Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Forest Science

Effects of tree retention on cavity-nesting birds in northern Sweden

Naturhänsyn på hyggen: effekter på hålhäckande fåglar i norra Sverige

Eva Domingo Gómez

Examensarbete i ämnet biologi
Department of Wildlife, Fish, and Environmental studies
Umeå
2014

Effects of tree retention on cavity-nesting birds in northern Sweden

Naturhänsyn på hyggen: effekter på hålhäckande fåglar i norra Sverige

Eva Domingo Gómez

Supervisor: Jean-Michel Roberge, Dept. of Wildlife, Fish, and Environmental Studies

Assistant Supervisor: Jon Andersson, Dept. of Wildlife, Fish, and Environmental Studies

Examiner: Lars Edenius, Dept. of Wildlife, Fish, and Environmental Studies

Credits: 60 HEC
Level: A2E
Course title: Master degree thesis in Biology at the Department of Wildlife, Fish, and Environmental Studies
Course code: EX0595
Programme/education: Management of Fish and Wildlife Populations

Place of publication: Umeå
Year of publication: 2014
Cover picture: Olalla Díaz-Yañez
Title of series, no: Examensarbete i ämnet biologi
Number of part of series: 2014:5
Online publication: http://stud.epsilon.slu.se

Keywords: clear-cuts, tree retention, cavities, biodiversity, primary excavators

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Forest Science
Department of Wildlife, Fish, and Environmental Studies

Abstract

Tree cavities are of high ecological value because they influence the abundance, diversity, and conservation of many terrestrial animals in forests worldwide. However, due to forest management practices, cavity-users are under a serious threat in many forest ecosystems. With the intention of reducing the impacts of timber harvest, since the mid-1990's variable amounts of green and dead trees are retained at the clear-cuts in Fennoscandia as a conservation measure supposed to improve conditions for biodiversity. I studied the availability and use of natural tree cavities in retention. It was conducted on a random selection of 100 clear-cuts up to 5 years old within a 20 km radius in the vicinity of Umeå, northern Sweden. A survey of those clear-cuts was performed to study tree retention and to investigate the availability and the potential use of cavities by cavity nesting birds on clear-cuts in boreal Sweden. All cavities and nests found were monitored during two months to study cavity-use. Previous studies have found that the majority of all tree cavities in Europe are natural decay cavities. In my study I found 133 cavity trees that held 241 cavities. Ninety-eight percent of the cavities found were excavated and just 2% were natural cavities produced by decay. This novel finding suggests that also in European boreal forest the majority of cavities available for secondary cavity nesters are excavated by woodpeckers. Cavity trees were 1.5-2% of the retention trees; Living broadleaved trees, especially aspen, were preferred by birds for breeding. A significantly larger proportion of the excavated entrance holes were facing a direction from east to south, possibly to maximize the heat from the sun during cold mornings. Estimated cavity tree density ranged from 0.21-0.31 cavity trees ha^{-1} and cavity density was 0.41 cavities ha^{-1}. All breedings found were in solitary retention trees showing that successful breedings can take place on clear-cuts in boreal forests. However, in order to compare cavity densities, their origin and their use by cavity nesting species, a similar study should be performed in old forest. I suggest the conduction of a survey simultaneously in forests and on clear-cuts to provide a basis for comparison between these two different environments.

Introduction

Boreal forests represent 26% of the world's total forested area (Imbeau et al. 2001). In these forest landscapes diversity of natural biotopes is determined on the one hand by differences in soil types, topography, access to nutrients and water and on the other hand by natural disturbances (Hunter and Schmiegelow 2011). Before the XIX century, boreal forest in Scandinavia was very different from the present forest; in former times the dominating disturbance agent was fire (Zackrisson 1977) but also diverse human influences such as subsistence forest utilization and grazing. All these factors have been replaced by modern forestry where the forest has been transformed into production units. This fact has caused changes in the structure, flora and fauna and increasing fragmentation of the landscape by subdividing larger forest tracts (Edenius and Elmberg 1996; Ericsson et al. 2000). Boreal forest is exposed to an increasing demand from commercial logging. (Imbeau et al. 2001).

In the 1950s Swedish forestry changed from selective cutting to clear-cutting (Lundmark et al. 2013). Clear-cutting consists in the removal of nearly all trees, regardless of size and species, from a limited area (Kuuluvainen et al. 2012). The clear-cut area is usually left bared for a short period and then regenerated through planting, sowing or through natural regeneration (Lundmark et al. 2013). Large-scale clear-cutting changes age composition in forest landscapes by reducing the area of old growth forest stands and increasing the area of young successional stages (Edenius and Elmberg 1996). Species belonging to a wide range of taxonomic groups have been negatively affected by forestry. Among others, bird populations have been affected by these changes (Edenius and Elmberg 1996; Carlson et al. 1998; Edworthy and Martin 2013). Not surprisingly, resident species depending on old successional stages have declined while migrant species preferring younger forests or even clear-cuts have shown a corresponding increase (Angelstam and Mikusinski 1994).

In Sweden, there is wide agreement among ecologists that forest management should mimic the natural disturbance regimes (Angelstam 1998). However, even if large clear-cuts sometimes mimic the character of severe burns, burnt areas have greater diversity compared to traditional clear-cuts (Hunter and Schmiegelow 2011). For this reason, a fundamental tool to preserve biodiversity on clear-cuts is to leave trees of importance to the flora and fauna after harvesting operations, i.e. tree retention. By leaving single trees, tree groups, buffer zones bordering lakes, watercourses and mires, and also by saving and creating dead wood, forestry aims to reduce the adverse effects of clear-cutting (Gustafsson et al. 2010). The ultimate goals of tree retention are to maintain local populations of some tree-dependent species *in situ* during the regeneration and young forest stages, to preserve structural complexity, to enhance connectivity among residual patches of forests, and, at the same time to continue the commercial harvesting of timber in an economically sustainable way (Carlson et al. 1998; Lindenmayer et al. 2006). Even though retention trees cannot maintain characteristics of intact mature forest, they may provide substrate for early-successional species and alleviate the most serious consequences of clear-cutting (Gustafsson et al. 2010; Kruys et al. 2013). Both national legislation and forest certification standards set requirements for tree retention at harvesting (Table 1).

Table 1 - Legislation and certification regulations in Sweden (Gustafsson et al. 2010).

Legislation (Swedish Forest Act)
Trees with special value for biodiversity conservation must be left standing on felling sites, preferably in groups. Protective buffer zones must be left adjacent to water, etc. No logging on non-productive forest land. Avoid damaging sensitive habitats and sites with rich flora and fauna (*Swedish forest act. 2009*)
Certification − FSC (Forest Stewardship Council)
10 million ha certified (45% of productive forest land). Retain all snags, wind throws and other trees that have been dead for more than a year plus all such dead wood originating from high biodiversity trees that have been dead for less than a year. Retain retention trees in a way that they will amount to at least 10 old, large, live trees in the next forest generation; prioritize high biodiversity value trees (cavity-bearing trees). Create at least 3 high stumps or girdled trees per hectare. Retain care-demanding patches, edge zones, groups of trees and biodiversity value trees (*FSC Principles and criteria for forest stewardship. 2002*)
Certification − PEFC (Programme for Endorsement of Forest Certification)
8 million ha certified (37% of productive forestland). Should be set aside: live conservation trees (deviating, old, large-diameter, deciduous trees, hollow trees, cavity bearing trees, etc.) in a way that they amount to 10 retention trees per hectare, some created high stumps per hectare, some representative logs per hectare, retention patches, and protective zones to sensitive habitats. (*PEFC International standard. 2012*)

One important feature which is prioritized in modern forestry − both according to legislation and certification standards − is cavity-bearing trees. Cavities in trees are key ecological resources created by primary cavity-nesters –normally woodpeckers (*Picidae*) but occasionally other types of birds– and reused by a range of secondary cavity-users (utilizing excavated or natural cavities in trees) for breeding and roosting (Carlson et al. 1998; Martin and Eadie 1999; Cockle et al. 2011; Remm and Lohmus 2011). Cavities in trees can also be caused by other factors such as years of fungal decay and insect activity, as well as from mechanical damage by fire and wind (Cockle et al. 2011). However, tree cavities are at risk in intensively managed forest landscapes because of their slow regeneration time and the high risk of being removed during logging (Lindenmayer et al. 2006; Edworthy and Martin 2013). Harvesting operations can be problematic since some cavity-nesting birds appear to be limited by nest cavity availability (Newton 1994). Therefore, sufficient abundance of cavity-bearing trees is critical for maintaining wildlife communities in harvested forests (Edworthy and Martin 2013).

