SILVA FENNICA

Silva Fennica 45(5) research notes

www.metla.fi/silvafennica · ISSN 0037-5330
The Finnish Society of Forest Science · The Finnish Forest Research Institute

A Comparison of Avian Diversity in Spruce Monocultures and Spruce–Birch Polycultures in Southern Sweden

Adam Felton, Erik Andersson, David Ventorp and Matts Lindbladh

Felton, A., Andersson, E., Ventorp, D. & Lindbladh, M. 2011. A comparison of avian diversity in spruce monocultures and spruce–birch polycultures in southern Sweden. Silva Fennica 45(5): 1143–1150.

The replacement of some spruce monocultures with stands composed of planted Norway spruce (*Picea abies*) and naturally regenerated birch (*Betula* spp.) has a range of potential benefits, but the implications for biodiversity are generally unknown. Here we conduct a paired replicated study in southern Sweden of the avian biodiversity found within Norway spruce monocultures, and within Norway spruce stands possessing approximately 20% birch. Our research leads us to three findings. First, avian diversity was significantly higher in the spruce–birch polycultures. Second, spruce–birch polycultures exclusively attracted broadleaf-associated bird species and retained the majority of conifer-associated bird species found in the spruce monocultures. Third, avian biodiversity within the spruce–birch polycultures did not incorporate threatened taxa. We suggest that in addition to the apparent benefits for stand level diversity, widespread use of spruce–birch polycultures could provide a means of softening the matrix for broadleaved-associated species, while concurrently providing an increased broadleaf base from which future conservation actions could be implemented. Our results are relevant to multi-use forestry, and recent policy initiatives by forest certification agencies which aim to increase broadleaf-associated biodiversity within conifer-dominated production forest landscapes.

Keywords biodiversity, conservation, sustainable forestry
Addresses Swedish University of Agricultural Sciences, Southern Swedish Forest Research Centre, Alnarp, Sweden
E-mail adam.felton@ess.slu.se
Received 22 June 2011 **Revised** 14 October 2011 **Accepted** 17 October 2011
Available at http://www.metla.fi/silvafennica/full/sf45/sf4551143.pdf

1 Introduction

Spruce monocultures can have negative impacts on the environment (Berg et al. 1994, Fridman 2000, Chapin et al. 2007, Gärdenfors 2010), and in-turn, may be relatively susceptible to abiotic and biotic disturbances exacerbated by climate change (Sykes and Prentice 1996, Sykes et al. 1996, Bradshaw et al. 2000, Koca et al. 2006, SCCV 2007). Because of this, there is an impetus to evaluate alternative tree species for use in production forestry (SCCV 2007). One such alternative being considered in southern Sweden involves the replacement of some spruce monocultures with stands composed of planted Norway spruce (*Picea abies*) and naturally regenerated silver or downy birch (*Betula pendula/pubescens*, hereafter birch). A recent review of the scientific literature suggests that this intervention would result in stand-level benefits for biological diversity (Felton et al. 2010). Unfortunately, the paucity of empirical studies directly comparing the biodiversity of these two production forest categories limited the extent to which conclusions could be drawn.

Here we begin to address this issue by conducting paired a replicated survey in southern Sweden of avian biodiversity in managed Norway spruce monocultures, and Norway spruce stands with an increased birch component. We discuss biodiversity differences in terms of species diversity, and the Swedish Red List (Gärdenfors 2010). We place our results in the context of recent policy initiatives to increase the proportion of broadleaved trees in landscapes dominated by coniferous monocultures.

