

# Habitat composition and restocking for conservation of the white-backed woodpecker in Sweden

*“En härlig dag i maj komma vi roende nedför Marman, med kurs på skogsudden, som skjuter ut i sjön. Utanför den ligga stora stenblock med krönen över vattnet. Där innanför stå asparna i tät församling, högresta, rakstammiga, med till synes nakna kronomfång. Högvattnet från sjön, som stått meterhögt kring träden därinne, sjunker undan efterhand, och ett stycke in i skogen ligger mattan av de brunröda aspbladen ännu våta och platträckta mellan moss- och lavklädda block och olvonbuskarna som ännu bära några röda bär.*

*Det är så stilla nu mot aftonen, när solen hållar mot nedgången och skenet glider in bland bråtet och stammarna. Våren är på färde, och livets röster vaka. Asparna har knopp på kvistarna och björkarna ha små utspringande blad. Det höres ett mjukt kraxande från en storskrak ute på sjön. En koltrast knäpper någonstans, och en rödhake sjunger. Under en ticka, ett stycke upp på en asp, är där ett runt hål. Vi knacka på stammen, och ett fågelhuvud med helröd hjässa tittar ut ur hålet, drar sig in igen och kommer åter tillsynes. Det är »den vitryggige» - han har bo däruppe. Han far till sist och blir borta bland skogens hemligheter. Men han finns där – det höres, svagt därinnifrån understundom, trummandet som är hans stämma i vårtiden.”*

*-Paul Rosenius*

*Ur Sveriges Fåglar och Fågelbon, sjätte bandet, 1949.*

*Örebro Studies in Life Science 14*



KRISTOFFER STIGHÄLL

**Habitat composition and restocking for conservation of  
the white-backed woodpecker in Sweden**

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## **Abstract**

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In Sweden, intense human land use, especially forestry, has led to profound changes in the landscape over time, especially within the forest ecosystems. A consequence of this is that several specialist species have become endangered. One group of specialists is the woodpeckers. The middle spotted woodpecker became extinct in Sweden in 1982 and the white-backed woodpecker is today Sweden's most critically endangered forest-living bird. The white-backed woodpecker is dependent on old deciduous forests, rich in dead wood. The woodpecker is area-demanding and hence one of the best indicators or umbrella species for biodiversity in this region. A long-term goal within the conservation of the species is to be able to make more accurate predictions of what is needed in the species habitat to establish a viable population, both in terms of composition of landscape and breeding territories. In addition to earlier studies better tools are needed for measuring the distribution of suitable and potential habitats and finding faster ways of creating optimal habitats. In an attempt to secure the future existence of the white-backed woodpecker in Sweden, restocking of birds are carried out. This presupposes availability of suitable habitats as well as strong enough landscape. Due to intense forestry the presumption for the species is, as stated above, alarming. Comparing the different populations around the Baltic Sea and Norway, great differences but also similarities can be seen, in landscape as well as in territory composition. It seems that fragmentation of foraging patches as well as amount of dead deciduous wood within the breeding territory is critical matters. Grey alder stands in Sweden should have high priority in conservation of habitat for the species.

*Keywords:* White-backed woodpecker, *Dendrocopos leucotos*, Sweden, deciduous forest, suitable habitat, fragmentation, saproxylic insects, captive breeding, restocking.

Kristoffer Stighäll, School of Science and Technology, Örebro University, SE-701 82 Örebro, Sweden. e-mail: kristoffer.stighall@oru.se.



# LIST OF PAPERS

## Paper I

Stighäll, K., Roberge, J.- M., Andersson, K. & Angelstam, P. 2011. Usefulness of biophysical proxy data for modelling habitat of an endangered forest species: the white-backed woodpecker *Dendrocopos leucotos*. *Scandinavian Journal of Forest Research* 26:576-585

## Paper II

Stighäll, K. & Olsson, P.- E. Habitat composition and fragmentation in breeding territories of the white-backed woodpecker *Dendrocopos leucotos* in Sweden, Finland and Latvia. **Manuscript**

## Paper III

Jonsell, M., Nitterus K. & Stighäll, K. 2004. Saproxylic beetles in natural and man-made deciduous high stumps retained for conservation. *Biological Conservation* 118:163-173

## Paper IV

Stighäll, K., Lindberg, P. & Lithander, L. Captive breeding and restocking of the white-backed woodpecker *Dendrocopos leucotos* in Sweden. **Manuscript**



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# INTRODUCTION

Most forests of northern Europe are intensively exploited by human activities, especially forestry operations. The exploitation has in a short period of time resulted in drastic changes of the forest landscape, with massive loss of old growth forest and decline in natural processes such as flooding and fires. In Fennoscandia the focus on coniferous wood production, for the forest industry, has led to a reduction in the number of older deciduous trees and deciduous forest stands (Mikusiński et al. 2003), a lowered occurrence of old forest (Angelstam & Kuuluvainen 2004) as well as loss of dead wood (Siitonen 2001, Shorohova et al. 2004). Modern methods of forest management aim at sustained optimal yield of wood and fibre. This often results in reduction of tree species diversity, truncated age distribution and structural variation of stands and landscapes. In naturally dynamic forests dead wood is a dominating feature and in the pre-industrial Scandinavian forest landscape, more than 20 % of the wood volume comprised of dead wood (Siitonen 2001). Unexplored coniferous- and mixed forests in European Russia still today consist of about 20 % of dead wood. In Sweden today just single percent of the wood is dead (Christiansen 2014). Additionally, the clearing of fertile soils and regulation of streams have contributed to the declining number of trees and forest stands where deciduous tree species dominate. This loss has been unfavourable to a large number of species and forestry is today one of the human activities contributing the most to decreasing biodiversity. Many resident bird species in the boreal and hemiboreal forests have declined and one group that is especially vulnerable is the woodpeckers.

## The white-backed woodpecker

The order *Piciformes* is one of the oldest and most isolated bird groups (Sibley & Ahlquist 1990). In Western Palaearctic they are represented by the Woodpecker family *Picidae* (Cramp 1985). In this region, woodpeckers are among the largest birds that are almost exclusively insectivorous and the most habitat-demanding of the resident species (e.g. Wesolowski & Tomiałojć 1986). Most woodpecker species are dependent on decaying wood for the nest and roost hole excavating and for feeding. Their ecological requirements make them particularly sensitive to modern forestry,



Figure 1. Male white-backed woodpecker close to nest hole. Photo Dan Mangsbo.

which usually involves removal of old forest, dead wood and the replacement by conifers (Short & Horn 1990, Angelstam & Mikusiński 1994).

Of the European woodpeckers, the white-backed woodpecker *Dendrocopos leucotos* is the largest species of its genus, with a length of 25 cm and weight of about 100 g (Glutz von Blotzheim & Bauer 1980, Figure 1). It is a resident bird dependent on food resources found in dead and decaying deciduous wood (Winkler et al. 1995). This demanding species of naturally dynamic forest, at least in northern Europe, avoids Norway spruce (*Picea abies*) and planted forest (Aulén 1988, Carlson 2000) and can utilise foraging trees at distances 6-10 km from the nest tree (Stenberg 1990) with a high proportion of dead and dying trees. The woodpecker also prefer areas with a high proportion of trees with a large stem diameter and forest stands exceeding 80 years of age, avoiding 20-50 year-old forests (Hogstad & Stenberg 1994).

Area-demanding species are among the best indicators (Roberge & Angelstam 2006), or umbrella species, for biodiversity in deciduous forests in northern Europe (Roberge et al. 2008b). In central and southern Sweden, more than 250 red listed species of vascular plants, mosses, lichens, fungi,

vertebrates and insects were found in the territories of the white-backed woodpecker (Mild & Stighäll 2005).