In boreal ecosystems cavity density is determined by rates of excavation and cavity persistence; it varies between regions due to biogeographical differences in excavator species' abundance, richness, behavior or in tree species' traits (Cockle et al. 2011). In the Swedish boreal forest, the dominating tree species in late successional stages are conifers. Scots pine (*Pinus sylvestris*) and norway spruce (*Picea abies*) constitute 98 to 100% of the conifers (Angelstam and Mikusinski 1994). In this cool climate, where decay processes are slower, primary cavity-nesters appear to be more important for the production of cavities and hence the availability of cavities for secondary cavity-nesters which require but cannot create cavities (Remm and Lohmus 2011). For the same reason, woodpeckers are considered as keystone species in boreal ecosystems (Angelstam and Mikusinski 1994; Blanc and Martin 2012) and so they are top priority for the conservation of cavity-using communities since they control the cavity supply (Martin et al. 2004; Cockle et al. 2011). There are some species called 'weak cavity excavators' such as nuthatches or tits that, in addition to using either old natural and excavated cavities, can excavate their own cavities in highly decayed trees. However, secondary cavity users do not excavate cavities and rely on existing cavities at their breeding sites (Martin and Eadie 1999; Ouellet-Lapointe et al. 2012). For instance, Tengmalm´s Owl (*Aegolius funereus*) use holes excavated by Black Woodpecker's

(*Dryocopus martius*) for nesting (Svensson et al. 2009). Among woodpecker species, the Black Woodpecker and the Great Spotted Woodpecker (*Dendrocopos major*) are more generalist species and so less sensitive to structural changes in the forest than other woodpecker species.

The aim of this study was to investigate the availability and the use of cavities by cavity nesting birds on clear-cuts in boreal Sweden. I also studied the origin of the cavities, characteristics and properties in relation to nest site selection by the primary cavity nesters.

Materials and methods

Study area

The study area was defined within a radius of 20 km around Umeå, in the county of Västerbotten, north-eastern Sweden (63°50′ N 20°15′ E) (Figure 1). The forest in this area is mainly dominated by Scots pine and Norway spruce, but broad leave species such as birch (*Betula pendula*, *Betula pubescens*) and European aspen (*Populus tremula*) are also present.

Figure 1 - Location of Västerbotten county (green) and Umeå (red dot) in Sweden, (SverigesNationalatlas 1999).

Selection of clear-cuts

In a circular buffer of 20 km radius one hundred 1-5 yr old clear-cuts were randomly selected. The clear-cuts were harvested between 2007-2011 with no limitation regarding size and ownership and they were randomly selected from a set of 734 clear-cuts that met the conditions established for the study (Figure 2). Forest harvesting data for the study was obtained from the Swedish Forest Agency (2012) and then exported to GIS for the study selection. Clear-cuts selected for the study were between 1-5 years old (i.e. harvested in the period 2007-2011) with no limitations regarding size. To minimize spatial dependence between the different clear-cuts (e.g. risk for the territory of one breeding bird pair to encompass two of the clear-cuts), the minimum distance between clear-cuts was 1 km from edge to edge. For example, when a clear-cut was selected, the surrounding clear-cuts were deleted within a circle of 1 km radius to ensure that they were not selected later on during the clear-cut selection procedure. Polygons that did not match to the real image seen on the aerial photo (2013) nor with the notes taken on the maps during the fieldwork, was modified in ArcGIS. Clear-cuts composed of two or more parts separated by a forest strip were defined as one clear-cut even though they were not in direct contact with each other. Clear-cuts with seed trees and shelter wood cuttings (here defined as stands with >50 large pines per hectare left evenly over the whole clear-cut) were excluded because seed trees and shelter wood are not usually retained in the long term.

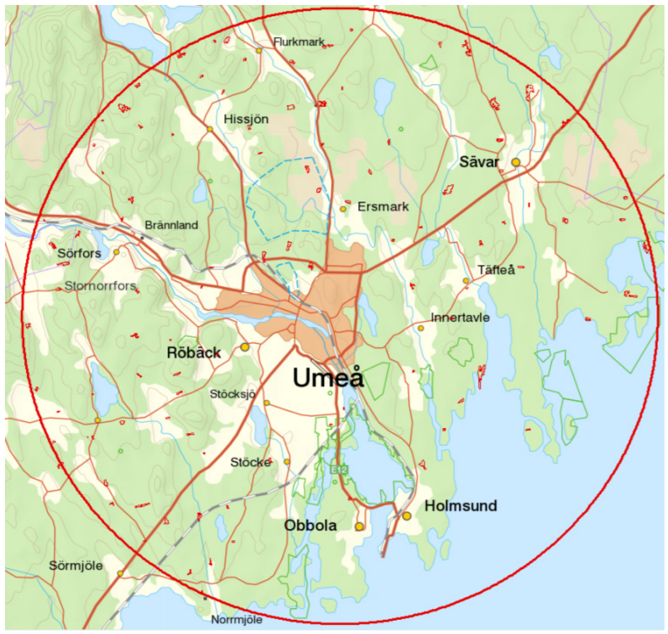


Figure 2 - The study area inside the red circle and the 100 randomly selected clear-cuts marked in red

Data collection

Retention tree survey

By walking along the clear-cuts with binoculars I scrutinized all retention trees. (See field sheet on Appendix 1). The survey trees included both the solitary retention trees and tree patches. Solitary trees were defined as trees left alone or in groups of ≤ 3 trees, with diameter at breast high (DBH) ≥ 10 cm and height ≥ 1.3 m. All trees were counted and classified into living, dead and high stumps. Different tree species were registered separately: scots pine, norway spruce, birch, aspen, rowan (*Sorbus aucuparia*), goat willow (*Salix caprea*), grey alder (*Alnus incana*) and others.

Retention patches were detected and surveyed in the field and were defined as ≥ 4 trees either dead or alive, excluding cut high stumps, standing together within a maximum distance of 5 meters from stem to stem. Here again, only trees with diameter at breast high (DBH) ≥ 10 cm and height ≥ 1.3 m were included. Retention patches in contact with the edge of the clear-cut were excluded due to the difficulty to distinguish true retention trees left at the clear-cut edge from the neighboring forest. Retention patches larger than 0.5 ha were not included in the survey since they could be considered as being separate stands within the clear-cut. For each retention group all trees were counted within a 5.64 m radius plot in the middle of the patch and classified in the same way as the solitary trees. Every retention patch was given a code with two numbers: clear-cut number with three digits and retention group number with two digits (e.g. patch 3 in clear-cut 4 → 004-03). The area of the retention patches visible on the aerial photos was measured in ArcGIS. The area of smaller retention patches, not visible on the aerial photos, was measured in field.

Cavity tree survey

For surveying cavity trees, I scrutinized all retention trees, both solitary trees and trees located in retention groups, from all angles with binoculars, on the whole clear-cut. This survey was performed in early spring before the breeding season, at the same time as the retention tree survey.

All suspected cavity trees were marked with GPS coordinates (Figure 3) and classified with an ID (clear-cut number with three digits; cavity tree number with two digits). Number of cavities and the height to each cavity on each tree were also estimated during this survey and each cavity was preliminarily registered as: reachable from the ground, reachable with 3 m ladder, reachable with 6 m ladder, reachable with telescopic pole or unreachable with the available equipment.

Figure 3 - Cavity survey; GPS marking. Cavity found in a birch high stump (orange arrow highlights the cavity).

When breedings were over, I took measurements of every cavity tree (see field sheet 'cavity tree measurements', Appendix 1): tree species; number of usable cavities; whether the tree was dead or alive; tree status (i.e. full tree height/ naturally broken top/ cut high stump). I also measured tree DBH; full tree height; height to the living crown –vertical distance from the level of the base of the tree to the lowest live branch; shortest distance from the cavity tree to the edge of any forest area (tree patch >0.5 ha or forest edge); mean slope and mean slope aspect within 20 m from the tree.

Cavity survey

When circumstances allowed, I used a 6 meter ladder to check how many of the cavities surveyed were usable. I also used a measuring stick for checking the depth and width of the cavities. All cavities reachable with the equipment were classified as either *usable cavities*, *presumed usable cavities*, *unreachable cavities* or *false cavities*.

All cavities were named with an ID (clear-cut number, three digits; cavity tree number, two digits; cavity number, two digits). In cases with several cavities in the same tree, cavity ID numbers were given from the lowest to the highest cavity.

A 'usable cavity' was defined as a cavity that accomplished at least the following measurements: (1) horizontal cavity depth and lateral cavity width ≥ 6.0 cm; (2) entrance hole diameter ≥ 23 mm if circular, a width ≥ 18 mm if slit-like; (3) bottom-top dimension ≥ 10.0 cm; (4) closed bottom; (5) cavity bottom above ground level (e.g. cavities between roots were not counted); (6) no substantial amount of water in the cavity; (7) the cavity, at least partly, roofed, i.e. not an open "chimney".

The criteria 1-4 and 6-7 above were taken from Van Balen et al. (1982). However another criterion used in Van Balen's methods "entrance should not be so large so the nest is exposed" was not included in my survey because such cavities may be useful for some species. Criterion (5) was added to exclude cavities between roots.

The criteria for a 'usable cavity' could only be checked if the cavity was reachable from the ground or with a ladder. For cavities which were not reachable, but which could be reached with the horizontal stick mounted on the telescopic pole, it was only possible to determine if the cavity was a 'presumed usable cavity'. A 'presumed usable cavity' was defined as: (1) entrance hole with diameter ≥ 23 mm if circular, or width ≥ 18 mm if slit-like (measured by testing the size of the entrance using the stick added to the telescopic pole) (Figure 4); (2) the horizontal stick mounted on the top of the telescopic pole could penetrate ≥ 7 cm into the hole and should be moveable sideways in the hole when dragged out half way to ensure that the hole was not a cavity trial without internal chamber; (3) the cavity should be (at least partly) roofed, i.e. not an open "chimney".

