Management of urban woodlands - effects on bird communities and recreational values

Erik Heyman

Department of Plant and Environmental Sciences

Faculty of Science

UNIVERSITY OF GOTHENBURG

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Faculty opponent: Professor Tomas Pärt, Department of Ecology, Swedish University of Agricultural Sciences, Uppsala.

Examiner*:* Professor Ulf Molau, Department of Plant and Environmental Sciences, University of Gothenburg.

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Department of Plant and Environmental Sciences
University of Gothenburg, Sweden

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Abstract

The ongoing urbanisation increases the pressure on urban nature. Urban woodlands are receiving growing attention as they provide valuable ecosystem services to urban citizens, mainly by providing areas for recreation but also through improving air quality and reducing noise. There is an increasing demand for knowledge of how urban woodlands should be managed to combine several functions, such as recreational values and biodiversity conservation. There are, however, few field experiments that evaluate the effects of forest management.

The work in this thesis is based on the results of large-scale, replicated field experiments in urban woodlands in southern Sweden. Management by clearance of woody understory (bushes and small trees) was conducted at five sites in oak-dominated forest stands on the fringe of three midsize cities. Two different types of clearance were applied: 90% removal of understory and 50% removal in regular 50x50 meter patches. Control plots of equal size were left unmanaged. Bird communities were surveyed before and after management, and the impact of bird predation on arthropods in bush and tree canopies were evaluated with exclosure experiments. Bird communities were affected by understory clearance and a decrease in bird abundance was observed in the stands with 90% removal of understory. Patchy clearance had no negative effects on bird abundance. Bird predation had strong effects on arthropods in the understory, which suggests that an important food resource for birds is removed when the understory is cleared. Arthropods were affected by bird predation in the tree canopies too, but the effects of bird predation were weaker in the managed areas, which further stresses the negative impact on birds by extensive clearance of understory.

The recreational values in relation to understory density were evaluated in a photo survey where pictures from the managed areas were shown to panels of students. Open forests were considered most attractive for recreation but 75% of the respondents claimed that they preferred a mix of open and closed forest. In a field study, the participants used cameras to take photos of liked and disliked places along a forest trail in an urban forest. The analysis of photo contents showed that both open and dense forest landscapes were appreciated while visible human impact was usually perceived negatively. Implications for management are that clearance of understory can enhance recreational values but should be conducted in a small scale pattern to promote visual variation and minimise the negative effects on birds. Visible impact from recreational facilities and forest management should be minimised as far as possible. Openness is often affected by management and was found to be useful as a key-variable to analyse management trade-offs between social and ecological values.

Keywords: arthropods, biodiversity, bird communities, clearance, ecosystem services, forest management, multiple-use, preference, recreation, suburban, understory, urban woodlands, visitor employed photography

Sammanfattning

Urbanisering är en stark global trend. Detta ökar pressen på stadsnära grönområden, men samtidigt uppmärksammas dessa områden allt mer för de värdefulla funktioner som de bidrar med till stadens invånare. Exempel på sådana funktioner, så kallade ekosystemtjänster, är att erbjuda plats för rekreation och friluftsliv, men även förbättrad luftkvalitet och lokalklimat samt bullerdämpning. Den biologiska mångfalden är relativt hög i svenska tätortsnära skogar, samtidigt som dessa skogsområden är viktiga för rekreation och friluftsliv. Det finns ett behov av kunskap om hur skötseln ska utformas för att kombinera sociala värden och bevarad biologisk mångfald. Det finns dock relativt få exempel på praktiska fältförsök där man testat olika skötselformer på ett systematiskt vis.

I min avhandling har jag studerat hur skötseln av tätortsnära skogsområden påverkar skogens ekologiska och sociala värden. Mitt arbete baseras på resultaten från storskaliga fältexperiment som bedrivits i tätortsnära skogsområden i Västra Götaland i Sverige. Vi genomförde skötselåtgärder i form av röjningar av buskar och mindre träd i fem lövskogsområden i närheten av tre medelstora städer: Alingsås, Borås och Skövde. Två olika typer av röjningar genomfördes, 90% röjning av buskskiktet över stora ytor och 50% röjning i ett rutmönster med cirka 50x50 meter stora rutor. De två typerna av röjningar utfördes på 3-5 hektar stora ytor. I varje skogsområde lämnades en yta av motsvarande storlek orörd för att användas som kontrollområde. Fågelfaunan i varje provyta inventerades före och efter skötselåtgärderna. Vi utförde även fältexperiment där fåglarnas konsumtion av insekter och andra leddjur på buskar och i trädkronor studerades genom att använda nät för att stänga ute insektsätande fåglar.

Fågelfaunan påverkades av röjningarna genom en minskning i antalet häckande fåglar i ytorna med 90% röjning. De mindre omfattande röjningarna hade inga negativa effekter på antalet fåglar. Fåglarnas predation hade stor påverkan på småkrypsfaunan i buskskiktet, vilket betyder att en viktig födoresurs för insektsätande fåglar försvinner om buskskiktet röjs bort. Småkrypen påverkades av fåglarnas födosök även i trädkronorna. Fågelpredationen i träden var dock svagare i de röjda områdena, vilket ger ytterligare stöd för slutsatsen att omfattande röjningar får negativa konsekvenser för fågelfaunan.

Vi undersökte skogens rekreationsvärden i förhållande till buskskiktets täthet genom att låta 85 försökspersoner se bilder från våra försöksområden och bedöma dessa. Öppna skogsmiljöer ansågs bäst ur rekreationssynpunkt, även om 75% av de tillfrågade ansåg att en blandning av öppen och sluten skog var önskvärt. Vi genomförde även en fältstudie där vi delade ut kameror till deltagarna (62 personer) som fick i uppgift att ta bilder på de platser som de tyckte bäst respektive sämst om längs en vandringsslinga i skogen. Analysen av bilderna visade att både öppna och slutna skogsmiljöer bedömdes positivt, medan spår av skötselåtgärder, skräp och annan synlig mänsklig påverkan mestadels uppfattades negativt.

Resultaten från den här avhandlingen visar att buskskiktets täthet är en viktig komponent för både ekologiska och sociala värden i den tätortsnära skogen. Våra försök visar att röjning av buskar och mindre träd kan öka skogens rekreationsvärden men bör utföras i begränsade områden för att skapa visuell variation och undvika negativ påverkan på fågellivet. Skogsskötsel och fasta anläggningar för friluftslivet (skyltar, soptunnor, bänkar etc) bör utformas för att smälta in i skogsmiljön i största möjliga utsträckning.

En ökande befolkning i städer kommer att öka pressen på kvarvarande tätortsnära skogsområden och deras skötsel kommer få en allt viktigare betydelse. Det är viktigt att den framtida skötseln av tätortsnära skogar följs upp kontinuerligt och anpassas efter ny kunskap om hur man bäst bör sköta skogen till glädje och nytta för stadens invånare.

List of papers

This thesis is based on the following five papers, which are referred to in the text by use of Roman numerals.

- **I.** Heyman, E. 2010. Clearance of understory in urban woodlands: Assessing impact on bird abundance and diversity. Forest Ecology and Management 260, 125-131.
- **II.** Gunnarsson, B., Heyman, E., Vowles, T. 2009. Bird predation effects on bush canopy arthropods in suburban forests. Forest Ecology and Management 257, 619-627.
- **III.** Heyman, E., Gunnarsson, B. 2011. Management effect on bird and arthropod interaction in suburban woodlands. BMC Ecology 11, 8.
- **IV.** Heyman, E., Gunnarsson, B., Stenseke, M., Henningsson, S., Tim, G. 2011. Openness as a key-variable for analysis of management trade-offs in urban woodlands. Submitted manuscript.
- **V.** Heyman, E. 2011. Analysing recreational values and management effects in an urban forest with the visitor-employed photography method. Submitted manuscript.