The main diet for white-backed woodpeckers is wood-inhabiting (saproxylic) beetle larvae found in dead and dying deciduous trees (e.g. Ahlén et al. 1978). Habitat loss has caused it to decrease drastically in most of its distribution area in Europe, and it has become extinct in several countries (Spiridinov & Vikkala 1997). Today the white-backed woodpecker is the rarest woodpecker species in Europe. Once widespread in Fennoscandia, it has declined dramatically during the last 60-70 years due to intense forest management and habitat fragmentation in many countries (Aulén 1988, Tiainen 1990, Rinden 1991, Gjerde et al. 1992, Virkkala et al. 1993). It used to be a breeding bird in most parts of Sweden (Nilsson 1835, Kolthoff & Jägerskiöld 1898, Rosenius 1949). In 2015 there were only three known breeding pairs and some single individuals of the species left in the whole of Sweden (Figure 2) and the species is classified as critically endangered in the national Red list (ArtDatabanken 2015). Still there are viable populations in Latvia and western Norway, due to topographic and hydrological conditions, as well as lack of forest management (Figure 3).



Figure 2. Trend in the Swedish white-backed woodpecker population 2005 - 2015. Breeding pairs (filled line) and other single individuals (dashed line).

A foraging behaviour and food choice study of the white-backed woodpecker in Sweden showed that about 96 % of the foraging sites were on deciduous trees. Birch (*Betula spec.*), aspen (*Populus tremula*), willow (*Salix caprea*) and grey alder (*Alnus incana*) were overused during winter whereas birch, aspen and pedunculate oak (*Quercus robur*) were overused during breeding. About 50 % of all species the woodpeckers searched for in the study were larvae or pupae of saproxylic beetles. Of the saproxylic insects, longhorn beetles (*Cerambycidae*) was the most abundant group (Aulén 1988).

Population viability analyses (PVA: s) is used to evaluate the sensitivity of small populations to different types of changes (Boyce 1992). PVA is species-specific methods of risk assessment frequently used in conservation biology. It is used to estimate the likelihood of a population's extinction and indicate the urgency of recovery efforts, and identify key life stages or processes that should be the focus of recovery efforts. PVA is also used to compare proposed management options and assess existing recovery efforts. PVA is frequently used in endangered species management to develop a plan of action, rank the pros and cons of different management scenarios, and assess the potential impacts of habitat loss (Reed et al. 2002). A PVA for white-backed woodpecker indicated that the amount of suitable habitats, genetics and extent of immigration were key factors for the long term survival in Sweden (Carlson & Stenberg 1995). Also the genetic variability of different white-backed woodpecker populations in northern Europe have been analysed, and indicated low genetic variation in the eastern Swedish population of white-backed woodpeckers (Ellegren et al. 1999).

## Conservation of the white-backed woodpecker in Sweden

One approach to safeguard the most threatened red-listed species used in Sweden is a concept of species- or habitat specific action plans (<http://www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sverige/Uppdelat-efter-omrade/Naturvard/Artbevarande/Atgardsprogram-for-hotade-arter/>). The plans include coordinate activities and conservation measures to protect, manage and restore functionally habitats for specific species, group of species or habitats. Today more than 100 different national action plans for threatened species are in progress in Sweden.

One such action plan involves the white-backed woodpecker and its habitats (Mild & Stighäll 2005). Authorities, forestry companies, scientists, landowner - and nature protection organizations are involved. Important contributions in the woodpecker action plan are monitoring, protection, restoration and management of habitats, supplemental feeding, captive breeding and restocking.

The rescue project requires improved understanding of habitat composition in landscapes, territory and habitat structures, as well as knowledge about food supply to determine if restocking is an option to aid the species recovery in Sweden. This thesis presents result from applied ecological research that will contribute to that understanding.

## **Forest management and restoration**

A lack of dead and dying wood and low numbers of deciduous trees, resulting from forest management practices, have been identified as major factors contributing to the loss of biodiversity in Fennoscandian forests (Essen et al. 1997, Niemelä 1997, Siitonen 2001, Dahlberg & Stokland 2004). In Sweden, about 1000 beetle species are saproxylic, i.e., they depend on dead or decaying wood during part of their life cycle. Without maintenance measures, most deciduous forests will gradually become spruce-dominated and unsuitable habitats for woodpecker nesting and feeding (T. Laine pers. comm.).

To reduce structural losses, dead wood is now retained during forest operations, often in the form of man-made snags (ca. 4 m high). Most often these snags are cut with a harvester or occasionally made with explosives.

In order to actively increase the quality and extent of suitable habitats also other protection actions have been undertaken. Two of the biggest logging companies in Sweden; Bergvik Skog and Sveaskog have chosen different landscape planning tools for favouring the white-backed woodpecker. Bergvik Skog has assigned 100 specific 100-ha areas for the species in which the aim is to manage and create suitable habitats (<http://www.bergvikskog.se/hallbarhet/miljo/artinriktade-insatser/>). Sveaskog has created so called Ecoparks, of which some are in regions with presence or former presence of white-backed woodpeckers (<http://www.sveaskog.se/jakt->

fiske-och-friluftsliv/besöksomraden/). In these Ecoparks, ranging from 1800 to 9200 ha in size, promotion of deciduous forest stands by selective harvest of spruce, creation of dead wood and also controlled forest fire will be important tools.

Further studies are needed to confirm the threshold levels for suitable landscape, suitable breeding territories and presence of structures important for the white-backed woodpecker. However, improved knowledge of captive breeding and restocking of the species, including pair formation, aviary size and location, method of release and supplemental feeding, are important steps in the process of saving the white-backed woodpecker in Sweden.

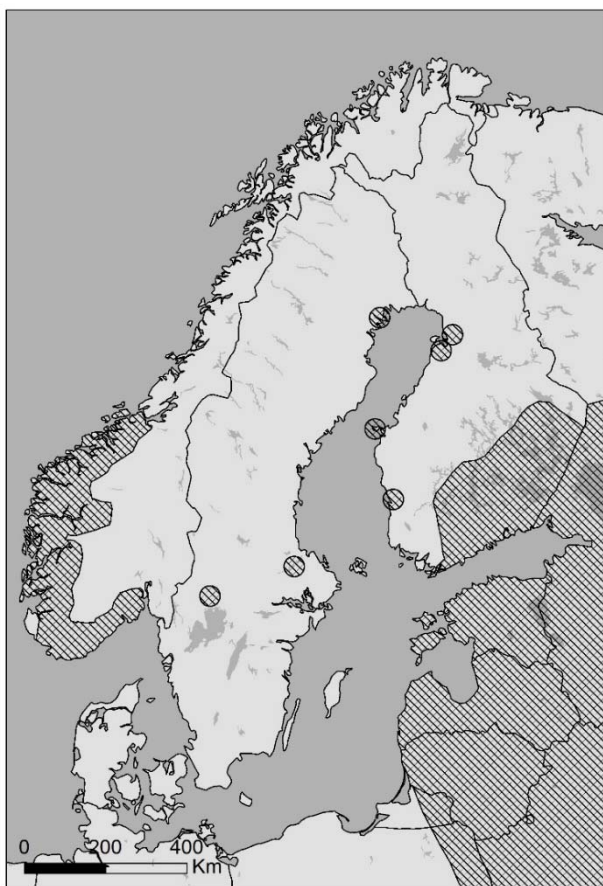


Figure 3. Distribution of white-backed woodpecker in northern Europe. Background layers downloaded from <http://www.diva-gis.org/>

## Landscape analysis

Fragmentation and loss of natural habitat are major threats to biological diversity (e.g. Wiens 1995). For biodiversity monitoring and conservation planning, landscape analysis by remote sensing allows collection of large amounts of land cover data at relatively low costs (Holmgren & Thuresson, 1998). One way to facilitate habitat suitability modelling for specialised threatened forest species is to complement remote sensing data with proxy data linked to management intensity or other processes potentially influencing habitat suitability for those species. Landscape analysis hereby could be used as a tool for scientific management of biodiversity.