2 Methods

2.1 Study Area

Study sites were located within the south-eastern region of Southern Sweden (Götaland; Fig. 1) in the counties of Blekinge, Kalmar, and Kronoberg. This region encompasses a transition zone between the boreal zone of northern Europe and the temperate (nemoral) zone of central Europe. Approximately 70% of each county's land area consists of productive forests, with Norway

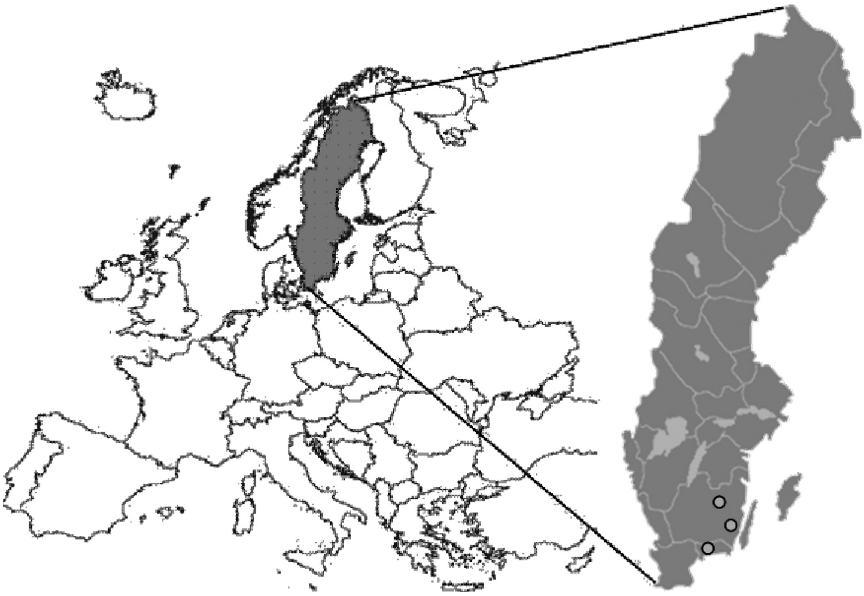

Fig. 1. Map identifying the location of Sweden relative to Europe, with the general location of the three field sites indicated.

spruce, Scots pine and birch contributing to the majority of standing volume (SFA 2009). We used the database of Sveaskog, a state owned company which owns a large amount of forest in the region, to search for and locate potentially suitable forest stands.

2.2 Stand Attributes

We selected spruce monoculture and spruce–birch polyculture forest stands based on the following attributes; 1) tree species composition, 2) active management, 3) late in the rotation stage, 4) above a minimum size, and 5) suitable proximity between comparison stands. Spruce monocultures were selected which contained at least 85% spruce and 3% or less of birch by volume. Spruce–birch polycultures were selected contain not less than 75% spruce, with at least 10% birch by volume. No additional tree species in the stand provided more than 10% of volume, thereby limiting the influence of other tree species on stand-level biodiversity. Stands were defined as being actively managed if signs of silvicultural prescriptions (e.g. thinning) were encountered through the majority of the stand. Our aim was to avoid the presence of unmanaged forest within managed stands, which would have a confounding influence on avian biodiversity.

Surveyed forest stands were at least 4ha in size and were between 39 and 49 years of age. Normal rotation time for spruce forests in this region range from 60 to 70 years. Targeting mature stands was consistent with our focus on assessing the biodiversity value of retaining birch within spruce stands throughout the rotation period. We targeted stands larger than 4 ha to reduce, as much as possible, the influence of ex-situ vegetation on the bird communities surveyed. In addition to stand level requirements, comparison stands were paired spatially, between 2 and 10 km apart. These spatial limits were a compromise between increasing the likelihood that the bird communities within the comparison stands were independent, and the need to reduce landscape level differences. Where suitable alternative comparison stands occurred, we chose pairs which were most closely matched in terms of age and size.