Contents

1. Introduction

1.1 Urban woodlands

For the last two centuries, urbanisation has been a major demographic process. In 1900, only 10% of the global population lived in cities, while today more than 50% live in urban areas, and this percentage is forecasted to increase to about 70% in 2050 (UN, 2008). In the industrialised world, about 80% of the population live in urban areas and Sweden is no exception with an urbanisation level of 84% (SCB, 2009). The ongoing urbanisation increases the pressure on urban nature. The field of urban ecology is emerging, and integrates the theory and methods of natural and social sciences to study the pattern and processes of urban ecosystems (Grimm et al., 2008). Urban nature provides important ecosystem services to the citizens, including air quality improvement, mitigating of heat island effects, and contributions to human health and well-being by providing recreational areas (Ulrich, 1984; McPherson et al., 1997; Beckett et al., 1998; Millennium Ecosystem Assessment, 2005; Yang et al., 2005; Matsuoka and Kaplan, 2008). These benefits are provided from several types of urban green areas, such as parks, allotment gardens and woodlands.

The work in this thesis is focused on urban woodlands. There is no generally accepted definition of this concept, as the landscape context and history of these forests are different between countries (Konijnendijk, 2003; Florgård, 2007). In my work, I have used the definition by Lehvävirta and Rita (2002). They define urban woodlands as indigenous forest stands of any size, within or in the surroundings of a city where the field and ground layer vegetation is not managed as in a park and stand structure is more similar to that of a natural forest than a park. In Sweden, urban woodlands mainly originate from old production forests, but also from newly reforested clear-felled areas and naturally afforested farmlands or wastelands (Rydberg and Falck, 2000). In the other Nordic countries the situation is similar, with urban woodlands that are structurally comparable to the rural forests in their respective vegetation zones, including tree species and management (Gundersen et al., 2005). In continental Europe, where the population density is higher and the landscape is more influenced by agriculture, urban woodlands have a more diverse origin. Some are remnants of pristine forests while most are shaped by cultural processes, such as old parks or restoration plantings (Kowarik, 2005). There are also large areas of younger woodlands on post-industrial areas, in e.g. Germany and England, which have been planted or are a natural recolonisation by forest vegetation (Jorgensen et al., 2005; Keil, 2005).

Different methods have been used to calculate the total national area of urban woodlands (e.g. Carlborg, 1991; Hedblom and Söderström, 2008; Nilsson and Cory, 2009). The estimated area depends on the spatial definition of urban woodlands, i.e. how far from the city limits woodlands should be defined as “urban”. In the report by Nilsson and Cory (2009), urban woodlands in Sweden were defined by applying buffer zones around urban areas, with different size according to number of inhabitants in the city. With this method, the area of urban woodlands in Sweden was estimated to 502 000 ha, which corresponds to 2.2% of the national forest area. Another recent GIS analysis showed that there is a total of about 48 000 ha of woodlands within city limits and 970 000 ha within 5km from city limits in Sweden. This corresponds to 0.2 and 4.3%, respectively, of the national forest area (Hedblom and Söderström, 2008). Despite their small proportion of the national forest area, urban woodlands serve important functions for people's health and well-being. More than half of the forest visits in Sweden are conducted in urban woodlands, and it has been shown that the distance between people's home and forest is critical for the occurrence of forest visits (Hörnsten and Fredman, 2000).

Even though they are highly influenced by human use, urban woodlands contain relatively high values for biodiversity conservation (e.g. Angold et al., 2006; Hedblom and Söderström, 2008; Mörtberg and Wallentinus, 2000; Rickets and Imhoff, 2003). In Sweden, urban woodlands have more old trees, higher proportions of deciduous tree species and higher volumes of dead wood, compared to rural forests (Table 1, Nilsson and Cory, 2009). This implies that their value for biodiversity conservation is high, as dead wood and deciduous trees are critical substrates for many red-listed forest species in Sweden (Niklasson and Nilsson, 2005).

The pressure on urban woodlands is increasing. In Sweden, the proportion of green area in the total urban area decreased by 16% between 1970 and 1990. In the ten largest Swedish cities, the green space area per citizen decreased between 2000 and 2005 (SCB, 2010). Urban woodlands have weak legal protection, and little is known about how management or densification and expansion of cities will affect their future status (Tallhage Lönn, 1999).

Region	Forest type	Urban	Non-urban
Norrland	Deciduous trees %	34	12
	Coniferous trees %	66	88
	Dead wood m^3/ha	2,7	1,7
Svealand	Deciduous trees %	32	13
	Coniferous trees %	68	87
	Dead wood m^3/ha	2,5	1,1
Götaland	Deciduous trees %	39	21
	Coniferous trees %	61	79
	Dead wood m^3/ha	4,2	1,8

Table 1. In Sweden, urban woodlands have higher proportions of deciduous tree species and higher volumes of dead wood, compared to non-urban (rural) forests. Data from Nilsson and Cory (2009).

1.2 Management of urban woodlands

Urban green areas are complex social-ecological systems with a high degree of uncertainty (Grimm et al., 2000; Picket et al., 2001; Alberti et al., 2003). Management of uncertain systems benefits from an adaptive management approach, which should be used not only to change a system, but also to learn about the system (Holling, 1978; McCarthy and Possingham, 2007). Management has in some cases created the values that are appreciated in nature, in others it is needed to preserve values created under conditions that are no longer present. Natural disturbance is a major force moulding the development, structure and function of forests and it follows that management of forests should be based on an understanding of ecological processes (Attiwill, 1994).

Management of urban woodlands is today highly topical, manifested in an increasing number of publications (reviewed by Konijnendijk et al., 2007; Bentsen et al., 2010). Urban forestry, which focuses on other goods and services than the traditional output of forestry, was developed in North America in the 1960s, and is an established concept in Europe since about 20 years (Konijnendijk, 2003). The increasing population pressure on urban environments has led to a need to develop strategies for multiple-use and balance of conflicting goals, which introduces a number of decision-making difficulties when it is necessary to plan for different goals to coexist (Gadow, 2002; Termorshuizen et al., 2007; Fuller and Gaston, 2009). There are, however, relatively few studies that deal with the problem of management trade-offs between biodiversity conservation and recreational values (Tyrväinen et al., 2003). Management recommendations for urban woodlands are often focused on creating a visually attractive forest (Ode and Fry, 2002; Tyrväinen et al., 2003).

The Swedish National Forestry Board provides management directions, where it is suggested that urban woodlands should be managed to promote recreational values by increasing the amount of deciduous and old trees and by adjusting the management to the specific users of each forest (Rydberg, 2004). These guidelines were proposed as early as in the 1970s, but they have only been weakly implemented in urban forestry in Sweden, possibly due to low priority in the plans of Swedish local authorities (Rydberg and Falck, 2000). In Sweden, as well as in many other European countries, urban woodlands are to high degree commonly owned (Konijnendijk, 2003). The municipalities own 40-60% (depending on the calculation method) of the urban woodland area in Sweden (Carlborg, 1991; Nilsson and Cory, 2009). A survey among Swedish municipalities showed that 78% of the municipalities in Sweden had adapted their forest management to promote recreational values, although there was still a large demand for more education and information about urban woodland management among the municipalities (Lundquist, 2005).