## Habitat composition

The white-backed woodpecker is highly specialized with regard to its habitat and foraging niche. When the amount of suitable habitats in forest landscape falls below 10 %, modelling suggests that the decline in population size is accelerated (Carlson 2000). Using empirical data, Carlson suggested habitat thresholds for the persistence of the white-backed woodpecker at 8-17 % of suitable habitat in a landscape. A landscape in this aspect should be at least 250 km<sup>2</sup>. In northern and Eastern Europe the species prefers forests dominated by birch, aspen and alder. Maximum densities of the white-backed woodpecker in optimal deciduous forests are suggested to 1.0 breeding pair/km<sup>2</sup> (Stenberg 1990, Wesołowski 1995a). Studies in Norway suggest that home-ranges over a year are between 4.5 and 6.0 km<sup>2</sup>/individual. Especially the winter foraging areas are large (I. Stenberg pers. comm.). Pynnönen (1939) suggest the foraging range to be about two km<sup>2</sup>.

Most of the previous studies have been carried out in outstanding regions or landscapes. Hence, additional studies are desirable, especially comparing different categories of territories in various more or less optimal landscapes.

## Food supply

Foraging behaviour and food choice of the white-backed woodpecker have been studied in several parts of Europe (e.g. Nourteva et al. 1981, Aulén 1988, Hogstad & Stenberg 1997, Czeszczewik 2009, Lõmus et al. 2010). The abundance and availability of the food supply in winter is obviously a critical factor that might limit the numbers of woodpeckers (e.g. Rolstad & Rolstad 1995). Also the outcome of reproduction of the species is to a large extent depending on the winter weather (Hogstad & Stenberg 2005). In general, the number of beetle species living in the wood of deciduous trees, as well as the overall abundance of insects, increases with warmer microclimates and higher site quality (Nilsson & Ericson 1992).

The most frequently used foraging trees in western Norway were birch (40 %) and grey alder (ca 30 %), and the most preferred trees were aspen and grey alder (Stenberg & Hogstad 2004). Correspondingly birch, sal-low, aspen, grey- and black alder (*Alnus glutinosa*) composed of about 80 % of the foraging records in Sweden (Aulén 1988). Aspects of foraging ecology have also been studied in central Europe (Ruge & Weber 1974), Japan (Matsuoka 1979), Slovakia (Pavlík 1999), Italy (Mellletti & Penteriani 2003) and Poland (Czeszczewik 2009). Most food consist of saproxylic insects, especially longhorn beetles (*Cerambycidae*) and bark beetles (*Scolytidae*), usually found in dead and decaying wood. The *Saper-da* species seem to be particularly important (Nuorteva et al. 1981). The prey delivered to the nestlings in the Norwegian study consisted mainly of surface-living insects. According to Aulén (1988) the foraging techniques often used by the birds are bark-pecking, bark-scaling and superficial wood-pecking.

In regions experiencing thick and lasting snow cover, most downed wood remains inaccessible in winter and standing dead trees and snags become crucial for woodpeckers (e.g. Aulén 1991, Bull & Holthausen 1993). Several methods of improving the food supply for endangered woodpecker species have been tried, e.g. by killing trees (Aulén 1991, Lindhe et al 2005) or by supplemental feeding during winter using animal tallow (Mild & Stighäll 2005). Aulén (1988) estimated that the average energy expenditure for the species were about 62 Kcal/24 hours, corresponding to the need to excavate about 60 big wood-boring larvae every day (every larvae weight about 0.5 g).

## Captive breeding and restocking

Captive breeding and restocking programmes are used in several countries in attempt to ensure a long-term survival of especially vulnerable or threatened species. Sometimes the process includes the release of individuals to the wild, when there is sufficient natural habitat to support new individuals or when the threat to the species in the wild is lessened. Captive breeding programs facilitate biodiversity and may save species from extinction. Reintroduction and restocking programmes are conservation tools which may be employed when a wild population is otherwise beyond recovery. According to Black (1991) the decision to undertake such programmes should be based on a series of “feasibility” assessments (e.g. the bird's ecology, current threats, suitability of available stock and regional human socioeconomic implications). Releases should only take place when the habitat is capable of sustaining a viable population and the original constraining factors no longer operate. Releasing birds into near-saturated areas may be harmful and should be avoided. Local, national and international support for the programme should be secured. The birds should be of optimal quality in terms of behaviour, health and genetics and they should be reared, released and monitoring according to sound strategies and criteria. In Sweden one such programme involves the white-backed woodpecker (Mild & Stighäll 2005).

# MATERIALS AND METHODS

Biogeographically, the studies were located in the European hemiboreal and southern Boreal vegetation zone (Ahti et al. 1968, Mayer 1984, Laasimer et al. 1993). The forests are dominated by Norway spruce, Scots pine (*Pinus sylvestris*) and various proportions of birch, aspen and alder. Towards the south of the hemiboreal zone the proportion of pedunculate oak, lime (*Tilia cordata*) and ash (*Fraxinus excelsior*) increases.

## Paper I

In paper I the focus was to determine if proxy variables and traditional forest data in remote sensing information, together with historic distribution of white-backed woodpeckers could be used to facilitate the identification of suitable habitats for the species. A proxy variable is a variable that is not in itself directly relevant, but that serves in place of an unobservable or immeasurable variable.

An area in Sweden inhabited by a remnant population of white-backed woodpecker was studied using remote sensing data to detect suitable habitat. A twenty-year series of bird observations, of the incidence and breeding attempts, was used.

Data on the most critical resources for the white-backed woodpecker is very costly to gather over large areas, as these can only be assessed using field surveys (dead wood, older deciduous trees, etc.). An alternative is to use remote sensing data as a means to identify areas with high potential (e.g. Manton et al. 2005, Pasher et al. 2007, Buermann et al. 2008, Bäter et al. 2009). However the disadvantage is that remote sensing does not have the resolution to include fine-scale elements such as dead wood or single deciduous trees. A range of biophysical and historical proxy variables like distance to roads, edge habitats, deciduous wet forests, slopes and other habitats that can be expected to be rich in deciduous trees and can be used to identify possible habitats (Angelstam et al. 2004b).

## Paper II

Paper II deals with habitat composition and fragmentation in three different regions around the Baltic Sea with presence or former presence of white-backed woodpecker. Ten known territories in each region were delimited and foraging sites inside each territory border were detected and plotted. For each territory a total of more than 50 plots were randomly placed. In the 50 plots all trees exceeding 10 cm in breast high diameter were measured. Tree species composition, volume, dead wood appearances and grade of decomposition were measured using traditional field measurements. Degree of fragmentation was tested according to number and areas of foraging sites (subareas) inside the outmost border of the territories (Figure 4).

## Paper III

In order to create suitable habitats for woodpeckers one useful method has been to increase the number of dead and dying trees. A method used has been to use explosives placed about 4 - 5 m above the ground on aspen- and birch trees. One widely used forestry practice is to cut some trees at the same height, to leave a snag that can be colonized by saproxylic organisms (e.g. Schroeder et al. 2006).