Figure 4 - Here I am investigating a 'presumed usable cavity' on a dead spruce with the telescopic pole.

Cavities that did not fulfil the criteria for a usable or presumed usable cavity were classified as 'false cavities' and an 'f' (for "false") was added at the end of the cavity tree ID.

With the equipment available, I could reach cavities up to 7.0 m. There were also two nests in cavities that were higher than 7.0 m (i.e 7.2 and 12 m) however since they sheltered breedings were automatically classified as usable cavities. This resulted in the verification of 73% (279 pcs) out of the total number of cavities marked during the fieldwork (384 pcs). Cavities that could not by any means be reached and checked with the available equipment were defined as 'unchecked'.

After breedings were over, data on the usable cavities was collected (See field sheet 'cavity measurements' on Appendix 1). Measurements in the following list marked with '*' were only possible to take when the cavities were reachable with a ladder:

- *Vertical diameter of entrance hole* (Figure 5).
- *Horizontal diameter of entrance hole* (Figure 5).
- *Shape of the entrance hole*: round, oval or other.
- *Aspect of the entrance hole*: the direction of the entrance hole.
- *Excavating species*: excavating species (only if a bird was seen excavating).
- *Height of the cavity entrance above ground*: measured from the lower lip of the cavity to the base of the tree.
- *Bird-excavated or natural decay cavity*
- *Fresh/old cavity*: if the cavity was excavated this year (fresh) or it was excavated in a previous year (old) (only for bird-excavated cavities).

- *Vertical cavity depth**: measured from the lower lip of the hole to the bottom of the cavity (Figure 5).
- *Vertical cavity height**: measured from the lower lip of the hole to the top of the cavity (Figure 5).
- *Horizontal cavity depth**: length from the back of the cavity to the inside edge of the hole (Figure 5).
- *Lateral cavity width**: widest dimension of the inside of the cavity measured at right angle from horizontal cavity depth (Figure 5).
- *DCH* (tree diameter at cavity height)*: measured at the bottom of the cavity opening.

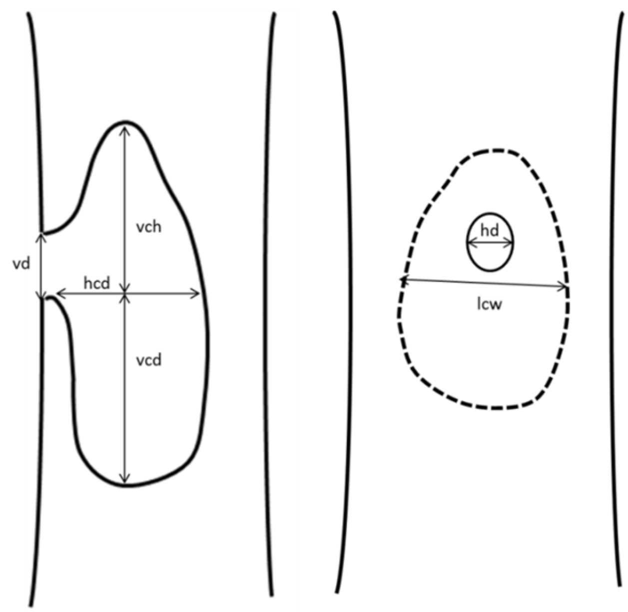


Figure 5 - Measurements taken of each cavity. vd: vertical diameter of the entrance hole; hd: horizontal diameter of the entrance hole; vcd: Vertical cavity depth; vch: Vertical cavity height; hcd: Horizontal cavity depth; lcw: Lateral cavity width.

Cavity monitoring

In order to find potential breedings, I monitored all usable, presumed usable and unreachable cavities. The monitoring period stretched from May 20^{th} until July 30^{th} 2013. All unoccupied cavities were visited once every 10 days starting May 20^{th}. When a cavity was found occupied, it was visited at least once every 5 days. After a breeding was over in a specific cavity, the monitoring interval went back to 10 days and lasted until July 30^{th} (see field sheets ´cavity monitoring' and 'breedings',Appendix 1).

To detect possible occupants, I scratched the bark of the tree while at the same time looking at the cavity entrance for birds looking through the hole. If a bird was observed at the entrance hole, but did not leave the cavity, I tried to identify the species and make a note to describe the behavior (see behavioral codes in Table 2).

Table 2 - Breeding indices and behaviors for cavity nesting species.

BREEDING INDICES AND BEHAVIOURS	CODE
Eggs seen inside nest	ES
Nestling(s) heard begging from the nest	NH
Nestling sitting with head in entrance hole and looking out	NE
Nestling(s) seen inside the nest cavity	NI
Nestling(s) fledged	NF
Adult sitting with head in entrance hole and looking out	AE
Adult sitting inside the nest cavity	AI
Adult flying into the cavity with nest material	AiM
Adult flying into the cavity (or to cavity entrance hole) with food	AiF
Adult flying into the cavity (but nothing seen in bill)	AiN
Adult flying out from the cavity with fecal sac	AoS
Adult flying out from the cavity (but nothing seen in bill)	AoN
Adult sitting within a few meters of the cavity and giving alert calls	AA
Adult feeding the young at the entrance hole but without entering the cavity	AfE
Adult excavating cavity	AEx

For cavities reachable with the camera on the telescopic pole and in cases when no activity was detected in the first step, I used the camera to search for laid eggs or birds inside the cavity (Figure 6).

All nestlings were approximately aged: *stage I*: newly hatched nestling (i.e. totally or almost naked, small size, closed eyes); *stage II*: nestlings with some feathers; *stage III*: nestlings with full (or nearly full) feather coat or nestling climbing to meet the parent at the entrance hole.

When the occupancy of a cavity had been confirmed during the previous visit or in the cases where nestlings were seen or heard, the camera was not used until the breeding was over. This was a precaution in order to avoid provoking the young to leave the nest prematurely and to avoid possible injuries to the birds. Therefore, to confirm breeding activity, I listened for begging young calling from the nest. I also looked with binoculars for young sitting in the entrance hole. If no young was detected, I stepped back 30 meters, sat down, and observed the cavity during 15 minutes waiting for adults to arrive to the nest. At the same time the breeding behavior was studied (Table 2).

When an active nest seemed to be inactive for the first time since the breeding started (i.e. no young were heard or seen at the entrance hole or no adults were seen flying to the nest), I looked into the hole with the camera to confirm fledging of the nestlings. I also noted indices of nest failure or mortality in case they were found (see field sheets 'cavity monitoring' and 'breedings', Appendix 1).

Figure 6 - Cavity survey; Monitoring of cavities with the camera in the field.

For the cavities that were not reachable with the camera and after scratching of the bark showed no activity, the cavity was observed during 5 minutes from a distance of 30 meters to detect any possible sign of activity.

Data analyses

I computed three different estimates of cavity densities. The first estimate (hereafter 'maximum estimate') included all checked usable and presumed usable cavities, as well as all unchecked cavities, assuming that all of the unchecked cavities were actually true usable cavities. As this estimate is most probably an overestimate I made a second estimate (hereafter 'minimum estimate') which included only the checked usable and presumed usable cavities, excluding all unchecked cavities. This is on the other hand most probably an underestimate. By using the data from the checked cavities higher than 5.0 m (230 pcs), both true and false, and calculating the proportion of true cavities, then applying these to the unchecked ones I computed a third estimate (hereafter 'best estimate'). For the third estimate, unreachable cavities were classified as *presumed usable cavities* for estimating the total number of cavities. I did not use the figures corresponding to cavities from 2 m and below because in this case it is possible to difference with the naked eye if the cavities are true or false and so it would have added an error to the estimation of the cavities. Within this range of cavities used for the calculations, 47% (108 pcs) turned out to be true cavities whereas a 53% (122 pcs) ended up being false.

I used R (R Development Core Team 2008) for conducting statistical analysis between retention trees and cavity trees and also between available cavities and breedings for studying the preferences of primary excavators. Fisher's exact test was used to analyze categorical data: tree species, tree status and shape of the entrance hole of the cavity. Wilcoxon test was used for the continuous data: DBH and distance to the edge. Finally, the Rayleigh test of uniformity was used to test potential differences of the orientation of the entrance that woodpeckers excavate for nesting.

For studying the relation between tree species and the selection of breeding trees, I only used the breedings of Great Spotted Woodpeckers (10 breedings) since they are the primary cavity nesters and therefore the ones actually selecting the trees for excavating the cavities. The relation between breeding birds and cavity trees, classified as living, dead or cut high stumps, were examined with Fisher test.

Results

Retention trees

I surveyed a total of 5610 trees looking for cavities. The density of solitary retention trees and trees in patches was approximately equal (Figure 7). However the distribution of retention trees among the tree status categories (live, dead or high stump) differed significantly between solitary trees and trees in retention patches ($P < 0.001$). Most of the trees in retention patches (93%) were alive. In contrast, only 44% of the solitary trees were living trees. Dead standing trees and high stumps represented 33 and 23% of the solitary trees respectively, but only constituted a minor proportion of the trees in retention patches.