A recent assessment of urban forestry research needs in northern Europe concluded that management was the most important theme for future research (Konijnendijk et al., 2007). Studies related to management of urban woodlands have used ad hoc measurements of management activities (Mörtberg, 2001; Sandström et al., 2006), modelling (Gadow, 2002; Ode and Fry, 2006), reviews of literature and management plans (Rydberg and Falck, 2000; Ode and Fry, 2002; Matsuoka and Kaplan, 2008) and questionnaires (Tahvanainen et al., 2001; Gundersen et al., 2006). There are few reports of controlled field experiments or systematic monitoring of management effects in urban woodlands even though such studies are of large importance for the implementation of an adaptive management approach (Walters and Holling, 1990). Cultural constraints, spatial complexity, and institutional agendas have been suggested as limitations to the establishment of ecological experiments in urban areas (Felson and Picket, 2005).

This thesis is based on the results of large-scale, replicated field experiments in urban woodlands in southern Sweden. The hypotheses are aimed to evaluate and improve management at the forest stand scale. Earlier studies have found a lack of planning and management of urban nature at a regional scale, possibly due to constrains from administrative borders (e.g. Borgström et al., 2006; Andersson, 2007). An adaptive management approach includes planning and management at a larger scale than the forest stand, but at the regional level management experiments would be very complicated to set up.

1.3 Bird communities in urban woodlands

The effect of urbanisation on bird communities has been addressed in several studies (reviewed by e.g. Marzluff et al., 2001; Chace and Walsh, 2006). Birds are easily monitored and their high mobility allow them to respond quickly to habitat changes, which make them well suited as response organisms to study ecological effects of urbanisation (Savard et al., 2000). At the landscape scale, woodland patch size, connectivity between patches and degree of urbanization have been shown to be important determinants of bird diversity and abundance in urban habitats. The typical response of bird communities to increased levels of urbanisation has been an increase in population densities but a reduction in richness (e.g. Fernandez-Juricic and Jokimäki, 2001; Crooks et al., 2004; Watson et al., 2005; Clergeau et al., 2006; Sandström et al., 2006; Husté and Boulinier, 2011).

Studies of bird communities in urban woodlands in Sweden suggest that some of the patterns found in other countries do not apply to Swedish cities. In a survey of 34 cities in southern Sweden, Hedblom and Söderström (2010) showed that bird species richness did not decline with increasing urbanisation. Mörtberg and Wallentinus (2000) found that several red-listed bird species were breeding in forest remnants close to the city centre of Stockholm, the largest city in Sweden. The different situation in Sweden is possibly due to the fairly high habitat quality of Swedish urban woodlands, with large amounts of deciduous, relatively old trees and dead wood. The forest cover is also comparatively high in Swedish cities (average 20% compared to <10% in most European cities) which may further explain the high bird diversities that were found (Hedblom and Söderström, 2010). At a local scale, birds respond strongly to vegetation composition and structure. Urban areas that retain native vegetative characteristics have been shown to be richer in native bird species than those that do not (Clergeau et al., 2001; Chace and Walsh, 2006).

Studies of urban bird communities have often used regression models to explain what factors on a regional or local scale that best explain the composition of the bird community (e.g. Clergeau et al., 1998; Mörtberg, 2001; Husté and Boulinier, 2011). Several studies conclude with recommendations for forest management, aimed at maximising bird diversity, while some studies also mention the potential dilemma between management for promoting accessibility and recreational values versus conserving high bird diversities (e.g. Sandström et al., 2006; Hedblom and Söderström, 2010). Comparative studies are relatively easy to perform and offer flexibility in choice of sampling area, but they have drawbacks concerning conclusions about causality. Manipulative experiments provide better opportunities of learning about natural systems and causal relationships (Johnson, 2002). There are few, if any, manipulative experiments in urban areas that have analysed management impacts on bird communities. Manipulative experiments could be applied, as in this thesis, on a local scale to investigate how bird communities in urban woodlands are affected by forest management.

1.4 Benefits to people from urban woodlands

The importance of urban woodlands for public health and well-being is being increasingly recognized (Rydberg and Falck, 2000; Matsuoka and Kaplan, 2008; Mitchell and Popham, 2008; Jorgensen and Gobster, 2010; Ward Thompson, 2010). There is strong medical evidence of positive health effects from nature visits, including reduced stress, improved attention, facilitated recovery from illness and behavioural changes that improve general well-being (Hartig et al., 2003; Velarde et al., 2007). Besides the improvements in health and quality of life, the positive health effects of nature visits also have economical implications. In Sweden, the yearly cost in health care and production loss due to lack of physical activity was estimated to € 700 million, and in the UK it was calculated to € 12.3 billion (Bird, 2004; Bolin and Lindgren, 2006). In the report by Bird (2004) it was shown that an urban green space of 8-20 ha that was used by 20% of the population within 2 km distance for 30 minutes of activity 5 days a week, would save the economy € 6.6 million a year.

A range of theories have been forwarded in order to explain and assess the influence of landscape on human health. The two most widely accepted models are the “Attention restoration theory”, which describes the restorative effect of natural environments in the context of attention and attention fatigue (Kaplan, 1995), and the “Stress recovery theory” which is based on evolutionary theories of landscape preferences (Ulrich et al., 1991). These two theories appear to complement one another with regard to the antecedent condition from which the person becomes restored (Hartig et al., 2003). The connection between health benefits and landscape structure is, however, not so well understood (Velarde et al., 2007). It is not clear if the most highly valued landscapes in preference studies provide the greatest health benefits to people, even though such a correlation would not be unexpected.

Studies of public preferences have shown that people often prefer semi-open forests with large trees and little undergrowth. Unmanaged forests, with large amounts of dead wood and dense understory, have been shown to be among the least appreciated for recreational purposes (Hultman, 1983; Ribe, 1989; Tyrväinen et al., 2003; Bjerke et al., 2006; Gundersen and Frivold, 2008). As dense forests are generally disliked, they are often managed to enhance visibility and feelings of safety (Nasar and Jones, 1997; Hedblom and Söderström, 2008).

Recently published studies have aimed to find indicators that could be used as a measure of both aesthetic and ecological values. Openness has been suggested as a possible indicator to summarise complex information about visual and ecological qualities of a landscape and to provide support for multiple-use planning (Fry et al., 2009). Jorgensen and Gobster (2010) found "structural landscape heterogeneity" to be a promising measure at the landscape level, with the potential to integrate different disciplinary perspectives and scales. In our work, we evaluated if forest openness is useful as a key-variable to analyse recreational values and management trade-offs between ecological and social values. We also conducted a field-study to analyse perceptions of an urban forest by letting participants take photos of the most liked and disliked places.

1.5 Objectives

The aim of this thesis was to analyse management alternatives with relevance to urban woodlands from different perspectives on the forest stand scale. Large-scale, replicated field experiments were used to study management effects on bird communities, arthropod-bird interactions and recreational values. The main questions in the work with this thesis were:

- Is bird abundance and diversity affected by understory clearance in urban woodlands? (Paper I)
- Are arthropods in the understory and tree canopies affected by bird predation in urban woodlands? Are bird predation rates affected by forest management? (Paper II and III)
- How are recreational values affected by openness in the understory? Is forest openness useful as a key-variable to analyse recreational values and management trade-offs? (Paper IV)
- What are the most liked and disliked aspects of an urban forest? Is visitor employed photography a useful method to evaluate public preferences of recreational forests? (Paper V)

Definitions and terms

Before after control impact (BACI) design = A method for assessing impact on the environment where sites affected by the impact are compared with unaffected control sites both before and after some intervention.