In paper III the work was focused on estimating the amount of beetle larvae in different categories of snags, categorised according to habitat, historical land use and sun exposure. The purpose was to determine if the man-made snags could be a complement to natural dead wood and if so, what tree species and what sun exposure would generate most insects.

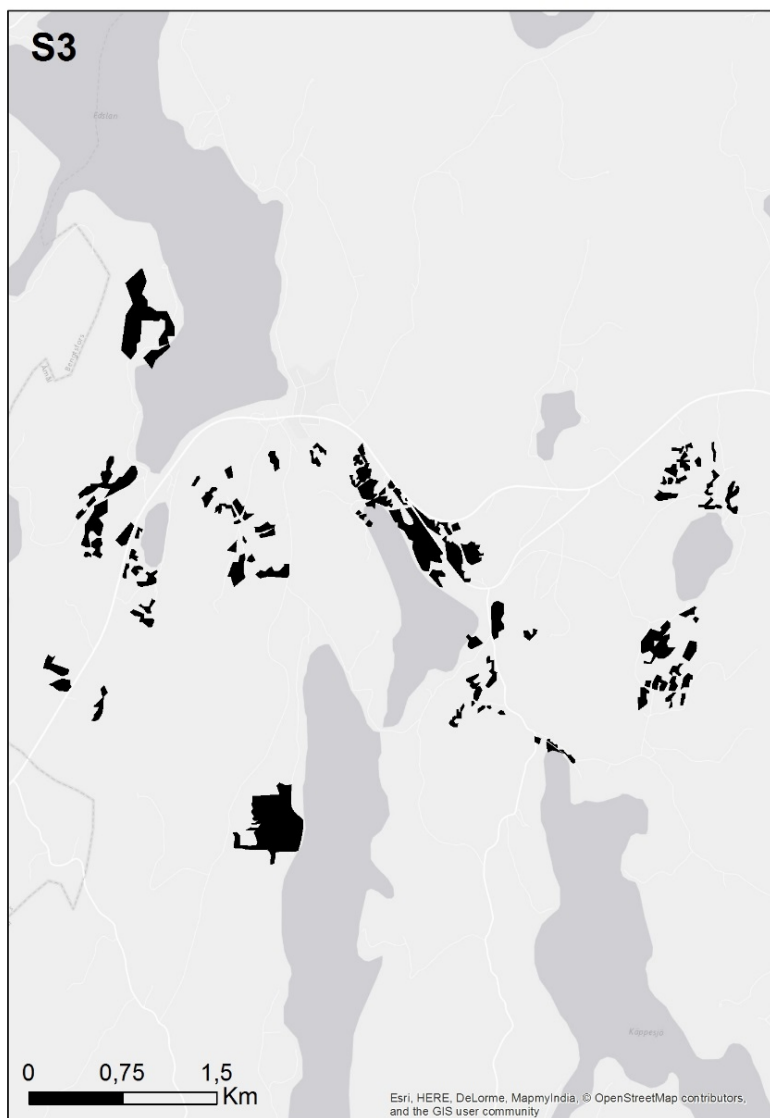


Figure 4. A fragmented territory of white-backed woodpecker in Sweden with numerous foraging patches.

Two different areas in west Sweden were studied where large numbers of snags had been cut to improve the food supply for the white-backed woodpecker. One area has previously been used for agriculture, mainly grazing, but has been abandoned for more than 50 years and naturally re-colonised with aspen and birch trees. The other site is situated in a forest landscape, dominated by coniferous trees but containing some deciduous trees, mainly aspen. The two different types of snags were found within the same forest stands. A similar number of man-made and natural snags were studied at both sites and diameter, decay-class and sun exposure were recorded.

## Paper IV

In paper IV we evaluated the methods used for captive breeding and release, to predict optimal procedures for restocking white-backed woodpeckers. Variables studied were the importance of different types of aviaries, location, mate matching, restocking methods and habitat structure.

Young woodpeckers were collected from nests in Norway and Latvia. The nestlings were handfed with insects at the breeding station, until fledged and released in an aviary. Later on pair formation was conducted on basis of territory code to avoid possible inbreeding.

Different sizes of breeding aviaries were tested, from volume of 30-60 m<sup>3</sup>/aviary, to a maximum height of 5.5 m and volume of about 400 m<sup>3</sup>/aviary (Figure 5). Different placings were tested; either a barn with several aviaries in a row or free standing aviaries. The free-standing aviaries were situated on a mean distance of 113 m (range 100-300 m) from each other so that the birds were not in visual contact but within hearing distance during drumming season in spring.

Two different methods were used for restocking; cross-fostering of nestlings and release of fledged birds from an aviary in a restored habitat, so called "hacking". In the cross-fostering experiments, an exchange was made between young and eggs in nests of great spotted woodpecker with one or two nestlings of white-backed woodpecker. Cross fostering was the main release method in the first five years.

Release of birds through hacking started in 2002. The woodpeckers were released at an age median of 65 days. The released birds were either collected as nestlings from the wild and handfed (in all 93 individuals, of which 47 were put in great spotted woodpecker nests and the rest released by hacking) or born in captivity and raised by their parents (83 individuals).

The release sites were selected according to the amount of deciduous forest on a landscape level (30 x 30 km), amount of suitable habitat (concentration of stands with high proportion of deciduous forest older than 60 years, low abundance of spruce mixture and high amount of dead deciduous wood), and areas where wild specimens still persists.

Different size of release aviaries, different amount and period of supplemental feeding with living insect larvae, and survival rate of the different release methods were tested.



*Figure 5. Large free-standing aviary used for captive breeding of white-backed woodpecker. Photo: Kristoffer Stighäll.*

# AIMS

Earlier studies concerning the ecology of the white-backed woodpecker have shown that the size of the territories, the distribution and variance of tree species and age, the amount of dead wood and the sun-exposure of substrate; all affects the species and its food supply. In paper I we try the hypothesis that white-backed woodpecker territories can be found when looking at the landscape from above.

Depending on the outcome of paper I, the hypothesis was also tested on territory data and degree of fragmentation when looking at territories in regions in northern Europe with different situation in population trend. The results of that study are presented in paper II.

On the basis of the data in paper I and II, artificial made forest structure and its food supply were tested. This was done by comparing man-made and naturally occurring snags, to see if it is possible to facilitate the development of insects (food for woodpeckers). The results from the study are presented in paper III.

Finally, on the basis of the outcome from paper I-III, attempts with captive breeding and restocking of woodpeckers in suitable habitats have been studied. Paper IV presents those attempts and results.

The studies were performed to identify new aspects of the ecology of the white-backed woodpecker, surveying territories from above and in the field, determining food supply and testing restocking as a population reinforcement method. The aims of this thesis are:

- to test prediction of presence of white-backed woodpeckers by comparing historical distribution of breeding territories with traditional forest and proxy variables using remote sensing,
- to identify threshold levels when comparing habitat compositions and fragmentations in three different north European woodpecker populations,
- to compare the amount of insects (food supply) in natural and man-made snags in white-backed woodpecker territories,
- to identify crucial conditions for successful captive breeding and restocking of white-backed woodpeckers.

# RESULTS AND DISCUSSION

## Paper I

Suitable habitats for white-backed woodpecker are usually described to be deciduous-rich older stands with large amounts of dead and decaying wood (e.g. Andersson & Hamilton 1972, Scherzinger 1982, Stenberg 1994). In the present study, we compared the composition in 94 known territories with an equal number of random sites in a region in West Sweden to determine if remote sensing could be used to detect areas suitable as habitats for white-backed woodpeckers. We observed that a model based on both traditional and biophysical proxy variables explained the presence and absence of woodpeckers better, than using just traditional variables. When using presence-absence and traditional variables only, the area of deciduous forest showed highly significant co-variation with occurrence of woodpecker. Adding proxy variables to the model showed that edge habitat towards farmland and to waterbodies; wetland forests and finally sites above the historical highest coastline had a positive effect on the woodpecker occurrence.