2.3 Vegetation Surveys

We conducted vegetation structure and floristic surveys during May of 2010. Vegetation surveys were conducted to supplement information collected by Sveaskog, which includes stand tree species composition, height, age, basal area, and thinning regime. Within each stand, vegetation surveys were conducted at the four bird count locations, and additionally at a fifth randomly located point close to the centre of the stand. At each survey point we measured out a 8.5m radius circular plot representing 0.022 hectares (0.11 hectares per site in total), within which we identified all tree species above 2m height and measured their DBH. Each point was assessed and assigned to one of five categories of understorey density and canopy closure. We randomly placed a $1m^2$ quadrat at each survey point and identified all vascular plant and moss species contributing to more than 5% of the total area assessed.

2.4 Bird Survey Design

We used the point count method of surveying bird species and their abundances in each stand (Bibby et al. 2000). Four survey points were located within each stand, with provisos that the minimum distance between two points was at least 100m, and at least 50m from the stand edge. The first marked survey point in each stand was located a set distance from the stand's centroid, identified off-site using stand maps to avoid selection bias. Surveys were conducted in the third week of April and May 2010. We chose survey periods to coincide with annual peaks in singing activity of breeding resident and migrant passerines. Daily surveys were begun at dawn, at approximately 5:30am in April and 4:30am in May, and finished at 9:15am and 8:15am respectively. This period overlapped with the daily peak in bird vocal activity. On the day of the survey, a spruce monoculture stand and a spruce-polyculture comparison stand were visited twice, representing an early morning survey (e.g. April: 5:30–7:15am) and a mid-morning survey (e.g. 7:30–9:15am). Surveys were only conducted in suitable weather for conducting bird surveys (i.e. minimal wind, no rain).

All point count surveys were conducted concurrently by three experienced bird ecologists (E.A., A.F., M.L.). Each point was surveyed for 5 minutes, after a 1 minute pause to reduce the impact on bird activity from the surveyors' approach. Distance to individual birds from the observers was estimated, and only those birds deemed to be within 50m were recorded for each survey point. This threshold distance was chosen to capture only those birds located within the stand, to avoid double counting birds at two survey points, and because it is substantially less than the maximum distance observers are estimated to be able to differentiate the distance to calling birds (i.e. 65m, see Alldredge et al. 2007). Due to the density of vegetation, most identification was made acoustically, rather than visually. In cases of uncertainty, the most conservative estimate of abundance was used.

2.5 Ecological Characteristics of Birds

We used descriptions of forest associations from the Swedish bird atlas (Svensson et al. 2000) and the Birds of the Western Palearctic (BWPi 2007) to classify bird species encountered during our surveys as broadleaf associated, conifer associated, or broadleaf/conifer for those species which did not exhibit a distinct association with different forest types due to broadleaf or coniferous attributes. We also assessed whether species encountered were included on the Swedish Red List of threatened taxa (Gärdenfors 2010).

2.6 Data Analysis

For the purpose of our study we use the relative encounter rate of bird species within the stands as an indicator of abundance (hereafter referred to as abundance). The abundance of each bird species in a given stand was determined by summing the encounter rates from each of the four point count locations for the early morning, and then repeating this procedure for the mid-morning survey, and then using the highest value. Research indicates that true avian abundance is best correlated with maximum rather than average abundance data from repeated surveys (Toms et al. 2006). Hence, we used the highest total from the two morning surveys as the measure of species abundance for that stand. Likewise, we use the highest abundance results from the April and May surveys to determine the abundance of a species in a stand. This approach accounts for seasonal differences in the song activity of resident and migrant bird species. We used the Shannon-Wiener index to obtain an index of species diversity for each stand (Krebs 1998). We used a paired t-test to test for overall differences in the diversity of the three paired comparison stands. We compared total basal area using paired t-tests. We used the one-way analysis of similarities (ANOSIM) randomization test (Clarke 1988) for differences in understorey composition among the compared stands. Statistical tests were conducted using SAS, R (RDCT 2010), and exploratory, graphical and multivariate analysis conducted using Primer-E (v. 6).