Biodiversity = Diversity of species, genes and ecosystems within a region.

Deciduous trees = Tree species that shed their leaves in the autumn.

Ecosystem services = Human benefits from resources and processes that are supplied by natural ecosystems.

Photo elicitation = Photographs generated by the researcher are shown to respondents to assess preferences of e.g. landscape structures.

Recreation = Activities for the sake of enjoyment, amusement, or pleasure during leisure time.

Suburban (peri-urban) woodlands = Forest stands on the fringe of cities. In this thesis the term "urban woodland" is used consistently as it has a more clear definition than "suburban woodlands".

Top-down effects = Refer to situations where the abundance, diversity or biomass of lower trophic levels depends on effects from consumers at higher trophic levels. For example, when a predator affects the density of its prey.

Understory = The layer of a forest which grows below the forest canopy. In this work it refers to the woody understory, i.e. bushes and young trees.

Urban woodlands = Indigenous forest stands of any size, within or in the surroundings of a city where the field and ground layer vegetation is not managed as in a park and stand structure is more similar to that of a natural forest than a park.

Visitor employed photography (VEP) = A technique which involves giving cameras to research subjects and asking them to take photographs to illustrate their personal views or experiences. It is equivalent to the "participant photography method" and the "projective method by photograph".

2. Methods

2.1 Study sites

The management experiment was carried out in the county of Västra Götaland in south-western Sweden in the boreonemoral zone, i.e., between the boreal forest in northern Europe and the temperate forest in the middle part of Europe (Niklasson and Nilsson, 2005). The five experimental sites were located in woodlands on the fringe of three midsized cities: Alingsås, 23 000 inhabitants (SCB, 2009), Borås (63 000 inhabitants) and Skövde (33 000 inhabitants). Figure 1 shows the location of the five study sites. The land on the study sites is owned by the municipalities and the experimental sites were selected in consultation with the local authorities. In all sites, the dominating tree species were oak *(Quercus robur)*, rowan *(Sorbus aucuparia)*, lime *(Tilia cordata)* and birch *(Betula spp.)*. The most common shrubs were rowan *(S. aucuparia)*, hazel *(Corylus avellana)* and alder buckthorn *(Frangula alnus)*. None of the sites had been subject to any recent (<10 years) clearance or thinning, so the understory was dense before the management experiment. All sites were popular recreation areas, frequently used by the public for walking, jogging and other activities.

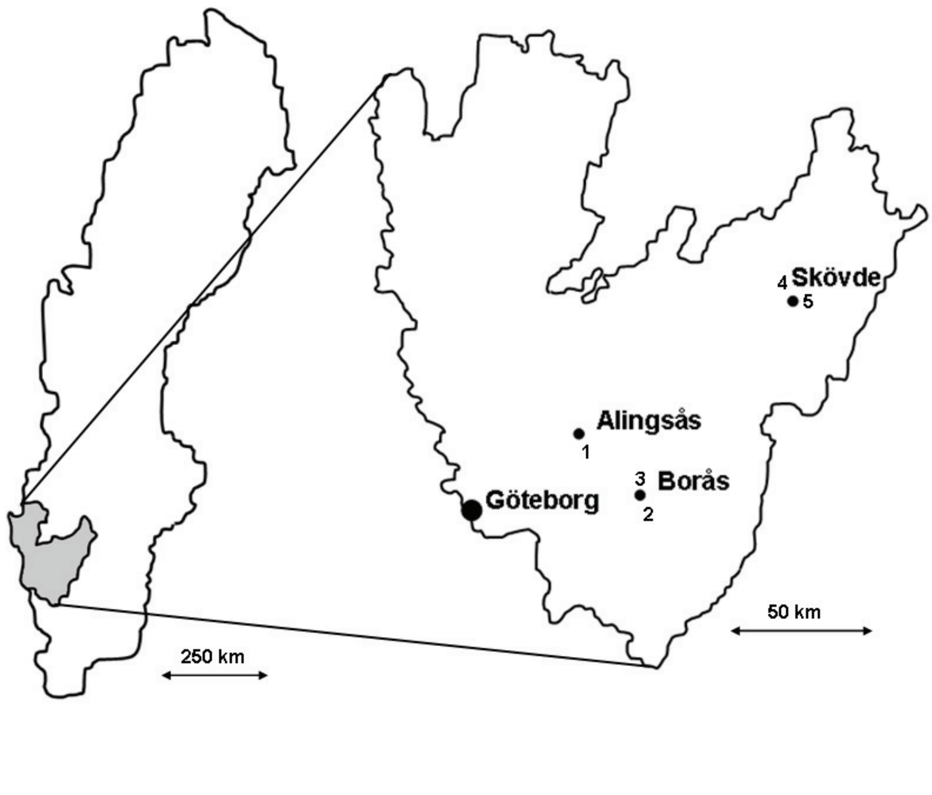

Figure 1. Map of Sweden (left) and the county of Västra Götaland (right), showing the location of the five study sites in the management experiment. 1) Ängabo, 2) Hultaberg, 3) Rya åsar, 4) Rånna ryd and 5) Stöpen.

2.2 Management experiment

The management experiment included two types of clearance of woody understory vegetation. Clearance of understory is common in urban woodlands as it is a way to promote aesthetic qualities and a sense of safety by increasing visibility and openness. A field survey in 34 Swedish cities showed that clearance of shrubs was commonly applied in urban woodlands (Hedblom and Söderström, 2008). Experimental plots were established at five study sites in 2005. Mean plot area was 3.9 hectares (n=13, range 3-5.5 ha). This is an appropriate scale for management experiments in urban forests, as the median size of woodlands within Swedish cities is 4.0 ha (Hedblom and Söderström, 2008). The plots were square or rectangular in shape, with some variation due to the shape of each forest stand. The experimental setup of the management experiment is shown in figure 2. At three of the sites (Rya åsar, Rånna ryd and Stöpen), the experimental plots were placed next to each other, while at two sites (Ängabo and Hultaberg) there was a distance of 50-250 m between the plots. This variation was due to the patchiness of the forest stands at the study sites.

The three management treatments "Complete", "Patchy" and "Control" were randomly assigned to the plots. At three sites: Ängabo, Rya åsar and Hultaberg, plots with the treatments "Complete", "Patchy" and "Control" respectively, were used in equal areas of the forest stand. In Rånna Ryd only the "Patchy" and "Control" treatments were used, as the management plan of the nature reserve did not allow "Complete" clearance of understory. In Stöpen only the "Complete" and "Control" treatments were used, because the area of this forest stand (8 ha) was not enough for all three treatments. Therefore, the experiment had a slightly unbalanced design: four plots with "Complete" clearance, four with "Patchy" clearance and five "Control" plots.