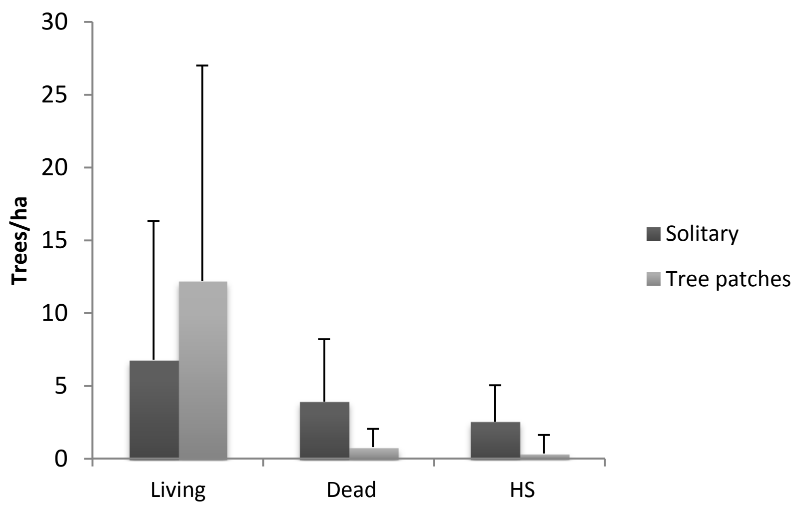


Figure 7 - Densities of solitary retention trees (dark grey) and of trees in retention patches (light grey) on the studied clear-cuts classified by tree status- living dead and cut high stumps. Error bars show 1SD from the mean.

Tree species assemblage differed significantly ($P < 0.001$) between solitary trees and trees in patches (Figures 8 and 9); most of the solitary trees were living pines (3.1 ha^{-1}), living birches (2.0 ha^{-1}) and dead pines (1.9 ha^{-1}) whereas the majority of trees in patches were living spruces (3.7 ha^{-1}) followed by living pines (2.5 ha^{-1}) and living birches (2.3 ha^{-1}). Among the solitary trees, a large proportion of the dead trees were pines (1.9 ha^{-1}), spruces (1.5 ha^{-1}) and spruce high stumps (1.6 ha^{-1}). The distribution of solitary birch trees (2.0 ha^{-1}) and birches in patches (2.3 ha^{-1}) as well as solitary aspens (0.5 ha^{-1}) and aspens in patches (0.5 ha^{-1}), was largely similar for both solitary trees and trees in patches. Living rowans were more common as solitary trees (0.6 ha^{-1}) than in tree patches (0.2 ha^{-1}). In both groups, living willow and alder, were less abundant.

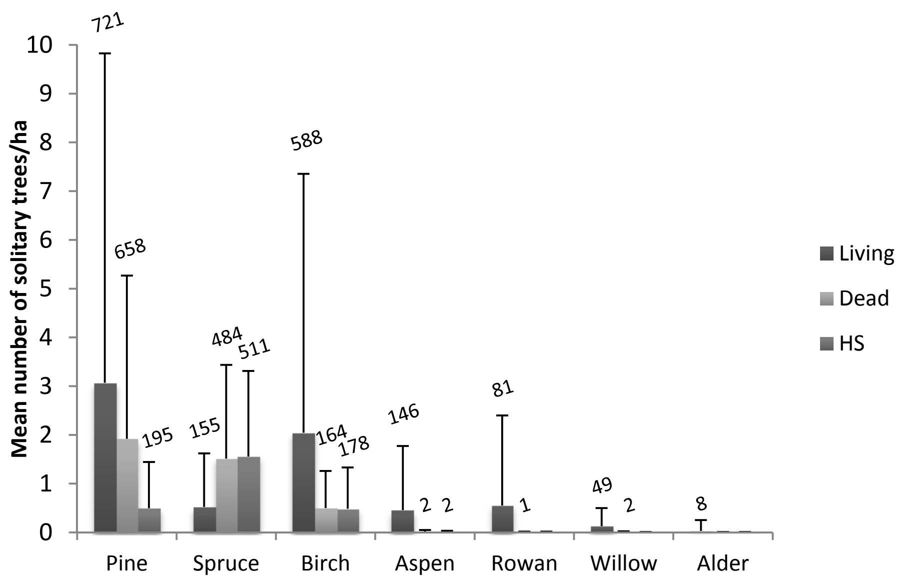


Figure 8 - Distribution of solitary trees by species and tree status (trees/ha). Above the bars are the total numbers of surveyed trees. Error bars show 1SD from the mean.

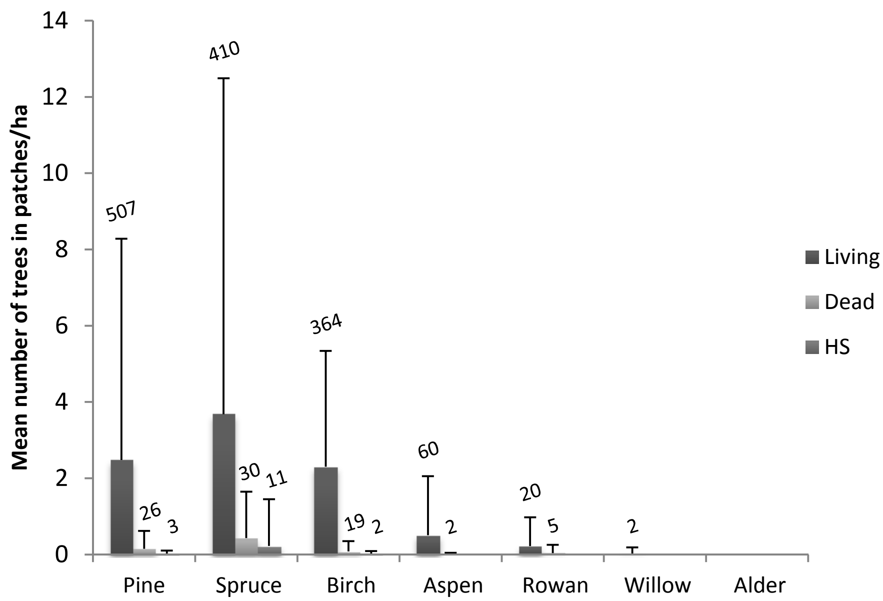


Figure 9 - Distribution of trees in retention patches by species and tree status (trees/ha). Above the bars are the total numbers of surveyed trees. Error bars show 1SD from the mean.

Cavity trees

During the survey I found 174 potential cavity trees (trees with at least one usable cavity). There were 41 trees (24%) that could not be checked because the cavities were too high up for being checked with the available equipment. After checking the remaining 76% of all cavity trees (133 pcs), 47 of these 133 trees ended up being false cavity trees and 86 were classified as true cavity trees.

The maximum-range estimate of the mean cavity tree density (assuming that all trees with unchecked cavities actually held usable cavities) was 0.31 cavity trees ha^{-1} whereas the minimum-range estimate (excluding all suspected cavity trees whose cavities could not be checked) was 0.21 cavity trees ha^{-1} (Table 3).

Table 3 - Density of cavity trees ha^{-1} according to two assumptions: the first column shows the number of true cavity trees ha^{-1} plus the unchecked ones (128 pcs) - assuming all unchecked cavity trees as true (i.e. probably an overestimate); the second column presents the number of cavity trees ha^{-1} based only on trees which could be checked (i.e. probably an underestimate of the true density because unchecked trees are not included).

	Max. estimate	Min. estimate
Mean	0.31 (130)	0.21 (88)
SD	1.70	1.18
SE	0.04	0.03

Cavity trees only represented 1.5-2.2% of all retention trees depending on the used estimate. However, the distribution of cavity trees among different tree species differed from the species composition of retention trees in general ($P < 0.001$) (Figure 10). Although pines constituted nearly 40% of all retention trees they represented only 11.9% of all cavity trees. On the other hand, aspens made up only 4.7% of all retention trees but represented 20.6% of the cavity trees. Birch and spruce were the tree species making up the largest percentage within the cavity trees 34.1% and 32.6% respectively. No cavities were found in willow or alder, tree species which were very rare on the clear-cuts (Figures 2-3). Only one rowan had a cavity. Most pines, spruces and birches with cavities were dead trees or cut high stumps (Figure 11) whereas nearly all aspens, and the only rowan found as cavity tree, were alive.

Cavity trees had a mean DBH of 29.2 cm and all were ≥ 11.8 cm. Cavity tree height varied from 1.5 to 27.6 m (Table 4).

Table 4 - Cavity tree measurements given by mean, standard deviation (SD) and range; DBH (cm). Height (m). Height live crown (m). Distance edge: (m).