3 Results

3.1 Stand Attributes

In the spruce monocultures, an average of 1.9% of total basal area consisted of birch, with at least 89% of the remaining basal area consisting of spruce (Table 1). On average these stands also contained, as a percentage of total basal area, 5% *Pinus sylvestris* and 0.2% *Fagus sylvatica*. In the spruce–birch polycultures, an average of 17% of total basal area consisted of birch, with at least 75% of the remaining tree species composition consisting of spruce. On average these stands also contained 1% *Salix* spp. and 0.3% *Quercus* spp. Individual representatives of the genera *Carpinus*, *Sorbus*, *Juniperus*, and *Populus* were also encountered at very low densities in at least some of the stands. There was no significant difference in total basal area between the monocultures and polycultures (t statistic 0.34, *df* =2, p=0.77). Likewise, there was no significant difference in understorey plant composition (Global R = 0.296, p = 0.1, number of permutations = 10). The understorey of both spruce monocultures and spruce–birch polycultures was dominated by either one of two species of moss, *Pleurozium schreberi* and *Hylocomium splendens*.

Table 1. Measured forest stand attributes for spruce monocultures (Mono) and spruce–birch polycultures (Poly) assessed in Blekinge, Kalmar, and Kronoberg. Percentages refer to total basal area (BA) in m^2/ha.

	Blekinge		Kalmar		Kronoberg	
	Mono	Poly	Mono	Poly	Mono	Poly
Age	43	44	49	39	41	43
Size (ha)	4.53	6.26	20.0	4.84	7.58	6.59
% Spruce	95.4	79.6	89.7	76.0	93.4	89.3
% Birch	2.4	17.2	0.2	23.8	3.0	10.7
% Pine	1.2	0	9.4	0	3.4	0
Total BA	25.8	30.2	36.1	22.6	25.4	28.6

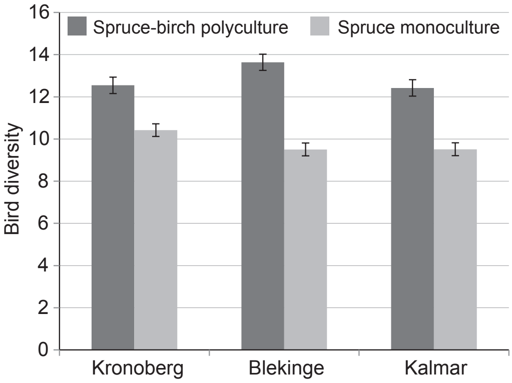

Fig. 2. Shannon-Wiener bird diversity indices (and associated standard errors) for spruce monocultures and spruce–birch polycultures assessed in Blekinge, Kalmar, and Kronoberg. Species diversity was significantly higher within polycultures than in spruce monocultures (t statistic 5.22, df=2 and p=.03).

3.2 Bird Communities

During the study we observed a total of 29 bird species, representing 20 families (Table 2). Spruce–birch polycultures had higher numbers of unique species ($\bar{x} = 6.5$) than spruce monocultures ($\bar{x} = 3.5$). No species encountered were included on the Swedish Red List of threatened taxa (Gärdenfors 2010). Broadleaf associated taxa, as classified using the Swedish bird atlas (Svensson et al. 2000), were encountered exclusively in spruce–birch polycultures (Table 2). Coniferous associated taxa were also encountered more frequently in the spruce–birch polycultures than in the spruce monocultures, however this pattern was not consistent across all bird species in this category (Table 2). Species diversity was significantly higher within polycultures than in spruce monocultures (t statistic 5.22, df=2 and p=.03; Fig. 2.).