When analysing the number of years with occurrence of the white-backed woodpecker in sites with presence of woodpecker, again deciduous forest was a strong predictor. Adding proxy variables to the model showed that edge habitats towards water bodies and wetland forest were positively correlated to the number of years with woodpecker presence.

Our result showed that the area of deciduous forest had a strong positive effect on occurrence of woodpeckers. This is in accordance with existing knowledge on white-backed woodpecker ecology in northern-Europe (Wesołowski & Tomiałojć 1986, Aulén 1988, Hogstad & Stenberg 1994, Wesołowski 1995b). The study demonstrated that a combination of traditional variables and some proxy variables, in addition to the area of deciduous forest, improved the models. These included edge habitats, wetland forest and sites above the highest coastline. It seemed that heterogeneous territories turned out to be the best ones. Focusing on those habitats, it was observed that they usually were richer in deciduous trees (Ha-

zell 1999, Mikusiński & Angelstam 1999) and more exposed to both wind and sunlight. This in turn resulted in a higher amount of dead, sun-exposed wood than in dense forest stands and these are important factors for many saproxylic insects (Martikainen 2000, Lindhe et al. 2005, Ehnström & Holmer 2007, Horák & Rébl 2013). Therefore, edge habitats are expected to be attractive to white-backed woodpeckers.

Wetland forests are usually more difficult to access for forestry operations. Floodings also weaken and kill trees faster. As with edge habitats, wetland forests usually support higher amount of deciduous trees as well as dead and dying trees. This leads to increased sun-exposure, more insects and food supply for birds (e.g. Prieditis 1999).

Sites located above the highest coastline had a higher probability of woodpecker presence than sites at lower altitudes. About 20 of the studied 94 sites were located above the highest coastline. Many of the sites have previously been inhabited in the 1990's, but rarely during the latter part of the study period. Due to poorer soils at the higher altitudes, both farming and forest activities have been less intensive than land at lower altitudes. As a result, important natural forest structures such as dying deciduous trees have been left to a greater extent above the historical highest coastline (e.g. Angelstam et al. 2004a). The territories located above the highest coastline have generally a relatively open structure and characterized by a large abundance of Scots pine and (often old) aspen trees. The aspen-rich stands at higher altitudes are among the last remnants of deciduous rich forests with a history of both natural and anthropogenic forest fires in the boreal forests in Sweden (Östlund et al. 1997, Hellberg 2004). Therefore the saproxylic insect faunae is especially rich, both regarding species and abundance (Martikainen et al. 2000), and hence provide good food supply for the white-backed woodpecker. Unfortunately the species do not inhabit these sites today. Recent forestry activities, habitat fragmentation and the rapid decline in the white-backed woodpecker population are thought to be the cause of this. Loss of disturbances (fires) and proper management of protected high altitude oldgrowth forest turn these sites into mixed spruce stands, which do not favour the white-backed woodpecker. Recent studies in Finland (Timo Laine pers. comm.) suggest that too large proportions of living spruce in deciduous and mixed stands may have negative effects on the saproxylic insect fauna, which constitutes the bulk of the woodpecker's diet.

Other proxy variables that were tested were steep slopes and areas far from roads, which both are difficult to access for forestry operations and therefore usually are expected to create higher amounts of deciduous trees and dead wood (Angelstam et al. 2004b). Contrary to the expectations, these variables did not contribute to the presence of woodpeckers. Possible reasons may be that these areas are too small and isolated from other suitable habitats to be utilizable by the woodpecker, or that forestry has been intensive even there due to a very dense forest road network. Also large steep areas are uncommon in the region, compared for instance with western Norway where steep slopes make forest nearly inaccessible to management.

One variable, the area of older forest, was not retained in the best models. This is in contradiction with many other European studies. In a viable population in Western Norway the woodpeckers preferred deciduous rich forest older than 80 years and avoided forest 20-50 years old (Hogstad & Stenberg 1994). In Finland the species is highly dependent on old-growth forest (Lehikoinen et al. 2011). The present result support the idea that a large proportion of the suitable habitat for the white-backed woodpecker may be found also in younger forest if management intensity has been low and trees are allowed to die through self-thinning, which may occur already in the pole stage of unmanaged deciduous forest succession (Löhmus & Löhmus 2005). Especially in younger, self-thinning stands of aspen, the large poplar longhorn beetle (*Saperda carcharias*), one of the species most important foraging specimens, can be abundant (Nuorteva et al. 1981. Figure 6).

Another variable, the total area of forest land, generally had a negative effect on the occurrence of woodpeckers. This could possibly be explained by low amounts of edge habitats and windthrow in areas with high forest cover. This in turn indicates lower sun-exposure which probably affects the insect faunae. Some of the most important food supply organisms, longhorn beetle larvae (*Cerambycidae*), favour sun-exposed trunks (Lindhe et al. 2005, Ehnström & Holmer 2007, Horak 2014).



Figure 6. Larvae of large poplar longhorn beetle (*Saperda carcharias*). Photo Timo Laine.

The study strengthens our knowledge about the possibility to search for suitable habitats for the white-backed woodpecker from above, combined with both traditional and some proxy variables. It also indicates areas of future research. The models could be improved if they included direct measurements of presence of important resources for the birds, such as dead wood. The abundance of saproxylic beetle larvae used as food by the woodpecker is also of crucial importance.

## Paper II

According to Carlson (2000) a landscape must contain between 9-17 % of suitable habitat in order to support a viable population. There is evidence suggesting that the birds' nutritional condition is affected by territory quality measured as amount of dead and deciduous wood (Carlson 1998). Old-growth deciduous forests with abundant dead wood represent a key habitat for the species (e.g. Aulén 1988, Angelstam & Mikusiński 1994, Gjerde et al. 2005). Today, the amount of suitable habitats for the species

in the landscape is below the expected threshold for persistence in both Sweden and Finland. However, contrary to what could be expected, the Finnish population of white-backed woodpecker is increasing (Lehikoinen et al. 2011).

In the present study the habitat composition and degree of fragmentation in territories in Sweden, Finland and Latvia were compared. It was observed that most territories had a high degree of variance in territory fragmentation, tree species distribution, number and volume of trees. The occurrence of white-backed woodpecker was positively correlated to both low numbers and large sizes of subareas. Many former Swedish breeding territories were too fragmented and the total area of subareas too small. According to Carlson & Aulén (1992) patches of suitable forests were closer in the high-density area than in the low-density area.

The numbers of trees (both living and dead) were higher in Sweden and Finland, compared to Latvia. Volume dead wood, and especially downed dead wood, was most abundant in Latvia and aspen counted for the highest volume of any dead tree species, indicating that Latvian territories comprises of large amounts of large, dead aspen trees. According to several studies aspen is one of the most preferred trees (Stenberg & Hogstad 2004). Dead, downed wood is of great importance for many saproxylic insects (Lindhe et al. 2005), and thus a great contribution to the Latvian territories. However downed dead wood is inaccessible in winter, and therefore, at least in snowy winters, will not contribute to the food supply (Lõmus et al. 2010).