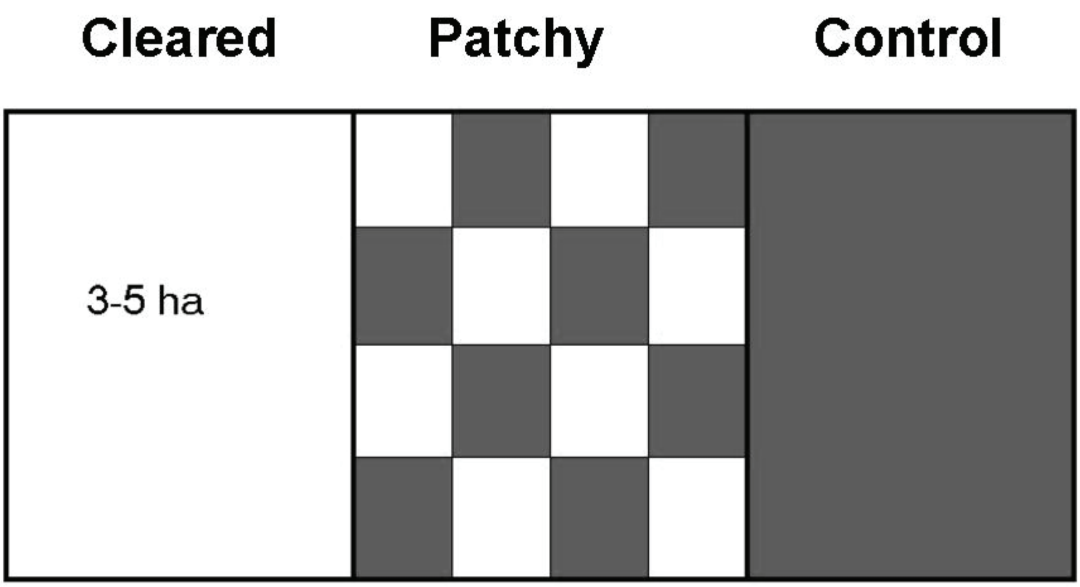

Figure 2. The experimental setup of the management experiment. The plots were square or rectangular in shape, with some variation due to the shape of each forest stand. The experiment was replicated at five sites.

Clearance of understory was carried out in autumn 2006 and early winter 2007. Bushes and trees with a base diameter of less than 10 cm were cut close to the ground, except for multi-stemmed bushes of hazel *(C. avellana)* which were retained. The woody debris from the clearance was transported out of the forest with light forestry machines. In the plots with "Complete" clearance, about 90% of the bushes, shrubs and small trees (base diameter <10 cm) were cleared in the whole plot area. In the plots with "Patchy" clearance the plot was divided into patches in a regular pattern, each patch roughly square in shape and measuring 50x50 m. Every other patch was cleared, the rest were left unmanaged. "Control" plots were left untreated during the whole experiment. Due to staff limitations at the municipality in Borås, we had to conduct the management at one of the sites (Hultaberg) by ourselves. This gave us the opportunity to estimate the time and effort required for this type of management. Clearance of 7 hectares took about seven days for one person to complete (the author, with no previous experience of understory clearance). Bringing out the woody debris was a more time-consuming process and required about ten days of work for two persons using a light forestry machine. Figure 3 shows three pictures from the management work at the Hultaberg site.

Figure 3. Clearance of understory at the Hultaberg site, Borås (upper left). The fine woody debris from the clearance was transported out of the forest with light forestry machines (upper right). 90% of the understory have been cleared on the left hand side of the road, on the right side is an unmanaged area (large picture). Photos by the author.

2.3 Studies of birds and arthropods

In paper I-III, forest birds and their arthropod prey were the studied organisms. In earlier studies, woodland birds have been shown to respond quickly to habitat alteration from forest management (Slagsvold, 1977; Rodewald and Smith, 1998; Camprodon and Brotons, 2006). As a well developed understory has been shown to be positively correlated with both species diversity and abundance of forest birds, a response in the bird community to understory clearance would not be unexpected (e.g. MacArthur et al., 1962; MacArthur, 1964; Donald et al., 1997; Fuller and Green, 1998; Brokaw and Lent, 1999; Forslund, 2003; Diaz, 2006). The experience of seeing wild animals and plants is one of the most important reasons for forest visits, and woodland birds have been shown to be the most appreciated animals in urban environments (Grahn, 1991; Holm, 2001; Bjerke and Østdahl, 2004).

Territory mapping was used to estimate density and diversity of breeding birds in the experimental plots. Surveys were conducted in spring 2006, 2007 and 2008, one year before the management experiment and two years after. The method includes repeated visits during the breeding season and provides an estimate of the number of territories for each bird species (Swedish Environmental Protection Agency, 1978; Bibby et al., 2000).

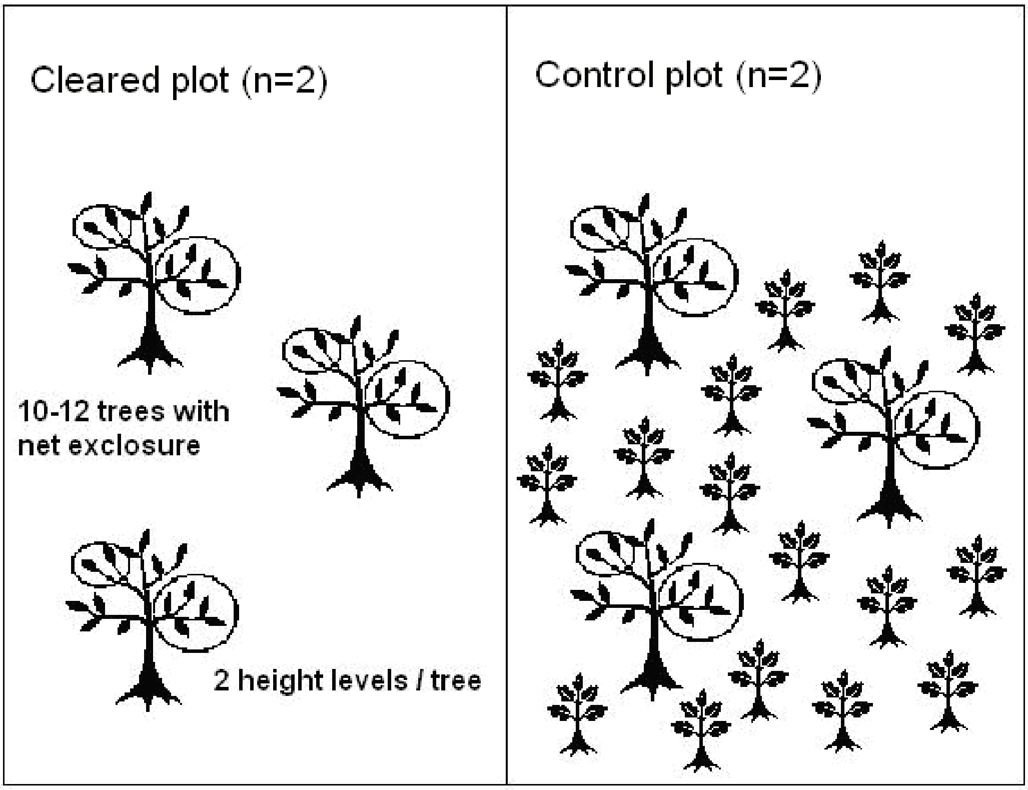

Figure 4. The experimental design of the field experiment in paper III. Bird exclosures were put up for one month at two foraging heights (3-5 m and 12-15m above the ground) in oak canopies in cleared and control plots. The experiment was replicated at two sites.

In two field experiments (Paper II and III), we studied the importance of top-down effects from insectivorous birds on arthropods in bush and tree canopies. In both experiments we used bird nets to prevent birds from foraging on certain branches or bush canopies. For each net-enclosed branch or bush, an adjacent branch of the same species and similar size was used as a control. The method with net-exclosures has been widely used to estimate top-down effects from birds on arthropods (see meta-analyses by Van Bael et al., 2008; Mooney et al., 2010).