4 Discussion

In a recent review of the published scientific literature, Felton et al. (2010) suggest that the addition of birch to spruce monocultures will likely benefit within-stand avian diversity in southern Sweden. Our results provide preliminary empirical support for this expectation. Although our study was limited by the availability of suitable stands, we nevertheless found that the diversity of bird communities was consistently and significantly higher in spruce–birch polycultures than in comparable spruce monocultures. Furthermore, bird species characterized as broadleaf-associated by the ornithological literature were exclusively encountered in spruce–birch mixtures. The similarity between spruce–birch polycultures and spruce monocultures with regards to basal area and understorey vegetation, indicates that the observed difference in bird community composition was driven by the increased prevalence of broadleaved trees (i.e. birch), and not by associated changes to forest structure or understorey (see Bibby et al. 1989, Peck 1989, Berg 1997, Poulsen 2002). As such, our results indicate that even a relatively small increase in the percentage of birch trees within spruce monocultures (17%) appears to have the capacity to elicit a positive response from broadleaf-associated bird species,

Table 2. List of bird species surveyed in the spruce–birch polycultures and spruce monocultures. Numbers refer to the maximum number of individuals for a given species recorded in a stand for the May and April surveys, as compared with their preferred habitat as indicated in Svensson et al. (2000).

Family	Scientific name	Common name	Forest preference	Spruce–birch polyculture	Spruce monoculture
Accipitridae	*Accipiter nisus*	Eurasian Sparrowhawk	Coniferous	1	0
Aegithalidae	*Aegithalos caudatus*	Long-tailed Tit	Broadleaf	1	0
Certhiidae	*Certhia familiaris*	Eurasian Treecreeper	Broad/Con	4	4
Columbidae	*Columba palumbus*	Wood Pigeon	Broad/Con	3	3
Corvidae	*Corvus corax*	Raven	Broad/Con	1	0
Corvidae	*Garrulus glandarius*	Eurasian Jay	Broad/Con	0	2
Emberizidae	*Emberiza citrinella*	Yellowhammer	Broad/Con	1	0
Fringillidae	*Carduelis chloris*	European Greenfinch	Broad/Con	0	1
Fringillidae	*Carduelis spinus*	Eurasian Siskin	Coniferous	11	16
Fringillidae	*Fringilla coelebs*	Common Chaffinch	Broad/Con	12	11
Fringillidae	*Loxia curvirostra*	Crossbill	Coniferous	1	1
Motacillidae	*Anthus trivialis*	Tree Pipit	Broad/Con	1	1
Muscicapidae	*Erithacus rubecula*	European Robin	Broad/Con	11	8
Paridae	*Periparus ater*	Coal Tit	Coniferous	6	3
Paridae	*Parus caeruleus*	Blue Tit	Broadleaf	3	0
Paridae	*Lophophanes cristatus*	Crested Tit	Coniferous	0	1
Paridae	*Parus major*	Great Tit	Broad/Con	5	3
Paridae	*Poecile montanus*	Willow Tit	Coniferous	2	1
Phylloscopidae	*Phylloscopuscollybita*	Chiffchaff	Broadleaf	1	0
Phylloscopidae	*Phyllscopus sibilatri*	Wood Warbler	Broad/Con	1	0
Phylloscopidae	*Phylloscopus trochilus*	Willow Warbler	Broadleaf	5	0
Prunellidae	*Prunela modulari*	Dunnock	Broad/Con	4	1
Regulidae	*Regulus regulus*	Goldcrest	Coniferous	4	5
Sittidae	*Sitta europaea*	Eurasian Nuthatch	Broadleaf	2	0
Sylviidae	*Sylvia atricapilla*	Blackcap	Broadleaf	2	0
Troglodytidae	*Troglodytes troglodytes*	Winter Wren	Broad/Con	4	2
Turdidae	*Turdus iliacus*	Redwing	Broad/Con	1	1
Turdidae	*Turdus merula*	Common Blackbird	Broad/Con	2	1
Turdidae	*Turdus philomelos*	Song Thrush	Broad/Con	3	4
Turdidae	*Turdus viscivorus*	Mistle Thrush	Coniferous	1	0

without incurring a corresponding loss for many of the conifer-associated species found in these production stands.