In breeding areas of a Norwegian viable population of white-backed woodpeckers the average abundance of dead trees > 5 cm in breast height diameter were 154 trees/ha (Hogstad and Stenberg 1994). Nearly the same estimation, 150 snags/ha, was made in Estonian breeding territories (Lõmus et al. 2010). Roberge et al. (2008a) found that the average basal area of deciduous snags should exceed 1.4 m<sup>2</sup>/ha over an area of 100 ha for a high occurrence probability of the species, which correspond approximately to 8–17 m<sup>3</sup> deciduous snags/ha. This is in accordance with the present study. This is a higher abundance than the mean volumes observed in managed forests. In hemiboreal Sweden, for example, Fridman & Walheim (2000) estimated that the mean snag volume was 1.5 m<sup>3</sup>/ha on managed forest land, only a fraction of which represented deciduous species.

The results showed no significant differences between the Swedish and the Finnish territories in terms of amount of different tree species, spruce mixture or amount of dead wood. But analysis of the fragmentation of the foraging patches in the territories showed that the Swedish territories were more fragmented. Fragmentation of a continuous habitat is considered a major threat to the survival of species (e.g. Wilcox & Murphy 1985, Fahrig 2002, Reed 2006, Rybicki & Hanski 2013). Fragmentation of these habitats is usually caused by forestry activities resulting in reduced patch size because of increasing areas of coniferous stands, especially spruce. Without disturbances or maintenance measures, most deciduous forests in northern Europe would gradually become spruce-dominated and therefore less suitable habitats for the white-backed woodpecker. The amount of spruce trees in mixed forest stands (Timo Laine pers. comm. and own observations) causes fragmentation both on a landscape scale as well as in territories.

Increasing proportions of spruce in the stands both affect the conditions negatively for sun-favoured insects (woodpecker food) and increases the risk for predation, especially by Eurasian sparrow hawks (*Accipiter nisus*) (Timo Laine pers. comm.). This will also be the case if the foraging patches of deciduous rich stands, as in Sweden, become reduced in size and surrounded by even-aged spruce stands. Even if the patches of suitable habitat are expected to be sufficient in terms of area, surrounding dense spruce stands may have a negative impact on the sun-exposure of the deciduous tree stands resulting in declining food supply and lead to isolation (Villard et al. 1999).

The result of this study indicates that the amount of dead deciduous wood in a breeding territory for white-backed woodpeckers is a critical feature. This is in accordance with results from Roberge (2008a) and Czeszczewik & Walankiewicz (2006). In outstanding territories in Latvia, the average amount of dead deciduous wood exceeded 25 m<sup>3</sup>/ha. Fragmentation of territories seems to be important in explaining the difference between the Swedish and Finnish situation of today.

One important aspect of the different population situations and territory occupancy in the three regions is the degree of immigration. Both Latvia and Finland have continuous populations to the east. On the contrary, the Swedish populations today are isolated and lack contact with neighbour-

ing populations (Spiridinov & Virkkala 1997). Therefore restocking with captive bred birds has been tested in Sweden (Paper IV). The findings of Lehtikoinen et al. (2011) showed the crucial impact of immigration on the population development. But, despite a weak positive trend in migrations in Finland, there was a strong additional positive trend in occupancy that was independent from the effect of immigration. Conservation efforts such as restoration of habitats, increased proportion of deciduous forest in the landscape, winter feeding and global warming are suggested as explanation for this (Väisänen 2008, Lehtikoinen et al. 2011).

### **Paper III**

In boreal and hemiboreal environments winter food base is critical for woodpeckers, especially for the specialist species that use dead and decaying trees most (Pettersson 1983, Aulén 1988). During cold winters, with deep snow cover, standing dead wood is of crucial importance for woodpeckers (Virkkala et al. 1993, Hogstad & Stenberg 1994). The Swedish Society for Nature Conservation aims to increase the amount of dead wood in white-backed woodpecker territories by cutting aspens and birches by using explosives. The aim was to create snags, which should contribute to the development of wood dwelling insects (Palm 1959), i.e. food supply for the woodpeckers. The man-made snags were compared to natural ones in the same locations.

Of 169 samples of bark from snags studied, 116 species of saproxylic beetles were found. 1026 individuals (79 species) were found in the “forest” site and 2412 individuals (96 species) in the “abandoned agriculture” site. Many species were more associated with man-made stumps than with natural stumps. However, estimated by rarefaction, in total, more species were found in the natural than in the man-made stumps for both birch and aspen. Considering the different levels of decay, the oldest stage seemed to be the most species rich. The total species numbers were similar for exposure and diameter categories. The total number of saproxylic beetle species in the “forest” site on aspen were 56 and on birch 55. In the “abandoned agriculture” site, 62 sieve samples were collected on aspen and 49 were collected on birch snags. The total number of saproxylic beetle species in that site on aspen were 70 and on birch 65.

Of 28 species occurring in more than 10 stumps, thirteen species showed a significant association with man-made stumps. Tree species was the variable that affected the most species, and aspen trees hosted most species. Among the other variables, more than half of the species were affected by sun-exposure and most of these were more common on shaded stumps. Decay stage affected a smaller proportion of the species (43 %) and diameter affected the smallest number of species. The natural snags were more species rich. Man-made snags can be expected to be more homogeneous than natural stumps. They are usually created in the same way and at the same time unlike the natural snags. The homogeneity in age and wood decay structure is most likely the explanation to this.

Several known beetle larvae-species usually preferred by the white-backed woodpecker, such as the large poplar longhorn beetle (*Saperda carcharias*) (Nuorteva et al. 1981) and other longhorn beetles (*Cerambycidae*) were nearly absent. The cause of this is probably that several beetle larvae are feeding on the fungi mycelium that grows in weakened and dying trees, which might be lacking in the man-made snags. The association of several species with man-made stumps is a strong indication of their value for insects and therefore for the white-backed woodpecker.

According to former studies of the preferred food choice (Aulén 1988) and nestlings diet (Hogstad & Stenberg 1997) most insects and insect larvae chosen were rather large-sized. The smallest sized food choices known were larvae from bark beetles (*Scolytidae*) and wood boring beetles (*Anobiidae*). With few exceptions those larvae are larger than 5 mm in length. Distinguish species whose larvae  $\geq 5$  mm, we found that 23 % of the species collected can be considered to be woodpecker food. Looking at the number of beetle larvae collected about 5 % of the insects in the man-made snags and about 10 % of the insects in the natural occurring snags could be considered to be woodpecker food (Figure 7).

Comparison of different types of natural- and man-made snags showed that most of the cut snags were made in even aged forest stands, resulting in similarly coarse trees and snags. Other studies have shown that tree size