Bird and arthropod interactions in bush canopies were studied to examine the importance of the understory as a foraging site for insectivorous birds (Paper II). As the understory vegetation was to a large extent removed in the management experiment, a measure of bird foraging in the understory in the unmanaged plots would be of interest in relation to the effects on bird abundance that were found in the managed plots (Paper I). The canopies of rowan (*Sorbus aucuparia*) and alder buckthorn (*Frangula alnus*) bushes, were net-enclosed for two months at three study sites. We compared abundance, biomass and body size distributions of arthropods between experimental and control canopies to estimate top-down effects.

Figure 5. A portable lift with four-wheel drive and a 15 meter telescopic boom with a working platform was used to reach the branches (left, photo by the author). Net-enclosed and control branches were cut from the trees as the experiment was terminated. Each branch was carefully enclosed in a large plastic sack before cutting (right, photo by Tage Vowles).

In paper III we studied bird predation rates on tree-living arthropods in relation to forest management (understory clearance) and foraging height. If bird predation rates were to be affected by management we suggested that there might be a conflict of interests between promoting recreational values and the ecosystem service that forest birds provide by controlling the population of tree arthropods. Bird exclosures were put up for one month at two foraging heights (3-5 m and 12-15m above the ground) in oak *(Q. robur)* canopies in managed (understory clearance) and control areas (dense understory). The experiment was replicated at two sites. Our experimental design would allow us to analyse bird predation effects in relation to management, height and the interaction between these factors. Figure 4 shows the experimental design used in paper III and figure 5 shows two pictures from the field work.

2.4 Forest vegetation and openness

Tree and understory density and "openness" were measured to quantify management effects on the vegetation (Paper IV). Ten random points in each plot were surveyed before and after management. At each point, all trees and bushes were counted within a circular plot of 100 m^2. Openness was estimated by taking photographs from 10 m distance of a board (30 x 50 cm) with red and white squares. The proportion of the chequerboard that was hidden by the understory was measured where the value 0 indicated a completely visible board (low understory density, high openness) and 1 indicated a completely hidden board (high understory density, low openness).

2.5 Analysing recreational values in relation to management

Pictures from the openness measures were used in a photo elicitation survey to study the relationship between forest openness and recreational values (Paper IV). The aim was to show pictures with a variation of understory density in a similar woodland setting. 28 pictures from seven locations at our experimental sites were shown on a big screen to 85 respondents, who were asked to rate the seven locations according to how attractive they looked for recreational use. Additional data about frequency of forest visits, forest preferences, recreational activities etc was also collected.

In Paper V, the visitor employed photography (VEP) method was used to evaluate visitors' perceptions of an urban forest. 62 participants were given cameras and asked to take pictures of the places that they liked and disliked the most along a trail with varied forest vegetation in a near-urban recreational area in Göteborg, Sweden. The survey was conducted on two occasions, in April and September. Photo content in combination with the participants' comments in their photo-logs was analysed with particular focus on features related to forest management. The photographs were assigned to different categories (forest landscape, human impact etc) which were analysed separately. A non-parametric statistical test was used to evaluate whether "liked" or "disliked" were dominant in each category. For instance, pictures of open forest landscapes were significantly dominated by "liked" pictures.

3. Results and discussion

3.1 Management effects on bird communities

The bird surveys showed that total densities of woodland birds were affected by clearance of understory. Bird densities decreased in the plots with ”Complete” removal of the understory compared to plots with “Patchy” clearance. ”Patchy” clearance had no significant effect on bird density compared to “Control”. Two years after management, bird densities were reduced by 18 % on average in the plots with “Complete” clearance, while there was an increase in bird densities in both “Control” plots (+15 %) and plots with “Patchy” clearance (+26 %). Bird diversity was not affected by the management. Separate analyses of the five most abundant bird species did not reveal which species that drove the pattern of decreasing densities in managed plots that was found at the community level.

The reduction in bird densities in plots with “Complete” clearance was not unexpected as the understory density was reduced by 90 percent. In the plots with “Patchy” clearance, understory density was reduced by about 50 percent but, interestingly, there was no decrease in bird densities compared to control plots. Understory density and structure have been shown to be one of the most important factors for habitat selection for woodland passerines (Cody, 1985; Marshall and Cooper, 2004). The understory provides both nesting and foraging sites, as well as protective cover against weather and predators (Willson and Comet, 1996). The strong top-down effects from insectivorous birds on bush canopy arthropods that we found in our first exclosure experiment, further stress the importance of the understory as an important foraging site in these forests (Paper II). If food is a limiting resource, the predicted response in the cleared plots would be an increase in territory size and, therefore, lower bird densities. The lack of management effect on bird densities in the plots with “Patchy” clearance (with about 50 % removal of understory) was more unexpected. It is possible that “Patchy” clearance would provide a similar effect as other small-scale disturbances, such as windfalls, forest roads and power line corridors, which in previous studies have been shown to have a positive or neutral impact on forest bird densities, compared to undisturbed forest (Kroodsma, 1982; Fuller, 2000; Ortega and Capen, 2002).

There was no management effect on the diversity of breeding birds, which was unexpected, given the large number of studies that show the importance of the understory layer for the diversity of woodland birds (e.g. MacArthur et al., 1962; MacArthur, 1964; Brokaw and Lent, 1999; Forslund, 2003). Separate analyses of the five most abundant bird species showed a significant management effect in only one species. In general, densities of these species followed the same pattern as total bird densities, but due to relatively small samples of each species and large variations in individual species data, interpretations about which species that drove the patterns were difficult.

Paper I showed that clearance of understory can have negative effects on bird densities if carried out over large areas, while clearance in patches was not found to have negative effects on bird densities. Treatment effects were not dramatic but may be of relevance as this was a relatively short-term study and it is likely that avian site fidelity may have delayed management effects on the avifauna. Additional research is needed to assess the long-term effects of understory clearance and other forest management practices on bird communities in urban woodlands.

3.2 Bird and arthropod interactions

We found strong top-down effects from insectivorous birds on arthropods, in the understory (Paper II) as well as in the tree canopies (Paper III). In the understory, we found that arthropod abundance and biomass were higher and arthropod body sizes were larger on the net-enclosed canopies, compared to controls. The data suggested that there were differences in treatment effects (net-enclosed versus control) between bush species for abundance and biomass. The treatment effect on arthropod biomass was significant on rowan but not on alder buckthorn. The top-down effects that we found in bush canopies supported earlier experimental results from this geographic region (e.g. Askenmo et al. 1977; Gunnarsson 1996; Gunnarsson and Hake 1999), as well as data from other temperate forests (e.g. Holmes et al. 1979; Marquis and Whelan 1994; Mooney and Linhart 2006). There was a variation in bird predation due to bush species, with more consistent predation effects on alder buckthorn than on rowan bushes. We suggested, tentatively, that arthropods gain better protection against bird predation on rowan due to more complex foliage structure than in alder buckthorn. If birds prefer to forage in certain bush species, management in urban forests could be adjusted to preserve favoured bushes.

Although the study in paper II clearly showed that birds exert a top-down effect on arthropods, there were no cascade effects on plants. A parallel study into leaf damage caused by herbivores, carried out simultaneously at the same sites, showed no significant difference between net-enclosed and control shrubs (Werthén 2007). As the understory seemed to be of importance for bird foraging, we suggested that there is a potential management conflict between promoting recreational values and providing foraging sites for birds. A landscape characterised by high openness in the understory is often favoured by people, but may not be optimal habitat for birds.

In the oak tree canopies (Paper III) we also found higher abundances and biomass of arthropods on the net-enclosed branches. The height in the canopy did not affect the bird predation rate but we found a management effect, with higher rate of bird predation in the control plots compared to managed areas. In the unmanaged plots, the effect of bird predation on arthropod abundance was about twice as high as in areas with understory clearance. This means that the intensity of bird foraging is higher in plots with dense understory compared to the plots where the understory was cleared.