	DBH (cm)	Height (m)	Height live crown (m)	Distance edge (m)
MEAN	29.2	9.1	9.4	36.2
SD	8.0	6.0	4.2	27.4
Range	[11.8 - 54.2]	[1.5 - 27.6]	[0 - 15.4]	[2 - 168]

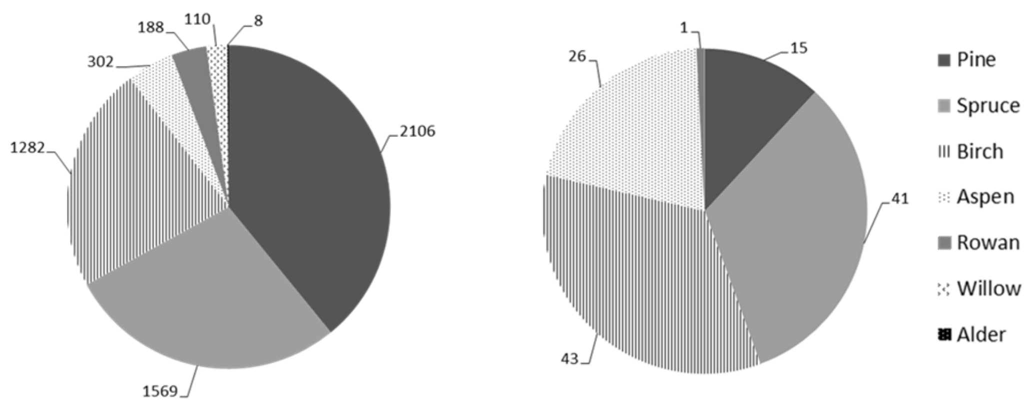


Figure 10 - Distribution of retention trees (right pie chart) and cavity trees (left pie chart) among different tree species. Numbers on the data labels are the total number of trees surveyed for each species.

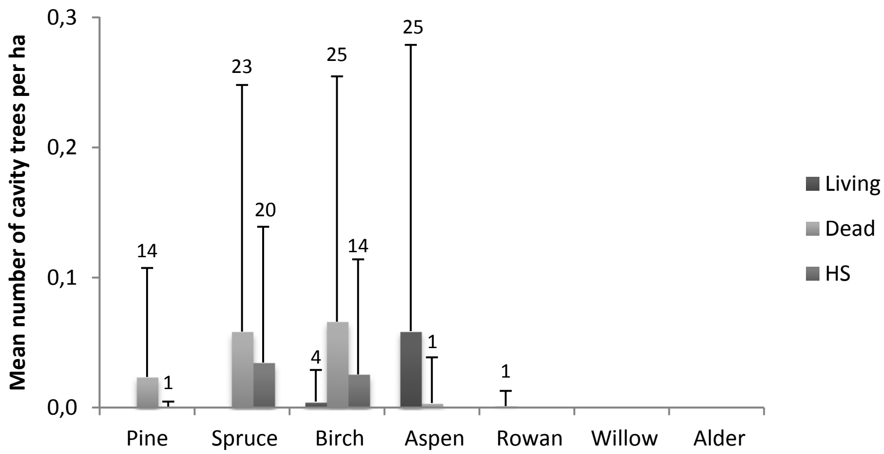


Figure 11 - Mean number of cavity trees per ha by species and tree status. Error bars show 1SD from the mean.

Cavities

I found 241 cavities in total. Most of them (88.7%) were originally excavated by woodpeckers as breeding or roosting cavities and 9.6% were holes that fulfilled the criteria established for defining a true (usable) cavity but had been excavated by Black Woodpeckers foraging for carpenter ants (*Camponotus* spp.). The remaining 1.7% which were defined as usable for nesting too were cracks. The cavities were distributed in trees of different status as follows: 59 in living trees, 121 in dead trees and 61 in high stumps.

The maximum-range estimate of the cavity mean density (assuming that all unchecked cavities were true cavities) was 0.58 cavities ha^{-1}, whereas the minimum-range estimate (excluding all unchecked cavities) was 0.32 cavities ha^{-1}. The best estimate of mean cavity density (see Materials and Methods was 0.41 cavities ha^{-1} (Table 3).

Table 5 - Density of cavities ha^{-1} according to three different assumptions: the first column gives the total amount of true cavities plus the unchecked ones (241) assuming all the unchecked cavities as true (i.e. probably an overestimate); the second column presents the number of true cavities ha^{-1} (only the checked ones); the third column is an estimation of the true cavities present at the clear-cuts.

CAVITIES/HA	Max. estimate	Min. estimate	Best estimate
Mean	0.58 (241)	0.32 (131)	0.41 (170.5)
SD	3.38	1.73	2.13
SE	0.08	0.04	0.05

The number of usable cavities per cavity tree was 1.4 and it ranged from 1 to 8 cavities. Aspen was the species with the highest amount of cavities per cavity tree (nearly two) whereas pines with cavities had close to one cavity per tree (Figure 6).

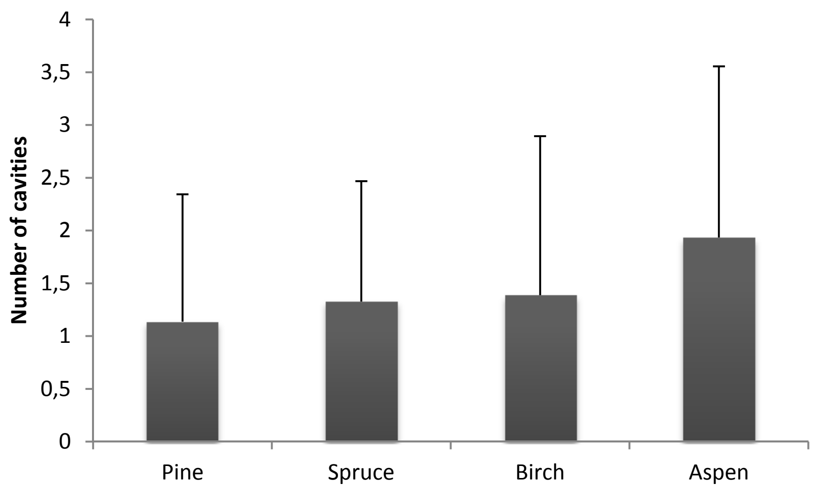


Figure 12 - Mean number of cavities per cavity tree on the main cavity tree species

The age of the clear-cut did not affect the number of cavities. i.e. older clear-cuts did not have more cavities than the younger ones (P = 1) (Figure 13).

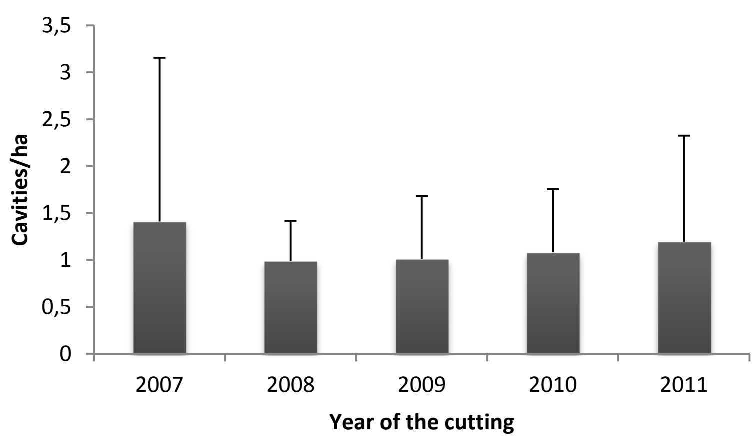


Figure 13 - Cavities/ha classified by the year of the cutting.

I tested the potential differences of the orientation of the entrance holes using three different alternatives: First I included all 241 cavities in the study; second I removed the 4 cracks for the analysis; third I removed the cracks and the 23 black woodpecker feeding holes. After this procedure the remaining cavities were specifically excavated for breeding or roosting. In all three alternatives the orientation of the entrance holes was significantly non-random ($P < 0.001$). The main direction of the cavity openings were east to south and the least frequent orientation was northwest to north (Figure 14).

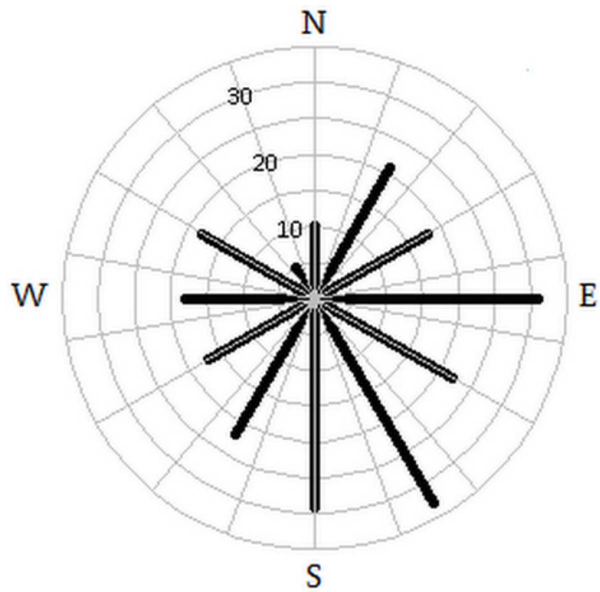


Figure 14 - Orientation of the entrance holes surveyed (241). The length of the lines show the number of cavities in each orientation grouped in 30º intervals.

There was a near significant difference (P = 0.056) between the shape of the entrance holes used for breeding and the shape of the rest of the cavities.

Mean cavity height was 5.4 m above ground and varied from 0.3 m to 14.8 m. The cavities varied widely in their dimensions (
Table 6).

Table 6 - Cavity measurements given by mean. standard deviation (SD) and range; Hgt: Height of the cavity entrance above ground (m). Vert. Ø: Vertical diameter of the entrance hole (cm). Hor. Ø: Horizontal diameter of the entrance hole (cm). Vert. C. Depth: Vertical cavity depth of the cavity (cm). Hor. C. Depth: Horizontal cavity depth of the cavity (cm). Vert. C. Hgt: Vertical cavity height of the cavity (cm). Lat. C. Wdth (Lateral cavity width of the cavity (cm). DCH: diameter at cavity height (cm).