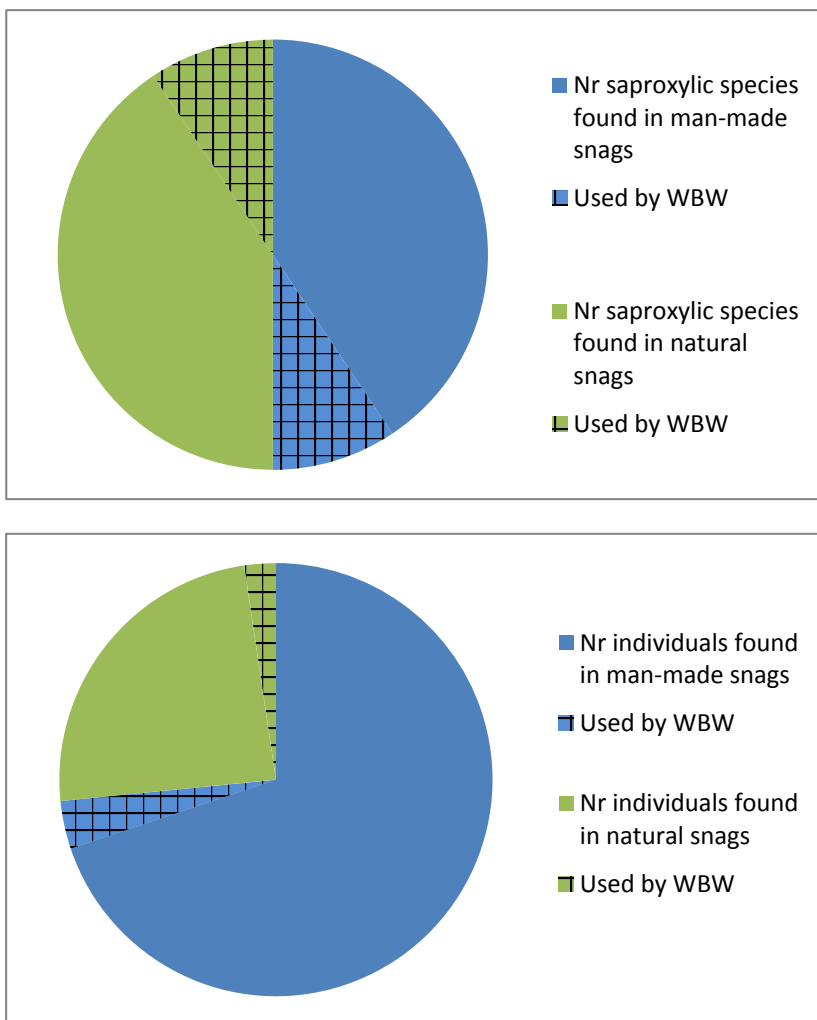


Figure 7. Relationship between number of species in man-made vs naturally occurring deciduous snags and the amount of species used as food by white-backed woodpeckers (upper). And (lower) the relationship between beetle individuals in man-made vs naturally occurring deciduous snags and the calculated number used as food by white-backed woodpeckers.

has effects on the abundance of insects. Löhmus et al. (2010) found that the density of insects (at least beetles) per surface area was higher in larger-diameter trees. Males used larger trees for foraging, especially during winter (Aulén & Lundberg 1991). The actual responses of insects to snag size may thus be highly species-specific (Lindhe et al. 2005). As suggested in paper I, suitable habitats for the woodpecker may be found in younger forest if management intensity has been low and trees are allowed to die through self-thinning. Younger self-thinning stands of deciduous trees may inhabit large quantities of important food supply for the white-backed woodpecker, e.g. the large poplar longhorn beetle (*Saperda carcharias*) on aspens, but also on thin alders (Saari & Nuorteva 1996).

## Paper IV

Captive breeding and restocking have been used in several countries in attempts of rescuing specifically endangered species, like the Bali starling (*Leucopsar rothschildi*) (van Balen & Gepak 1994), the black stilt (*Himantopus novaezelandiae*) (van Heezik 2005) and the Californian condor (*Gymnogyps californianus*) (Snyder & Snyder 1989). In Sweden similar projects have involved the Eurasian eagle owl (*Bubo bubo*), the peregrine falcon (*Falco peregrinus*) and the white stork (*Ciconia ciconia*) (e.g. Lindberg & Sjöberg 2009). In paper IV the captive breeding and restocking of white-backed woodpecker in Sweden were studied. The origin of birds, attempts with different breeding aviary types, feeding, partner composition, breeding success and restocking were analysed.

In the present study it was observed that successful captive breeding of the white-backed woodpecker was dependent on the size and the placing of the aviaries. A breeding facility with ten cages placed in a row next to each other has so far not resulted in any breeding woodpeckers. Behavioural studies were conducted, in order to identify patterns of behaviour associated with breeding conditions and disturbance in captivity. Several birds showed signs of stress in the smaller aviaries and in close contact with other pairs. A significant difference in stereotypic behaviour between birds in smaller (volume 60 m<sup>3</sup>) versus larger aviaries (volume 390-405 m<sup>3</sup>) was also observed. These behavioural patterns are well-known among mammals and birds kept in captivity and most commonly in spatially restricting cages with artificial habitats. Stereotypic behaviours are often a

sign of poor welfare and might inhibit normal reproduction (Asher et al. 2009). In contrast, large free-standing aviaries offers free view in all directions and no neighbouring disturbance.

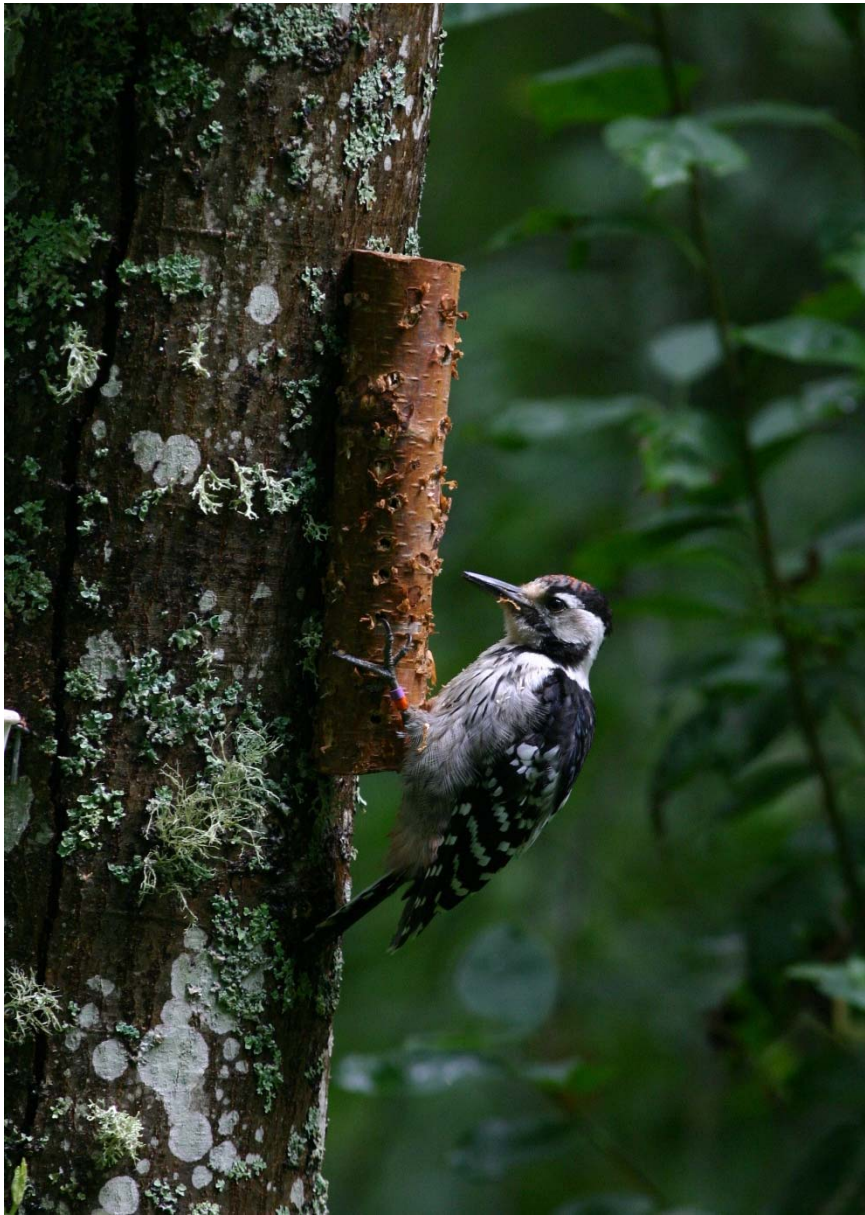
Large free-standing aviaries (volumes 400 m<sup>3</sup>) situated between 100-300 m (mean 113 m) apart have until 2015 resulted in 43 successful breedings in captivity and 88 fledglings. Mean brood size was 2.35, mean annual production of fledged young was 2.05/female and the sex ratio was even. The median age at first successful breeding was 4 years (3 to 7 years), where males started to breed later (Median age 6 years) than females (Median age 4 years). The largest brood (5 young) resulted in 5 young fledglings. The result clearly shows that distractions of neighbouring birds, together with aviary size, are of crucial importance for captive breeding of the species.