The exclosure experiment in the tree canopies (Paper III) gave support to previous studies that have shown that insectivorous birds significantly decrease arthropod populations in forest and agricultural ecosystems (Eveleigh et al., 2007; Mooney et al., 2010; Philpott et al., 2009; Van Bael et al., 2008). Furthermore, our data suggest that the potential for population control of arthropods is higher in areas with dense understory than in cleared areas. This supports the idea that bird predation on arthropods can be affected by forest management. Based on theoretical predictions, we could have expected the opposite effect to what we observed, with stronger impacts of bird predation in the cleared areas than in the areas with dense understory. The forest in the cleared areas is structurally less complex and theory implies that top-down effects of predation will be stronger where complexity and diversity are lower (Polis and Strong, 1996; Van Bael et al., 2008). Another possible effect of understory removal could be that the remaining birds would forage more frequently in the tree canopies in the cleared plots compared to in control plots. In contrast to these theories, we found that bird predation pressure in the oak canopies was lower in managed areas than in control plots.

We suggest two possible mechanisms behind the observed management effect on avian predation: A) The bird abundance decreased by on average 37 % in the cleared plots compared to unmanaged plots. B) Reduced predation pressure on arthropods in the cleared plots could be a result of a shift in bird foraging behaviour. Possibly, birds avoid foraging in the more open plots to reduce the risk of exposure to predators. These two mechanisms may act simultaneously, decreasing options for avian control of arthropod abundance. Contrary to our hypothesis, no height effect on bird predation rate was found. The removal of the understory did not increase bird predation in the lower oak canopies in the managed plots which might have been expected if birds that predominantly forage in the understory had remained at the same sites after clearance.

Experiments from a range of ecosystems have shown that insectivorous birds are important in controlling the populations of their invertebrate prey (Bock et al., 1992; Fayt et al., 2005; Gradwohl and Greenberg, 1982; Mols and Visser, 2002; Perfecto et al., 2009). Several studies have shown that bird predation can contribute to dampen the outbreaks of forest pests, even though such predation is most effective at controlling low to moderate invertebrate populations (Crawford and Jennings, 1989; Sekercioglu, 2006; Whelan et al., 2008). Mass-occurrences of insect pests are rather rare in northern Europe except for e.g. *Tortrix viridana* on Oak *Q. robur* in southern Scandinavia (Ivashov et al., 2002) and *Operophtera brumata* and *Epirrita autumnata* on Birch *Betula sp.* in northern Scandinavia (Bylund, 1997; Tenow et al., 2007). It has been suggested that there might be an ecological and evolutionary relationship between high bird predation pressure and relatively low abundance of pest outbreaks in the forests of southern Fennoscandia (Tanhuanpää et al., 2001). There are, however, few experimental tests on the effects of habitat management on ecosystem services provided by birds. Our study was, to our knowledge, the first to show experimentally that forest management can affect naturally occurring predation pressure on arthropod abundance. We conclude that management for enhanced aesthetic values of the forest, such as clearance of understory, may have a negative impact on the biological control of forest arthropods.

3.3 Recreational values and forest openness

In our analysis of forest openness in relation to management (Paper IV), openness was found to be greatly influenced by management but the effects appeared to be site-dependent. The implication is that even if clearance of shrubs is being performed according to a clearly defined management plan, the outcome can be different in various sites. Understory density was found to be negatively correlated with the recreational value given on the 5-point scale. Photos of open woodland, with few or no bushes, had higher scores for being suitable for recreation than sites with a dense shrub layer. It can seem contradictory that, at the same time, about 75% of the respondents claimed that they preferred a landscape with a mix of open and closed woodland, but may not be so. Our methods for investigating preference were about point locations, while recreational activities in forests often involve movement and are thus related to impressions of larger areas.

The majority of the respondents were frequent visitors to forests: 82% visited a forest at least once per month. Interestingly, those who were frequent forest visitors preferred less open woodland. The same pattern was also observed in a study by Tyrväinen et al. (2003) who found that active visitors preferred natural or unmanaged forest environments, while less frequent visitors preferred managed forests. Our findings support the idea that the degree of openness in woodlands is important for forest recreational values. High preference scores for relatively open forests have also been shown in earlier photo surveys (e.g. Lindhagen and Hörnsten, 2000; Bjerke et al., 2006; Jorgensen and Gobster, 2010). Most preference studies conducted in Fennoscandia (Sweden, Norway and Finland) have been related to boreal coniferous forests and their management (Gundersen and Frivold, 2008). This corresponds to the most abundant vegetation system in Fennoscandia, while the majority of the population live in the south where more southern vegetation systems occur (Gundersen et al., 2005). Our study should be of relevance for planning of recreational forests as it was conducted in broadleaf woodland and had a particular focus on understory density, which is often affected by management.

In the visitor employed photography study (Paper V), the majority of pictures taken by the participants showed forest landscapes. Pictures of “open” as well as “dense” forests were dominated by “liked” pictures ($p<0.001$, for open and dense forest, respectively). Separate analyses by season also showed significant dominance of “liked” pictures for open and dense forests, in April as well as September. The second largest class of pictures was “human impact”, with the majority of pictures (78 %) in the “disliked” category. The pictures of the golf course were analysed separately as these turned out to constitute a large part (38 %) of the “human impact” photos. There were significantly more golf course photos categorised as “disliked” than “liked” ($p<0.001$). Pictures of dead wood were evenly distributed between the two preference categories. There were slightly more photos in the “disliked” category (41 out of 68), although the difference was not statistically significant ($p=0.146$). The pictures in the “miscellaneous” class mostly showed small natural objects such as water, plants, mushrooms and mud. There was a clear dominance of “liked” pictures in this class ($p<0.001$).

The analyses of photo content showed that the main differences in the participants' preferences were between natural and human-made objects or landscapes. Forest with dense or open understory as well as "natural" objects along the trail were perceived as positive, while most signs of human impact were perceived negatively. Forests with dense understory and dead wood were perceived more positively in this study than in earlier studies that have used off-site methods, such as photo surveys. Pictures of dead wood have been given very low ratings in earlier preference studies (Karjalainen, 2006; Lindhagen and Hörnsten, 2000; Tyrväinen et al., 2003). The more positive attitudes towards dead wood which was found here, suggest that there may be a difference in how it is perceived in a picture compared to in the field. The comments in the photo-logs showed that dead wood was, by some participants, seen as an interesting natural object that added positive value to their forest experience. Negative comments regarding dead wood mostly stated aesthetic reasons, such as "ugly" or "untidy", but also concerns about dead forests and pollution of the environment.

Even though pictures showing objects created by humans were mostly classed as "disliked", two human made objects were mostly perceived as positive: a wooden bench and a children's hut, both built from natural material. This gave support to the idea that "natural" versus "human made" was a major divisor in the participants' preferences in the present study. Traces of human activity such as litter, construction work, roads and signs of forestry have been given very low ratings in previous studies. In a North American study that used VEP methodology in combination with interviews, Dorwart et al. (2010) found that litter and rubbish detracted significantly from the participants' outdoor experiences. Management influences, such as shelters, trail signs and steps were mostly perceived as positive by the participants. The golf course attracted attention from a large part of the participants, mainly as a "disliked" object. Our intention with including the view of the golf course along the trail was to provide a large variation in landscape openness along the trail, with the golf course representing the most open landscape. We did not, however, anticipate the participants' negative opinions of the sport of golf. Some participants wrote in their photo-logs that they liked the view over the golf course but did not like the sport. Therefore, they categorised their picture as "disliked". The negative opinions of the golf course may not be of direct use to forest management planners, but give support to earlier findings about public opinions of golf (Wheeler and Nauright, 2006; Briassoulis, 2010).