Variable	Mean	SD	Range
Hgt (m)	5.5	2.8	0.37-14.8
Vert. Ø (cm)	6.4	3.6	3 - 32
Hor. Ø (cm)	7.5	32.4	2.5 - 20
Vert. C. Depth (cm)	13.3	7.6	2.5 - 31
Hor. C. Depth (cm)	14.4	4.2	6 - 27.2
Vert. C. Hgt (cm)	13.2	19	3 - 140
Lat. C. Wdth (cm)	17.5	69.3	6 – 27.6

DCH (cm)	29.9	8.2	16.5 - 55

Breedings

Sixteen of the 241 cavities (6.6%) were used by breeding birds. Among these breedings, ten were of great spotted woodpecker (*Dendrocopos major*), three great tit (*Parus major*), one blue tit (*Parus caeruleus*), one redstart (*Phoenicurus phoenicurus*) and one pied flycatcher (*Ficedula hypoleuca*). In all cases breedings were located in solitary trees.

The monitoring period started May 20th. However, no breeding was detected until the first week of June (Table 5). In all cases Great Spotted Woodpecker breedings were over the last week of June. The redstart's breeding could not be followed until the end because the breeding took longer to finish than the duration of the fieldwork which ended on the 30th of July. At that time three out of five nestlings were still in the nest. Sixty-nine percent of the breedings (11) were in living trees whereas 31% (5) were in dead trees; both naturally dead trees and high stumps. The mean height of the entrance hole was 4.4 ± 2.6 ranging from 1.7 m to 12.0 m. In most cases it was unfeasible to count the clutch/brood size, because when the breedings were detected there were nestlings inside thus the use of the camera implied a risk to hurt them. Two breedings – great spotted woodpecker and great tit were found in the same tree.

Table 7 - Data of the breedings monitored; Nest code: Identification code of the nest. Tree Sp: Tree species where the breeding took place. D/A: Whether the tree was dead or alive. Bird Sp: Bird species found nesting at the cavity. H (m): Height of the cavity entrance above ground in m. Distance edge: Distance from the cavity tree to the forest edge Beginning date: Date when the breeding was detected (DD/MM/YY). Ending date: Date in which activity was no longer detected (DD/MM/YY). Breeding index: Strongest breeding index observed during the monitoring of the breeding. [clutch s.; brood s.]: Number of eggs/nestlings seen in the cavity. GSW: Great spotted woodpecker (*Dendrocopos major*). P. flycatcher: Pied flycatcher (*Ficedula hypoleuca*). AE: adult sitting in entrance hole and looking out. NE: nestling sitting in Entrance hole and looking out. NH: nestling(s) heard begging from the nest. AI: adult sitting Inside the nest cavity. AiF: adult flying into the cavity (or to cavity entrance hole) with food. NI: nestling(s) seen inside the nest cavity. NF: nestling(s) fledged.

Code	Tree Sp.	D/A	Bird Sp.	H (m)	Ø (m)	Start	End	Index	[clutch s.; brood s.]
123-02-02	Spruce	D	Blue tit	7.2	14.8	June 26	July 29	AE	[- ; -]
686-01-03	Aspen	A	GSW	4.8	102	June 6	June 26	NE	[- ; -]
666-06-01	Birch	A	GSW	2	29.2	June 10	June 24	NE	[- ; -]
331-01-01	Birch	A	GSW	4.4	35.4	June 6	June 26	NH	[- ; -]
719-01-01	Pine	D	GSW	12	80.8	June 7	June 27	NH	[- ; -]
701-01-02	Aspen	A	GSW	6.8	99.4	June 7	June 27	NH	[- ; -]
352-05-01	Birch	A	GSW	4.6	28.4	June 7	June 27	NE	[- ; -]
166-01-01	Aspen	A	Great tit	5.2	36.8	June 23	July 18	AI	[- ; -]
689-03-02	Birch	D	GSW	2.5	2.5	June 4	June 29	NE	[- ; -]
214-02-01	Birch	D	P. flycatcher	2.6	36	June 21	July 11	AiF	[- ; -]
394-01-01	Rowan	A	GSW	2.4	21	June 5	June 28	NH	[- ; -]
512-02-01	Birch	D	Redstart	1.7	3	June 8	July 30	NI	[5 ; 5]
018-04-01	Aspen	A	GSW	2.8	42.8	June 11	June 28	NE	[- ; -]
018-04-02	Aspen	A	Great tit	3.2	42.8	June 11	July 3	NH	[- ; -]
018-07-01	Aspen	A	Great tit	3	33.4	June 23	June 3	NI	[- ; 4?]
589-02-02	Aspen	A	GSW	5.2	23	June 11	June 28	NF	[- ; -]

*: Activity signs still present when the monitoring period ended.
?: Clutch/brood size might have greater but the entire nest could not be seen.

Aspen and birch were overrepresented as cavity trees since great spotted woodpeckers selected them for excavating their breeding/roosting holes (P = 0.026). Moreover 13 breedings out of 16 were found in these two tree species (Figure 15). Birds also preferred living deciduous trees for breeding P = 0.001). Nevertheless, DBH and distance to the edge did not have a significant effect on the breedings found or the cavity trees available for cavity nesting species (P = 0.51 and 0.70 respectively).

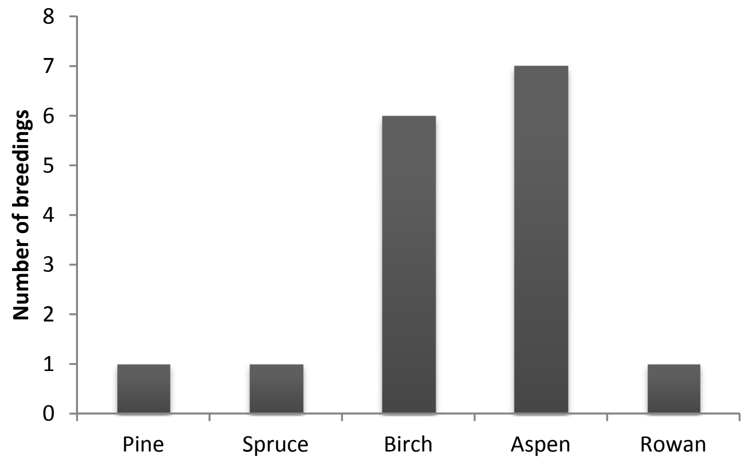


Figure 15 - Number of breedings per tree species

I want to highlight the presence of three nest boxes found in three different clear-cuts during the survey. The nest boxes were not checked during the fieldwork because there were no cavities in those clear-cuts and so they were not visited a second time.

Discussion

Although the percentage of cavity trees among retention trees was very low this study shows that, even during the regeneration phase, retention of trees during clear-cutting results in the presence of cavity-trees. I found that 98% of all surveyed cavities were excavated by woodpeckers (either for nesting/roosting or for foraging). This novel finding for European boreal forest challenges the conclusions of Cockle et al. (2011) who suggested that outside North America most non-excavators rely on the use of cavities formed by decay and damage processes. In contrast to excavated cavities, natural decay cavities comprised only 2% of the available cavities in my study. However, in the study by Cockle et al. (2011) European boreal forests was not included. A general pattern is that natural decay and damage processes provide a larger proportion of cavities in temperate forests than in boreal forests, where woodpeckers would play a more important role for cavity creation (Cockle et al. 2011). This difference is probably due to tree species' traits together with climatic conditions that in the boreal regions make decay processes slower (Remm and Lohmus 2011; Ouellet-Lapointe et al. 2012) and therefore natural cavities are very scarce making the presence of primary excavators crucial for the availability of suitable cavities. There are several factors affecting cavity density in clear-cuts: (1) new excavated cavities by woodpeckers; (2) the lifespan of cavity trees. Blanc and Martin (2012) estimated that cavity bearing trees remained in a forest stand for an average of 11.8 years, however this estimation might be lower in clear-cuts because of cavity disappearance due to tree fall. This is more common in clear-cuts than in forest since retention trees are in general isolated, therefore they do not have much protection against wind and the number of tree uprooting increases after felling (Hautala and Vanha-Majamaa 2006).

Cavity trees constituted a low percentage (1.5-2%) of the retention trees. Deciduous trees (aspen, birch and rowan) were overrepresented as cavity trees although they made up a small proportion of the retention tree species. In previous studies, aspen has been found to be preferred by primary cavity nesters (Angelstam and Mikusinski 1994; Martin et al. 2004; Drever and Martin 2010; Blanc and Martin 2012; Edworthy and Martin 2013;). For instance Martin and Eadie (1999) found that trembling aspen (*Populus tremuloides*) was the most strongly-selected tree species holding the 95.5% of all woodpecker nests found. The reason for this is that aspens present different decay stages while they are alive and the wood is therefore better for excavation (Blanc and Martin 2012). Moreover, aspen is an outstanding species because each cavity tree has an average of nearly two cavities so this could give shelter to more than one nest in the same breeding tree –as I found during my survey. In contrast to cavities in aspens, which were generally alive, the majority of birches found as cavity trees were either dead or cut high stumps. Woodpeckers also selected for trees that were alive for excavating their cavities. In my study living aspens and birches were overrepresented within the trees used for breeding and similar behavior has been observed in other studies (Ingold 1994; Martin et al. 2004; Robles et al. 2007; Blanc and Martin 2012). Blanc and Martin (2012) found that living and recently dead aspens have some of the lowest annual probabilities of falling down, with a relative standing period of about 5 years after death, this feature in aspen trees may be desirable for nest site selection by woodpeckers since there is a lower risk for the tree to break.