Not surprisingly, red-listed taxa were not encountered during our limited surveys. Red-listed forest birds are 1) not common, and 2) require habitats that rarely persist in forests managed using rotational clear-cutting of even-aged stands (Berg et al. 1994, Bengtsson et al. 2000, Svensson et al. 2000, Nilsson et al. 2005, Gärdenfors 2010) However, this is not to indicate that vulnerable taxa cannot gain from an increased percentage of spruce–birch polycultures in the landscape. For instance, the widespread use of such stands may facilitate increased movement by species, and reduce edge effects at the boundaries of natural vegetation patches (see Fischer et al. 2006). In addition, the use of spruce–birch polycultures would provide an increased broadleaf base from which future conservation actions could be implemented. For example, the preference several species of woodpecker exhibit for using birch as a nest tree (Hagvar et al. 1990, Poulsen 2002, but see Remm et al. 2006) raises the possibility of integrating spruce–birch polycultures with green tree retention or longer rotation periods, to increase the availability of potential nest sites in the landscape. Likewise, the distinctive understorey micro-climate provided by birch (Saetre et al. 1999, Brandtberg et al. 2000, Felton et al. 2010), could be combined with altered thinning regimes to produce a greater diversity of understorey vegetation for the benefit of ground or shrub-associated bird species (Bibby et al. 1989, Berg 1997, Poulsen 2002).

The potential for broadleaf tree species to accrue within the conifer dominated landscapes of southern Sweden has recently increased, due to a policy initiative by the Forest Stewardship Council (FSC). The FSC in Sweden now requires, where feasible, at least 10% broadleaved tree species by volume, be retained until the time of final felling within certified coniferous monocultures (FSC 2010). As at least 33% of productive forests in the south of the country are FSC certified, and the majority of those consist of spruce monocultures, such an addition of broadleaf trees may be sufficient to elicit a positive response from broadleaf-associated bird species at the stand or landscape level. We suggest that further research is needed into threshold habitat requirements for broadleaf-dependent taxa, to help guide the development of future policy initiatives.

Acknowledgements

We thank Annika M. Felton, and three anonymous reviewers, whose suggestions greatly improved the manuscript.

References

Alldredge, M.W., Simons, T.R. & Pollock, K.H. 2007. A field evaluation of distance measurement error in auditory avian point count surveys. Journal of Wildlife Management 71(8): 2759–2766.

Bengtsson, J., Nilsson, S.G., Franc, A. & Menozzi, P. 2000. Biodiversity, disturbances, ecosystem function and management of European forests. Forest Ecology and Management 132(1): 39–50.

Berg, A. 1997. Diversity and abundance of birds in relation to forest fragmentation, habitat quality and heterogeneity. Bird Study 44: 355–366.

— , Ehnstrom, B., Gustafsson, L., Hallingback, T., Jonsell, M. & Weslien, J. 1994. Threatened plant, animal, and fungus species in Swedish forests – distribution and habitat associations. Conservation Biology 8(3): 718–731.

Bibby, C.J., Aston, N. & Bellamy, P.E. 1989. Effects of broadleaved trees on birds of upland confier plantations in north Wales. Biological Conservation 49(1): 17–29.

— , Burgess, N.D. & Hill, D.A. 2000. Bird Census Techniques. Academic Press, London.

Bradshaw, R.H.W., Holmqvist, B.H., Cowling, S.A. & Sykes, M.T. 2000. The effects of climate change on the distribution and management of Picea abies in southern Scandinavia. Canadian Journal of Forest Research 30(12): 1992–1998.

Brandtberg, P.O., Lundkvist, H. & Bengtsson, J. 2000. Changes in forest-floor chemistry caused by a birch admixture in Norway spruce stands. Forest Ecology and Management 130(1–3): 253–264.

BWPi. 2007. Birds of the Western Palearctic interactive. DVD. Bird Guides. Oxford University Press, Sheffield.