The respondents in both paper IV and V were undergraduate students with a relatively narrow age span. A wider span in age and educational level among the participants would have been desirable, as it has been shown that age and background might be an important factor in the individual's preference for forest environments (Tyrväinen et al., 2003; Bjerke et al., 2006). There are, on the other hand, studies (including one meta-analysis) that have compared the preferences of students with the general public and found high correlations (e.g. Kellomäki and Savolainen, 1984; Stamps III, 1999; Hill and Daniel, 2008). A more representative sample of the population would still have been advantageous to allow more general conclusions about public opinions of forest management.

Taken together, our two studies of recreational values in relation to openness and forest management provided interesting and, in some ways, contrasting results. The photo survey, with variation in understory openness among the pictures, showed that open understory is preferred to dense. The field survey, using VEP methodology, showed that both dense and open forest landscapes were appreciated, while visible human impact was the most negatively perceived element. The two methods are in some ways difficult to compare, as they were conducted in different environments (laboratory and field) and testing somewhat different hypotheses. The differences that were found are still important to take into consideration, as management recommendations for recreational forests are mainly based on the results from preference studies (Ode and Fry, 2002). Reviews have shown that photo elicitation surveys and other off-site methods are in large dominance in studies of public preferences of nature areas even though they may not reveal the complexity that is involved in field evaluations (Gundersen and Frivold, 2008; Jorgensen and Gobster, 2010).

4. Conclusions

4.1 Management trade-offs between social and ecological values

In paper IV, we evaluated the use of openness as a key-variable in the analysis of management trade-offs and as a tool in the planning process. We suggested that variables related to openness can be used in the planning at fine-grained scales, to analyse different management options and make trade-offs between interests in multiple-use woodland sites. We stressed the importance of openness because it can be related functionally to aspects of management for recreation and biodiversity. The theoretical and empirical importance of openness in connection with landscape variables is supported by studies ranging from plant species diversity (e.g. De Clerck et al., 2005; Wang et al., 2009) to landscape preference studies (e.g. Kaplan and Kaplan, 1989; Tveit et al., 2006; Gundersen and Frivold, 2008; Jorgensen and Gobster, 2010). In a more comprehensive analysis of the landscape, a number of other concepts can be used to describe the visual character, e.g., “coherence” (including connectivity), “disturbance” and “complexity” (e.g. Tveit et al., 2006). Several studies have explored visual aspects in landscapes but there is no consensus about how the indicators should be used for analysis of management trade-offs (e.g. Palmer, 2004; Jessel, 2006; Tveit et al., 2006; Termorshuizen et al., 2007; Ode et al., 2008). Recently published studies have also aimed to find indicators that could be used as a measure of both aesthetic and ecological values (Fry et al., 2009; Jorgensen and Gobster, 2010). Based on the empirical data from our studies, we suggest openness as a possible indicator to summarise complex information about visual and ecological qualities of a landscape. The model presented in Paper IV shows how openness can be included in the management and provide support for multiple-use planning of urban woodlands.

4.2 Implications for management of urban woodlands

As urban woodlands are intensively used ecosystems, their management is of central importance. Urban woodlands would benefit from being managed with an adaptive management approach, where practices are constantly tested and evaluated (Gunderson, 1999; Johnson, 1999). Our work was based on replicated field experiments with controls, randomisation and replication. Such studies provide powerful ways of learning about natural systems and causal relationships, but are still rare in the field of forest management (Johnson, 2002).

It has been argued that management recommendations should be based on larger bodies of knowledge than single studies and that conclusions about management reached in published papers are not always appropriate (Johnson, 2002). The work in this thesis is focused on relative short-term management effects on the forest stand scale in deciduous urban woodlands and the monitoring of ecological effects was limited to forest birds and their interactions with arthropods. Monitoring of other organism groups before and after management, e.g. vascular plants, would have been of interest as they also contribute to the recreational values and have been shown to respond quickly to alterations in forest openness (Götmark et al., 2005). Despite these reservations I will conclude with some management recommendations based on our findings.

The results from our management experiment and studies of recreational values suggest that variation in management at the forest stand level would probably be a favourable strategy in urban woodlands. Clearance of understory in small patches is an example of a management strategy that could introduce small-scale variation in a forest stand if the understory vegetation is dense. This type of management did not affect forest birds negatively even though more than 50% of the understory was removed.

Our studies of recreational values imply that the increased openness and variation in stand structure from “Patchy” clearance would also enhance the visual qualities of the forest. Creating small openings in the forest has been suggested previously as a method to enhance habitat diversity in relatively uniform areas and to increase the amenity value of forests (Rydberg and Falck, 2000; Gundersen and Frivold, 2008). Clearance of understory should preferably be conducted near paths and frequently visited areas. In the photo survey, the majority of the respondents claimed that they prefer a mix of open and dense forests, and the visitor employed photography study showed that dense as well as open forests were appreciated. This gives support to the recommendation that clearance of understory should not be conducted over large areas. Large-scale clearance of understory can vegetation might increase recreational values in unmanaged forests, but with the risk of negative effects on both breeding bird densities and the ecosystem service provided by forest birds through arthropod population control. Maintaining stand structural complexity, including both horizontal and vertical canopy heterogeneity, has been identified as one of the most important conservation measures at the forest stand level (Lindenmayer et al., 2006). Visible impact from forest management should be minimized, as it was perceived negatively. Recreational facilities, such as benches and dustbins, should be constructed to appear as “natural” as possible, i.e. made of wood.

In paper IV we suggest a stepwise approach to adaptive planning and management of urban woodlands, intended for management at the stand level. By including openness as a key-variable in the detailed planning, it may be possible to predict potential conflicts of interest in the planning process.

4.3 Suggestions for future research

To enhance methods for assessing recreational values and perceptions of nature, comparative studies using several methods at the same study sites could be used. Field methods, such as visitor employed photography, could then be compared to photo elicitation and written surveys. It would also be possible to conduct preference studies using the pictures taken in a VEP study and show these to a new set of participants. The ratings of pictures in the photo survey could then be compared to the classification by the participants in the VEP study.

Additional research is needed to assess the long-term effects of understory clearance and other forest management practices on bird communities in urban woodlands. Further experimental studies would be desirable to elucidate the importance of forest management to pest control by insectivorous birds.

More field experiments with a replicated design would be of great value to evaluate management effects on ecological and social values in urban woodlands. Due to their high cost and time consumption, large-scale management experiments in urban woodlands will probably be relatively few in the future. In urban areas there are cultural constraints, spatial complexity, and complicated patterns of ownership which may further limit the establishment of ecological experiments (Felson and Picket, 2005). Monitoring of ecological data before and after management interventions can be done with less effort, and could provide valuable information on how to improve and adjust management practices. There are major opportunities for research ecologists to become involved in the design and conduct of forest management, to the benefit of scientists, managers, and resource users.

As urban woodlands are intensively used ecosystems, their management is of central importance. Urbanisation will proceed in the foreseeable future and further increase the pressure on urban green areas. At the same time, there will be an increased demand for ecosystem services provided by urban woodlands. Improved knowledge of management effects in urban woodlands is paramount to enable adaptation of management practices in the future.

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