Most of cavities excavated by woodpeckers for breeding/roosting were facing south-east. This same pattern has been observed previously. In Stenberg (1996), 53-83% of the woodpecker nest holes was facing south. The reason to this might be that woodpeckers choose to excavate their nests in relation to thermal demands. If the cavity is facing south-east it gets the first hours of morning light and as a result the warmth from the sun is maximized which facilitates warming-up of the cavity after cold nights in the spring.

Seventy-two percent of the cavities in my study could be checked; nearly half of the checked cavities were true cavities and the other half ended up being false. This number of true cavities is higher than the one obtained in the study of Ouellet-Lapointe et al. (2012) were they found that only 38% of the cavities were suitable. Therefore, even if ground cavity surveys are fast and inexpensive, they highly overestimate the amount of cavities in boreal forest. For that reason I recommend direct inspection surveys –as the one conducted for my study– since they are more accurate.

Cavity densities also vary between studies. In my study, the estimated cavity density (calculated with the proportion of true vs. false cavities) was 0.4 ha^{-1}, which is less than half of the density obtained in a subarctic forest in Finland (1.13 ha^{-1}) by Pulliainen and Saari (2002); it is also much lower than the cavity densities obtained in Canadian boreal forest (11.2 ha^{-1}) by Ouellet-Lapointe et al. (2012) and substantially lower than the one obtained in boreal forests in Mongolia by Bai et al. (2003) (30 ha^{-1}). However Bai et al. (2003) was using ground cavity survey, so the result is most probably an overestimation. Yet, the cavity density found in my study is the lowest. The most likely reason for this could be that my study is the only one based on a cavity survey conducted on clear-cuts in boreal forest, thus results might differ in mature forest in the same area.

The density of solitary retention trees in my study generally met the requirements set for certification standards by both FSC and PEFC, i.e. ≥10 retention trees ha^{-1}, and the creation of at least 3 high stumps ha^{-1}. Retention patches and protected buffer zones left close to water were also surveyed. Nevertheless, there are differences regarding species composition and tree status between solitary trees and retention patches; solitary trees accounted for most of the dead trees and high stumps, whereas few such trees were found in retention patches. Living spruces are also uncommon as solitary trees relative to their density in retention patches. This is probably because managers avoid the retention of solitary living spruces since they are the species most susceptible to uprooting after felling in boreal ecosystems (Hautala and Vanha-Majamaa 2006). Another finding regarding tree retention based on my results is that the trees more important for cavity nesting species were scarce as retention trees. For instance aspen made up a 4% of tree retention but it was selected as cavity tree being a 20% of cavity trees.

This study highlights the importance of deciduous living trees as retention trees to ensure the creation of new cavities and to preserve viable populations of cavity-nesting species. For this reason forest management guidelines should focus on management strategies that, apart from dead wood and cut high stumps, would favor living deciduous trees which is a significant resource for primary cavity nesters. Since natural cavities are extremely scarce, the presence of woodpeckers is crucial to maintain the creation of new cavities in the boreal forest. Therefore conservation efforts to favor woodpecker's requirements when retaining trees should be mandatory for meeting biodiversity requirements. This has special importance in cases where conservation efforts to preserve secondary cavity nesting species have to be done in a certain area; by favoring woodpeckers, we will improve the conditions for the cavity-dependent species.

I found 16 successful breedings in retention trees. All breedings found in my study were located in solitary trees and the distance to the forest edge (36.7 ± 27.4 m) did not have a significant effect. This finding shows that cavities out on the open clear-cuts can be used by cavity-nesting species for breeding. Due to the low number of breedings detected during my study, I suggest that a similar study should be performed in forest. This survey should be conducted simultaneously in forest and clear-cuts to provide a basis for comparison between the possible different use of these environments for breeding.

References

Angelstam, P. (1998), 'Maintaining and restoring biodiversity in European boreal forests by developing natural disturbance regimes', *Journal of Vegetation Science,* 9 (4), 593-602.

Angelstam, P. and Mikusinski, G. (1994), 'Woodpecker assemblages in natural and managed boreal and hemiboreal forest - A review', *Annales Zoologici Fennici,* 31 (1), 157-72.

ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Bai, M. L., Wichmann, F., and Muhlenberg, M. (2003), 'The abundance of tree holes and their utilization by hole-nesting birds in a primeval boreal forest of Mongolia', *Acta Ornithologica,* 38 (2), 95-102.

Blanc, L. A. and Martin, K. (2012), 'Identifying suitable woodpecker nest trees using decay selection profiles in trembling aspen (Populus tremuloides)', *Forest Ecology and Management,* 286, 192-202.

Carlson, A., Sandstrom, U., and Olsson, K. (1998), 'Availability and use of natural tree holes by cavity nesting birds in a Swedish deciduous forest', *Ardea,* 86 (1), 109-19.

Cockle, K. L., Martin, K., and Wesolowski, T. (2011), 'Woodpeckers, decay, and the future of cavity-nesting vertebrate communities worldwide', *Frontiers in Ecology and the Environment,* 9 (7), 377-82.

Drever, M. C., et al. (2008), 'Woodpeckers as reliable indicators of bird richness, forest health and harvest', *Biological Conservation,* 141 (3), 624-34.

Drever, M. C. and Martin, K. (2010), 'Response of woodpeckers to changes in forest health and harvest: Implications for conservation of avian biodiversity', *Forest Ecology and Management,* 259 (5), 958-66.

Edenius, L. and Elmberg, J. (1996), 'Landscape level effects of modern forestry on bird communities in North Swedish boreal forests', *Landscape Ecology,* 11 (6), 325-38.

Edworthy, A. B. and Martin, K. (2013), 'Persistence of tree cavities used by cavity-nesting vertebrates declines in harvested forests', *Journal of Wildlife Management,* 77 (4), 770-76.

Ericsson, S., Ostlund, L., and Axelsson, A. L. (2000), 'A forest of grazing and logging: Deforestation and reforestation history of a boreal landscape in central Sweden', *New Forests,* 19 (3), 227-40.

Gustafsson, Lena, Kouki, Jari, and Sverdrup-Thygeson, Anne (2010), 'Tree retention as a conservation measure in clear-cut forests of northern Europe: a review of ecological consequences', *Scandinavian Journal of Forest Research,* 25 (4), 295-308.

Hautala, Harri and Vanha-Majamaa, Ilkka (2006), 'Immediate tree uprooting after retention-felling in a coniferous boreal forest in Fennoscandia', *Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere,* 36 (12), 3167-72.

Hunter, M. L. and Schmiegelow, F. K. A. (2011), 'Wildlife, Forests, and Forestry Principles of Managing Forests for Biological Diversity 2(nd) edition', *Forestry Chronicle,* 87 (4), 570-70.

Imbeau, L., Monkkonen, M., and Desrochers, A. (2001), 'Long-term effects of forestry on birds of the eastern Canadian boreal forests: a comparison with Fennoscandia', *Conservation Biology,* 15 (4), 1151-62.

Ingold, D. J. (1994), 'Nest-site characteristics of red-bellied and red-headed woodpeckers and northern flickers in east-central ohio', *Ohio Journal of Science,* 94 (1), 2-7.

Kruys, N., et al. (2013), 'Retaining trees for conservation at clearcutting has increased structural diversity in young Swedish production forests', *Forest Ecology and Management,* 304, 312-21.

Kuuluvainen, T., Tahvonen, O., and Aakala, T. (2012), 'Even-Aged and Uneven-Aged Forest Management in Boreal Fennoscandia: A Review', *Ambio,* 41 (7), 720-37.
Lindenmayer, D. B., Franklin, J. F., and Fischer, J. (2006), 'General management principles and a checklist of strategies to guide forest biodiversity conservation', *Biological Conservation,* 131 (3), 433-45.
Lundmark, H., Josefsson, T., and Ostlund, L. (2013), 'The history of clear-cutting in northern Sweden - Driving forces and myths in boreal silviculture', *Forest Ecology and Management,* 307, 112-22.
Martin, K. and Eadie, J. M. (1999), 'Nest webs: A community-wide approach to the management and conservation of cavity-nesting forest birds', *Forest Ecology and Management,* 115 (2-3), 243-57.
Martin, K., Aitken, K. E. H., and Wiebe, K. L. (2004), 'Nest sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: Nest characteristics and niche partitioning', *Condor,* 106 (1), 5-19.
Newton, I. (1994), 'The role of nest sites in limiting the numbers of hole-nesting birds - A review ', *Biological Conservation,* 70 (3), 265-76.
Ouellet-Lapointe, U., et al. (2012), 'Woodpecker excavations suitability for and occupancy by cavity users in the boreal mixedwood forest of eastern Canada', *Ecoscience,* 19 (4), 391-97.
Pulliainen, E. and Saari, L. (2002), 'Nest site selection of hole-nesting passerines in natural habitats in eastern Finnish Forest Lapland', *Aquilo Ser. Zool.,* 30, 109-13.
Remm, J. and Lohmus, A. (2011), 'Tree cavities in forests - The broad distribution pattern of a keystone structure for biodiversity', *Forest Ecology and Management,* 262 (4), 579-85.
Robles, Hugo, et al. (2007), 'Sylvopastoral management and conservation of the middle spotted woodpecker at the south-western edge of its distribution range', *Forest Ecology and Management,* 242 (2-3), 343-52.
Stenberg, I. (1996), 'Nest site selection in six woodpecker species', *Fauna norv. Ser. C Cinclus,* 19: 21-38.
Svensson, L., et al. (2009), 'Collins bird guide', (Collins), 416.
SverigesNationalatlas (2014), 'Västerbotten County', (updated 29-06-2012) 14-1-2014.
Swedish_Forest_Agency (2012), *Geografiska data från Skogsstyrelsen*.
Van Balen, J. H., et al. (1982), 'Studies on hole-nesting birds in natural nest sites.', *Ardea,* 70 (1), 1-24.
Zackrisson, O. (1977), 'Influence of Forest Fires on the North Swedish Boreal Forest', *Oikos,* 29 (1), 22-32.