Chapin, F.S., Danell, K., Elmqvist, T., Folke, C. & Fresco, N. 2007. Managing climate change impacts to enhance the resilience and sustainability of Fennoscandian forests. Ambio 36(7): 528–533.

Clarke, K.R. 1988. Detecting change in benthic community structure. In: Proceedings XIV International Biometric Conference. Société Adophe Quélét, Namur. p. 131–142.

Felton, A., Lindbladh, M., Brunet, J. & Fritz, Ö. 2010. Replacing coniferous monocultures with mixed-species production stands: An assessment of the potential benefits for forest biodiversity in northern Europe. Forest Ecology and Management 260(6): 939–947.

Fischer, J., Lindenmayer, D.B. & Manning, A.D. 2006. Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes. Frontiers in Ecology and the Environment 4(2): 80–86.

Fridman, J. 2000. Conservation of forest in Sweden: a strategic ecological analysis. Biological Conservation 96(1): 95–103.

FSC. 2010. Swedish FSC standard for forest cerification including SLIMF indicators. FSC, Sweden. p. 95.

Gärdenfors, U. 2010. Rödlistade arter i Sverige 2010. The 2010 red list of Swedish species. ArtDatabanken, Uppsala.

Hagvar, S., Hagvar, G. & Monness, E. 1990. Nest site selection in Norwegian woodpeckers. Holarctic Ecology 13(2): 156–165.

Koca, D., Smith, B. & Sykes, M.T. 2006. Modelling regional climate change effects on potential natural ecosystems in Sweden. Climatic Change 78(2–4): 381–406.

Krebs, C.J. 1998. Ecological methodology. Benjamin Cummings, New York.

Nilsson, S.G., Niklasson, M., Hedin, J., Eliasson, P. & Ljungberg, H. 2005. Biodiversity and sustainable forestry in changing landscapes – Princicples and southern Sweden as an example. In: Blennow, K. & Niklasson, M. (eds.). Sustainable forestry in Southern Sweden. The SUFOR Research Project. The Haworth Press Inc., New York. p. 11–43.

Peck, K.M. 1989. Tree species preferences shown by foraging birds in forest plantations in northern England. Biological Conservation 48(1): 41–57.

Poulsen, B.O. 2002. Avian richness and abundance in temperate Danish forests: tree variables important to birds and their conservation. Biodiversity and Conservation 11(9): 1551–1566.

RDCT, R.D.C.T. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Remm, J., Lohmus, A. & Remm, K. 2006. Tree cavities in riverine forests: what determines their occurrence and use by hole-nesting passerines? Forest Ecology and Management 221(1–3): 267–277.

Saetre, P., Brandtberg, P.O., Lundkvist, H. & Bengtsson, J. 1999. Soil organisms and carbon, nitrogen and phosphorus mineralisation in Norway spruce and mixed Norway spruce–birch stands. Biology and Fertility of Soils 28(4): 382–388.

SCCV. 2007. Sweden facing climate change – threats and opportunities. Swedish Commission on Climate and Vulnerability, Stockholm.

SFA, S.F.A. 2009. Swedish statistical yearbook of forestry 2009. Jönköping.

Svensson, S., Svensson, M. & Tjernberg, M. 2000. Svensk fågelatlas. ArtDatabanken, Lund.

Sykes, M.T. & Prentice, I.C. 1996. Climate change, tree species distributions and forest dynamics: a case study in the mixed conifer northern hardwoods zone of northern Europe. Climatic Change 34(2): 161–177.

— , Prentice, I.C. & Cramer, W. 1996. A bioclimatic model for the potential distributions of north European tree species under present and future climates. Journal of Biogeography 23(2): 203–233.

Toms, J.D., Schmiegelow, F.K.A., Hannon, S.J. & Villard, M.A. 2006. Are point counts of boreal songbirds reliable proxies for more intensive abundance estimators? Auk 123(2): 438–454.

Total of 31 references