinavian boreal forest landscape since the 19th century. *Canadian Journal of Forest Research*. 27, pp. 1198-1206.

PEFC. (2012). Svensk PEFC Skogsstandard; PEFC SWE 002:3.

Ranneby, B., Cruse, T., Hägglund, B., Jonasson, H. & Swärd, J. (1987). Designing a new national forest survey for Sweden. *Stud. For. Suec.* 177, pp. 1-29.

Regeringens proposition 1990/91:90. *En god livsmiljö*. Riksdagen, Stockholm.

Regeringens proposition 1997/98:145. *Svenska miljömål. Miljöpolitik för ett hållbart Sverige.* Riksdagen, Stockholm.

Regeringens proposition 2000/01:130. *Svenska miljömål – delmål och åtgärdsstrategier.* Riksdagen, Stockholm.

Regeringens proposition 2009/10:169. *Förändrat uppdrag för Sveaskog AB.* Riksdagen, Stockholm.

Regeringens proposition 2013/14:141. *En svensk strategi för biologisk mångfald och ekosystemtjänster*. Riksdagen, Stockholm.

Rosenvald, R. & Lohmus, A. (2008). For what, when, and where is green-tree retention better than clear-cutting? A review of the biodiversity aspects. *Forest Ecology and Management*, 255, pp. 1-15.

Rudolphi, J. & Gustafsson, L. (2005). Effects of forest-fuel harvesting on the amount of deadwood on clear-cuts. *Scandinavian Journal of Forest Research*, 20, pp. 235-242.

Rydberg, M. (1973). Gran eller långskägg – eller båda dera? In*: Svenska Naturskyddsföreningens årsbok1973.*

SCA. (2011). *Naturhänsyn vid gallring.* Sundsvall: SCA Skog AB.

SCA. (2012). *Final felling and Conservation*. Sundsvall: SCA Skog AB.

Segerström, I. (1978). Fjällskogarna i farozonen! *Sveriges Natur*. (4), pp. 310-311.

Segnestam, M. (1981). Urskogar i Sverige – SNFs krav. In*: Svenska naturskyddsföreningens årsbok 1981*.

Selander, S. (1936). Naturskydd och samhället. In: *Svenska naturskyddsföreningens Årsskrift 1936.*

SFS. (1974). *Svensk författningssamling*. 1974:1026.

SFS. (1979). *Svensk författningssamling.* 1979:429.

SFS. (1993). *Svensk författningssamling.* 1993:553.

Sikström, U. & Pettersson, F. (2005). *Föryngring av gran under högskärm– avgångar i skärmen, plantförekomst och planttillväxt*. SkogForsk; Arbetsrapport. 589.

Sirén, G. (1973). Markberedning – ett nödvändigt ont? In: *Svenska naturskyddsföreningens årsbok 1973.*

Sjöberg, F. (1993). *Verkligheten på hotlistan? – en granskning av den svenska bevarandebiologins basfakta*. Sveriges Lantbruksuniversitet. Inst. för skogsekonomi. Rapport 103.

Skogen. (1978). Inget skogsbruk i urskogen. *Skogen.* (3), p. 5.