So far the survival rates of the captive woodpeckers have been slightly higher than originally calculated. Juvenile survival was 0.54 (calculated 0.35) and adult survival 0.95 (calculated 0.93). Also production of fledglings per captive breeding pair corresponds well compared to wild woodpeckers (Hogstad & Stenberg 1997). However, the process of establishing a captive breeding population has developed considerably slower than expected. Birds have started to breed later than calculated, due to lack of a sufficient number of large free-standing aviaries.

Restocking programmes can be used when a wild population is otherwise beyond recovery. Important assessments for restocking are the bird's ecology, current threats, suitability of available stock and habitat as well as socioeconomic implications (Black 1991). Those factors were considered to be achieved in some regions in mid Sweden and the trials of restocking took place in prepared habitats, expected to be suitable. A total of 129 (both captive bred and wild collected) white-backed woodpeckers have been released by hacking (i.e. release of fledged birds from an aviary). So far seven territorial pairs have been found of the released birds and their offspring. All these pairs have been breeding at least one time and four pairs have bred successfully. Another 47 birds were released by cross-fostering into nests of greater spotted woodpecker (*Dendrocopos major*). None of those birds has been contributed to any wild breeding pair.

A total of 15 % (19 out of 129) of the released woodpeckers have survived into their second calendar year. This corresponds well with a wild population in west Norway (Stenberg 1998). Estimation of breeding success so far are based on nine (7 %) individuals that are known to have bred on 15 occasions, producing 23 fledglings in total, with a mean breeding success of 1.5 produced young/pair and year.

Some complications observed during the restocking of the woodpeckers were predation, mostly by sparrowhawks, interference with wild woodpeckers and availability of food. The latter was improved by supplemental feeding using food cups and hollow wooden cylinders with living insect larvae (Figure 8). According to expectations, the large amount of food in combination with suitable habitat (removal of spruce which reduced the predation of hawks), size of release aviaries and reduced disturbance was important features of successful restocking.



*Figure 8. Usage of hollow wooden cylinders prepared with living insect larvae placed on trunks were used during release periods of woodpeckers. Photo Dan Mangsbo.*

## CONCLUSION

The main findings of this thesis are summarized as follows:

A combination of traditional forest data and certain proxy variables can be used to find suitable habitats for white-backed woodpeckers. Important proxy variables include permanent edge habitats, deciduous wetland forest and to some extent sites located above the highest coastline had a higher probability of presence of the woodpecker than sites at lower altitudes.

Territories important for the white-backed woodpecker should be heterogeneous and highly sun-exposed which results in large amounts of food (insects and insect larvae).

The occurrence of white-backed woodpecker was positively correlated to both low numbers and large sizes of subareas. Many former Swedish breeding territories were too fragmented. A combination of different variables of dead wood and the total volume of all deciduous trees contributed to explaining the presence of white-backed woodpeckers and occurrence of breeding pairs.

Restoration of breeding habitats for white-backed woodpeckers should concentrate on reduction of spruce and increasing the amount of dead deciduous wood. Especially stands with high amounts of grey alder should be prioritized for protection as those habitats generate large quantities of dead wood in a relatively short period of time.

Many beetle-species were more associated with man-made snags, but in total, more species were found in the natural snags. Man-made snags, as a complement to natural snags, can contribute to several saproxylic insect species and therefore also for the white-backed woodpecker. The man-made snags were more homogeneous than natural snags. If possible aspen trees should have priority before birch trees, when choosing tree species for producing snags. Another finding was that man-made aspen snags turned out to live much longer than expected. Therefore the colonization of saproxylic beetles took longer time.

Captive breeding of white-backed woodpecker is possible and depend on both size and placing of aviaries. Large, free-standing aviaries resulted in successful breedings. The results support the hypothesis that large single aviaries stimulate captive pairs to breed. Pairs in large aviaries showed significantly less stereotypic behaviour, than pairs in smaller cages placed close to each other. Although several of the pairs in smaller cages have attempted breeding, none has been successful.

Survival rate into the second calendar year of the birds released by hacking is equal to the wild population in west Norway. Important features are the quality of the release areas, size of the release aviary and the extent of supplemental feeding.

## FUTURE PERSPECTIVES

A (even though many years ahead) future possible self-maintaining Swedish population of white-backed woodpecker would, as stated also for the Finnish population (Virkkala et al. 1993, Lehtikoinen et al. 2011), require development of a conservation-area network of suitable habitats in the landscape. Likewise a survival analysis, including both young and adult birds, would be useful to thoroughly assess the ability of the current critically endangered Swedish restocked population.

In order to achieve good enough year-around territories, complementary studies on both the movement patterns of the birds as well as landscape content are desirable. According to Carlson (2000) a landscape must contain between 9-17 % of suitable habitat, i.e. mature deciduous forest, in order to support a viable population of white-backed woodpecker. The accuracy of the parameter value in the same study was not satisfactory, given a quite wide interval. The model used (Lande 1987, Lande 1988) for prediction requires parameters for proportion of a larger region composed of suitable territories; fractions of suitable territories that is occupied by adult females; the demographic potential of population. Given this predictions, neither Sweden nor Finland should have any woodpeckers today. More tests using new knowledge about the species habitat and foraging requirements should be done. This should include studies concerning amount of presently suitable habitat in a landscape; amount of future suitable habitat in a landscape; feeding range of breeding and non-breeding birds; amount of protected and properly managed habitats for the species today and in the next 50 years; dispersal ecology of the species in a scattered and homogenous forestry affected landscape; the extent of moose and deer grazing of deciduous plants in upcoming forest.

Recent studies in Finland (Timo Laine pers. comm. and own observations) suggest that too large proportions of living spruce in deciduous and mixed stands may have negative effects on the saproxylic insect fauna, which constitutes the bulk of the woodpecker's diet. It seems that the lower proportion of spruce, the more likelihood of colonisation of the species from neighbouring areas. At least in the species northernmost part of its European distribution of today, this might be a crucial knowledge to be explored.

Knowing the woodpeckers “food base” of saproxylic insect larvae (e.g. Aulén 1988), the expected amount of food supply (insect larvae) per volume and type of wood/snag should be studied. A comparison of food supply in different types of stands (e.g. deciduous mixed; aspen; birch; grey alder), sun-exposure, tree diameter, height of snags and substrate heterogeneous, could most certainly contribute to the ecology and future survival of the species.

In the absence of large scale disturbances, especially forest fires, as the main agent supporting a dynamic network of deciduous succession in boreal and hemiboreal landscapes, active management are employed to mimic the effects of fire (e.g. Fries et al. 1997). An urgent study would be to find methods of mimicking disturbances in protected areas which stress the presumption of increased food supply (insects).

Scherzinger (1990) meant that competition by the great spotted woodpecker could be the cause for white-backed woodpeckers’ rarity in Bavarian Forest national Park in Germany. Therefore interactions between white-backed woodpeckers and great spotted woodpeckers, especially in breeding sites and location used for restocking, should be studied.

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