APPENDIX 1 -Field sheets

RETENTION TREE SURVEY

Date	**Clearcut**

SOLITARY TREES:

	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

RETENTION GROUPS:

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

N:	PINE	SPRUCE	BIRCH	ASPEN	ROWAN	G. ALDER	WILLOW	OTHERS
LIVING								
DEAD								
H. STUMP								

CAVITIES:

ID									
Number cavities									
Height cavities									
Tree Sp									

CODE FOR HEIGHT:

R: Reachable
L-3: 3m ladder
L-6: 6m ladder
T: Telescopic pole
U: Unreachable

CAVITY TREE MEASUREMENTS **CLEARCUT**:

CODE	Tree sp	Nb. usable cavities	**D**ead or **A**live	Status	Tree health (Table)	Decay class

CODE	DBH	Height	Height to live crown	Tree count (Radius 5.64)			Distance to the edge	Mean slope	Mean slope
				Living	Dead	High stump			

10 CLOSEST TREES:

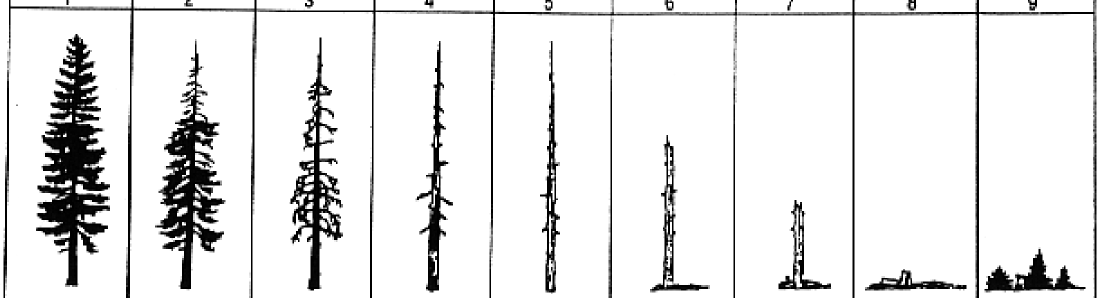
Sp										
L, D, HS										
Sp										
L, D, HS										
Sp										
L, D, HS										

STATUS: **F**ull tree height/ **N**aturally **b**roken top/ **C**ut high stump

<u>TREE HEALTH</u>:

1) BT broken top
2) BF bracket fungus (= polypore)
3) BU burned trunk
4) RB rust broom (on SX or FD)
5) BI boring insect (can generally see their entry/exit holes/tunnels)
6) BN brown needles
7) TG trunk gall
8) MD mechanical damage (e.g. axe wound or scar from forestry operations)
9) AR antler rubbing (scars the bark, sometimes girdles the tree – this code also covers 'cribbing', or bark feeding)
10) BD beaver damage
11) BL bark blistering & seeping sap
12) SL split leader (= forked tree shape -- only applies to conifers)
13) UK unknown/undetermined

<u>DECAY CLASS:</u>



	LIVE		DEAD					DEAD FALLEN	
Class	1	2	3	4	5	6	7	8	9
General Description of Tree	Live/healthy – no decay	Live/ unhealthy – internal decay or growth deformities	Dead – hard	Dead – hard	Dead – spongy	Dead – soft	Dead – soft	Dead – soft	Debris

CAVITY MEASUREMENTS

CLEARCUT:

CODE	**N**atural/ **E**xcavated:	**F**resh/**O**ld	Shape **R**ound, **O**val…	Excavating sp:	Height (m)	Vertical diameter (cm)	Horizontal diameter (cm)	Aspect

CODE	Vertical cavity depth* (cm)	Horizontal cavity depth* (cm)	Vertical cavity height* (cm)	Lateral cavity width* (cm)	DCH (cm)

***→** Measurements that are only possible for cavities which can be reached from the ground or using a ladder.

e → Estimated measurements

f → False cavity

CAVITY MONITORING

CLEARCUT:				Number of trees with cavities:				
Cavity code:	STATUS (Visit number / Date)							
	1/	2/	3/	4/	5/	6/	7/	8/

Cavity code:	STATUS (Day number / Date)							
	1/	2/	3/	4/	5/	6/	7/	8/

BREEDING INDICES AND BEHAVIORS	**CODE**
Eggs **S**een inside nest	ES
Nestling(s) **H**eard begging from the nest	NH
Nestling sitting in **E**ntrance hole and looking out	NE
Nestling(s) seen **I**nside the nest cavity	NI
Nestling(s) **F**ledged	NF
Adult sitting in **E**ntrance hole and looking out	AE
Adult sitting **I**nside the nest cavity	AI
Adult flying **i**nto the cavity with nest **M**aterial	AiM
Adult flying **i**nto the cavity (or to cavity entrance hole) with **F**ood	AiF
Adult flying **i**nto the cavity (but **N**othing seen in bill)	AiN
Adult flying **o**ut from the cavity with fecal **S**ac	AoS
Adult flying **o**ut from the cavity (but **N**othing seen in bill)	AoN
Adult sitting within a few meters of the cavity and giving **A**lert calls	AA
Adult **Ex**cavating cavity	AEx
NEST FAILURE OR MORTALITY INDICES (abandonment or predation)	
Entrance hole **E**nlarged by predator	EE
Other **S**igns left by predator (e.g. hairs, feathers, feces)	OS
Holed **E**ggs (= pierced by predator, e.g. teeth marks of stoat *Mustela erminae*)	HE
Broken **E**ggshells (large parts of eggshells → would normally be removed by parents)	BE
Egg **C**ontents	EC
Eggs found **U**nattended long after incubation period (= deserted nest)	EU
Dead (whole) **N**estling(s)	DN
Dead (whole) **A**dult(s)	DA
Bird body **P**arts (e.g. broken wings, flight feathers, headless carcasses)	BP
Nest **U**surpation by other bird before completed breeding	NU
Predator **S**een in nest cavity or on the cavity tree	PS

BREEDINGS

CLEARCUT:

Cavity code	Date / Time	OBSERVATIONS

CLEARCUT:

Cavity code	Date / Time	OBSERVATIONS

BREEDING INDICES AND BEHAVIORS	**CODE**
Eggs **S**een inside nest	ES
Nestling(s) **H**eard begging from the nest	NH
Nestling sitting in **E**ntrance hole and looking out	NE
Nestling(s) seen **I**nside the nest cavity	NI
Nestling(s) **F**ledged	NF
Adult sitting in **E**ntrance hole and looking out	AE
Adult sitting **I**nside the nest cavity	AI
Adult flying **i**nto the cavity with nest **M**aterial	AiM
Adult flying **i**nto the cavity (or to cavity entrance hole) with **F**ood	AiF
Adult flying **i**nto the cavity (but **N**othing seen in bill)	AiN
Adult flying **o**ut from the cavity with fecal **S**ac	AoS
Adult flying **o**ut from the cavity (but **N**othing seen in bill)	AoN
Adult sitting within a few meters of the cavity and giving **A**lert calls	AA
Adult **Ex**cavating cavity	AEx
NEST FAILURE OR MORTALITY INDICES (abandonment or predation)	
Entrance hole **E**nlarged by predator	EE
Other **S**igns left by predator (e.g. hairs, feathers, feces)	OS
Holed **E**ggs (= pierced by predator, e.g. teeth marks of stoat *Mustela erminae*)	HE
Broken **E**ggshells (large parts of eggshells → would normally be removed by parents)	BE
Egg **C**ontents	EC
Eggs found **U**nattended long after incubation period (= deserted nest)	EU
Dead (whole) **N**estling(s)	DN
Dead (whole) **A**dult(s)	DA
Bird body **P**arts (e.g. broken wings, flight feathers, headless carcasses)	BP
Nest **U**surpation by other bird before completed breeding	NU
Predator **S**een in nest cavity or on the cavity tree	PS

SENASTE UTGIVNA NUMMER

Hela förteckningen på utgivna nummer hittar du på www.slu.se/viltfiskmiljo