Skogen. (1982). Flummigt av Kungliga Vetenskapsakademien. *Skogen.* (11), p. 5.
Skogen (1984a). Urskogsinventeringen. *Skogen*. (5-6), p. 66.
Skogen (1984b). Det går att åstadkomma ny skog om man satsar tillräckligt. *Skogen*. (9), p. 11.
Skogen. (1992). Nätverk sätter press. *Skogen.* (10), p.11.
Skogsindustrierna. (2015). *Levande Skogar.* Om skogsindustriernas arbete för skogen, människan och den biologiska mångfalden. Stockholm: Skogsindustrierna.
Skogsstyrelsen. (2002). *Skogsvårdsorganisationens Utvärdering av Skogspolitikens effekter - SUS 2001*. Jönköping: Skogsstyrelsen, Huvudmeddelande. Meddelande 2002:1.
Skogsstyrelsen. (2008). *Skogsbrukets frivilliga avsättningar.* Jönköping: Skogsstyrelsen, Meddelande 3:2008.
Skogsstyrelsen. (2012a). *Skogsbrukets frivilliga avsättningar*. Jönköping: Skogsstyrelsen. Rapport 5:2012.
Skogsstyrelsen. (2012b). *Swedish Statistical Yearbook of Forestry*. Jönköping: Skogsstyrelsen.
Skogsstyrelsen. (2014a). *Swedish Statistical Yearbook of Forestry*. Jönköping: Skogsstyrelsen.
Skogsstyrelsen. (2014b). *Målbilder för god miljöhansyn.* Jönköping: Skogsstyrelsen, Rapport 5:2013.
Skogsstyrelsen. (2015) *Skogliga konsekvensanalyser 2015 – SKA 15*. Jönköping: Skogsstyrelsen. Rapport 10:2015.
Skogsstyrelsen. (2016). Nulägesbeskrivning om nyckelbiotoper. Jönköping: Skogsstyrelsen. Rapport 7:2016.
Snäll, T., Lehtomäki, J., Arponen, A., Elith, J. & Moilanen, A. (2016). Green infrastructure design based on spatial conservation prioritization and modeling of biodiversity features and ecosystem services. *Environmental management,* 57, pp. 251-256.
SOU. (1962). *Naturen och samhället*. Betänkande avgivet av 1960 års naturvårdsutredning. SOU. 1962:36.
SOU. (1978). *Skog för framtid*. Betänkande av 1973 års skogsutredning. SOU 1978:6.
SOU. (1992). *Skogspolitik inför 2000-talet*. Huvudbetänkandet. SOU 1992:76.
SOU. (1997a). *Skydd av skogsmark. Behov och kostnader.* SOU 1997:97.
SOU. (1997b). *Skydd av skogsmark. Behov och kostnader.* Bilagor. SOU 1997:98.
Statens Naturvårdsverk. (1973). *Skogsbruket och naturvården*. Stockholm: Allmänna förlaget. Statens Naturvårdsverk.1973:3.
Statens Naturvårdsverk. (1976). *Inventering av urskogar och ädellövskogar. Del 1. Urskogar.* Stockholm: Statens Naturvårdsverk. PM 704.
Sveaskog. (2012). *Sveaskogs naturvårdsarbete.* Stockholm: Sveaskog.
Svenska Dagbladet. (1938). Största privata initiativet för svenskt naturskydd – Stora skogsreservat avsätts. *Svenska Dagbladet.* 1938-11-14.
Svenska Naturskyddsföreningen. (1973). *Skogsbruk och naturvård.* Svenska Naturskyddsföreningens årsbok 1973.
Svenska Naturskyddsföreningen. (1978). *Levande Skog.* Stockholm: Svenska Naturskyddsföreningen.
Svenska Naturskyddsföreningen. (1988). *Gräns för storskaligt skogsbruk i fjällnära skogar: förslag till naturvårdsgräns.* Stockholm: Svenska naturskyddsföreningen.

Sveriges lantbruksuniversitet. (1994). *Skogskonferensen 1994 – Från hotlistor till tillämpning: Landskapsplanerad skog*. Uppsala: Sveriges lantbruksuniversitet. Skogsfakta Konferens 20.

Sveriges lantbruksuniversitet. (2016). *Forest statistics 2016*. Official Statistics of Sweden.

Sveriges Natur. (1976). SNF begär skydd av urskogar. *Sveriges Natur*. (4), p. 160.

Sveriges Natur. (1994). Kalhyggesbojkott skakar skogsindustrin. *Sveriges Natur.* (2) p. 62.

Sveriges Officiella Statistik. (2016a). *Habitat protection areas and nature conservation agreements on forest land in 2015.* Statistiska meddelanden JO 1402 SM 1602.

Sveriges Officiella Statistik. (2016b). *Protected nature 2015*. Statistiska meddelanden MI 41 SM 1601.

Sveriges Skogsvårdsförbund. (1978). *Skogsbrukets metoder*. Djursholm: Sveriges skogsvårdsförbund.

Tamm, C-O. (1979). *Högmekaniserat skogsbruk och ekologiska principer – kan de förena?* Sveriges Lantbruksuniversitet. Institutionen för ekologi och miljövård. Rapport 3:1979.

Tirén, L. (1937). Skogshistoriska studier i trakten av Degerfors i Västerbotten. *Meddelanden från Statens Skogsförsöksanstallt.* (30), pp. 67-322.

Tittler, R., Messier, C. & Fall, A. (2012). Concentrating anthropogenic disturbance to balance ecological and economic values: applications to forest management. *Ecological Applications*, 22, pp. 1268-1277.

Wramner, P. (1986). Fjällskogarna och naturvården. *Skogen.* (6-7), p.55.

Wramner, P. & Hjelm, K. (1987). Hela det fjällnära barrskogsbältet ska bevaras. *Sveriges Natur.* (5), p. 43.

Wramner, P. & Nygård, O. (2010). *Från naturskydd till bevarande av biologisk mångfald: utvecklingen av naturvårdsarbetet i Sverige med särskild inriktning på områdesskyddet.* Huddinge: COMREC.

Zackrisson, O. (1977). Influence of forest fires on the North Swedish boreal forest. *Oikos*, pp. 22-32.

Zackrisson, O. (1981). Skogen och elden - Behöver naturskogen skötsel? In: *Svenska naturskyddsföreningens årsbok 1981.*

Zaremba M. (2012*). Skogen vi ärvde*. Stockholm: Weyler.

Epilogue

I have worked in conservation for my entire working life. My interest in conservation started in the 1960s. The trigger was the extensive cutting of beech forests around my home in Skåne. The beech forests were felled and then transformed into fast-growing, dense spruce plantations that were inaccessible and lacked undergrowth. I got involved in the youth organisation "Fältbiologerna" and we demanded that the County Administration should protect more forests from being cut and that laws should be passed to prohibit the felling of beech forests. During my high-school years I already knew that I wanted to work professionally in ecology and conservation, and therefore started to study Biology at Umeå University. At the same time I was also active in the Swedish Society for Nature Conservation. After finishing my studies I started working at the County Administration Board of Västernorrland. One of my first tasks was to survey old-growth forests in the County, and I went on to work on the formal protection of these as Nature Reserves. The job at the County Administration Board gave me extensive contact with the forestry sector in the region. As a public official I was careful not to get personally involved with ENGOs, as these organisations must be free to criticise the work of public organisations. In 1992 I started working for SCA, Europe's largest private forest owner. There was a need to organise the company's conservation work and develop clear instructions for all forestry personnel, following the change in government forestry policy in the early 1990s. I have continued to work in conservation for SCA since then. In 2009 Pelle Gemmel, who was my boss at the time, suggested that I commence post-graduate studies as part of my employment at SCA. After some initial doubt, I started my PhD project in 2010, for which this thesis marks the end.

I have been part of the incredibly rapid development of conservation work in Swedish forests since the 1980s. This includes both the development of measures taken by forest owners as well as the extent of formal forest protection that public agencies are responsible for. At the same time, the transformation of boreal forests has continued as areas of naturally regenerated forests become fast-growing production forests. A new forest landscape is evolving, with clear divisions between production forests and various set-asides. For my research I have focused on how the debate proceeded over time, on which drivers affected the development, and on what actually happened in the forests. I consider that my background from ENGOs as well as conservation in the public and private sectors has given me insights into how the different parties think and act. This has of course facilitated my understanding of the debate, but maybe also coloured my interpretation of it.

Tack

Stort tack mina kära handledare Lars och Lena för att ni lotsat mig fram till denna avhandling. Ni har alltid ställt upp och hjälpt mig när jag har ropat på hjälp och även sett när jag behövt stöttning! Jag kommer verkligen att sakna våra handledarmöten på ”Vetekatten” i Stockholm.

Tack Pelle för att du kom på idén att jag skulle börja som doktorand och tack Lena för att du pushade på mig i mina första funderingar om att börja forska. Och tack Ola och SCA för att jag delvis kunnat göra detta inom ramen för mitt arbete.

Tack Hanna för din fantastiska första sållning av materialet ifrån tidskrifterna Sveriges Natur och Skogen. Jag hade aldrig själv kunna eller orkat göra detta jättejobb som la grunden till min första artikel. Tack Lena för att du insåg detta och fixade pengar för Hannas jobb.

Tack Anna-Maria, Hanna och Gudrun för alla trevliga diskussioner vi hade under våra läsecirklar.

Stort tack till Jonas D och Jonas F för alla körningar på taxmaterialet som ni gjort till mig och att ni alltid ställde upp på att göra nya körningar som jag ville få gjorda

Tack Nic, Mike och Aida för hjälp med översättningar, figurer och att lägga in min text i avhandlingsmallen. Tack vare er hjälp har jag förlängt mitt livet med några år genom att slippa bli så frustrerad på översättningar och finesser som jag inte är så bra på.

Tack Clas för att du ville ha med mig i skrivandet av Paper II för 20 år sedan då naturvården ännu var i sin linda.

Tack mina kära barn för att ni ifrågasatt hela mitt doktorandprojekt och inte kunnat förstå vad jag ska ha en doktorstitel till! – Ska det stå på din gravsten att du är doktor? - var en fråga jag fick en gång. Ni har hjälp mig att få lite distans till forskningsjobbet när jag varit väl mycket inne i mina funderingar.