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RESEARCH PAPER

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Densities of the Eurasian Three-toed Woodpecker *Picoides tridactylus* calculated from sap row surveys are on par with estimates from fixed route bird censusing

Den tretåiga hackspettens Picoides tridactylus *populationstäthet beräknad från savrader är i paritet med uppskattningar från inventering av standardrutter*

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SPECIES-SPECIFIC TRACKS of animals can be an effective way of mapping species that are hard to find even if they are present. We used observations of sap rows on trees to calculate densities of Eurasian Three-toed Woodpeckers *Picoides tridactylus*. We surveyed 14 fixed routes in northern Sweden below the montane forest for sap rows during the autumn of 2020. We used our observations of fresh sap rows together with average home range and proportion of active territories per year derived from the literature, to calculate large-scale woodpecker population density. The density based on sap rows was 0.19 pairs per km². Densities from fixed route bird observations for different parts of Västerbotten County below the montane forests were 0.13–0.14 pairs per km², in relative agreement with the estimates from sap rows. We also calculated the population density from fixed route observations in the montane forests, and these were almost three times higher. Our density calculations correspond to 7,900 pairs in Västerbotten County. These results indicate that systematic counts of sap rows can quickly provide credible population density estimates of Eurasian Three-toed Woodpeckers.

Keywords: population size | bird surveying | methodology | forestry | montane forest | northern Sweden

Introduction

A global key question is how we can manage land use so that it contributes to the well-being of humans, without jeopardizing the rest of life on Earth. Monitoring the population development of endangered bird species is an important part of that work. In Sweden, territory mapping was used as the main method for bird surveys in the past. This method is based on detailed, repeated surveys of birds in specific habitats, and mostly in relatively small areas (Enemar 1959).

National population sizes for different species can then be calculated from recorded bird densities and the total area of the specific habitat in the whole country. Since 1996, the most important tool for following bird population trends in Sweden is the line transects of the Swedish Bird Survey's fixed routes (Green *et al.* 2020). The fixed routes are surveyed once a year in early summer, mainly in June, and cover the whole of Sweden in a systematic way.

The advantage of the fixed routes is that they, by the systematic approach, represent all larger-ranging habitats in more or less the same proportion as these cover Sweden. Hence, results from the fixed routes are more representative of the whole country than territory mapping in smaller, non-systematically selected areas. One disadvantage, if one wants to know true population sizes, is that line transects do not result in true densities of birds in the same way as territory mapping does. Line transect data can, however, be used for calculating densities, and overall population size, if assumptions of, or data on, detectability is available for the species and habitats in question. Another disadvantage if one wants to calculate densities and total population sizes based on line transect data collected on the fixed routes is that certain species—such as woodpeckers—are more active at other times of the year or the day than when the fixed routes are surveyed. This means that for the birds that are actually present, the proportion that are seen or heard is relatively low for such species. For following population trends, this does not affect the results in any way as long as the proportion of recorded birds in relation to the ones present remains at the same level. For calculating true densities and overall population sizes, however, this may be a problem. The Eurasian Three-toed Woodpecker *Picoides tridactylus* (henceforth referred to as the Three-toed Woodpecker) is such a species.

The Three-toed Woodpecker prefers mature, often conifer-dominated forests with large amounts of dead or dying trees (Hogstad 1970, Cramp 1985, Virkkala 1991, Stenberg 1996, Hagemeier & Blair 1997, Fayt 1999, Pechacek & Kristin 2004). The presence of the Three-toed Woodpecker is valuable for forestry as it can play a role in regulating the populations of bark beetles (Coleoptera: Curculionidae, Scolytinae), and especially the European spruce bark beetle *lps typographus*, in coniferous forest landscapes (Fayt *et al.* 2004).

However, the species is considered difficult to survey (Winkler *et al.* 1995, Winkler & Christie 2002). It is easily overlooked, partly because established pairs are very quiet and withdrawn, and it is very difficult to find unless birds are drumming or calling (Amcoff & Eriksson 1996). In addition, some Three-toed Woodpeckers only occasionally respond to playback of recorded drumming. In many cases, the presence of Three-toed Woodpeckers in an area is not detected through observations of the bird itself, but of the tracks and signs of it.

The species has a typical way of pecking rows of small holes around tree trunks, so-called sap rows, to utilize the sap flowing from the holes. The month before nesting starts, Three-toed Woodpeckers can use up to 33% of its foraging time to drink sap (Pakkala *et al.* 2018), and sap rows on Norway spruces *Picea abies* are in Sweden considered to be a very good indication of nesting pairs nearby (Artdatabanken, 2019). Other woodpeckers too, especially the Great Spotted Woodpecker *Dendrocopos major*, make sap rows and they also do so at least occasionally on silver birches *Betula pendula* in Finland (Pakkala *et al.* 2018). We have not found any accounts of whether Great Spotted Woodpeckers also make sap rows on birches *Betula* sp. in northern Sweden.

Here we use systematically recorded observations of sap rows to calculate population densities of Three-toed Woodpeckers in inland areas, below the montane forest, in Västerbotten County, northern Sweden. We do so by combining the recorded proportion of fixed routes with fresh sap rows with the average home range and the proportion of active territories per year derived from the literature. This way, we can calculate densities (pairs per km^2) of Three-toed Woodpeckers without observing a single bird. For comparison, we also calculate densities based on bird observations from fixed routes (2010–2019) and correction factors for detectability based on Finnish line transects. We do this separately for three different sections of Västerbotten County: the montane forests, the inland, and the province of Västerbotten (which makes up the eastern part of Västerbotten County) closer to the coast. Finally, we use the calculated densities to estimate total population size of Three-toed Woodpeckers in the three different parts of Västerbotten County. By summing up these three figures we eventually present an overall population size for the whole county.

Methods

FIXED ROUTES AND SAP ROW DATA COLLECTION

We selected a cluster of 14 fixed routes from the Swedish Bird Survey, to record the presence of trees with sap rows. There are 716 fixed routes systematically distributed over Sweden, the distance between the routes is 25 km in both north–south and west–east direction. Each route consists of eight line transects of 1 km along a 2 × 2 km square, and eight point counts of 5 minutes at each full km where all seen or heard birds and larger mammals are counted. Lines and points are two separate samples of the same routes. The route starts and ends in the southwest corner and is surveyed clockwise. The routes are surveyed once a year during a three-week period adapted to local conditions, when the activity of most breeding bird species is expected to be as high as possible. As explained above this is not the case for all species, but for most of them. In the boreal part of northern Sweden, the routes are surveyed

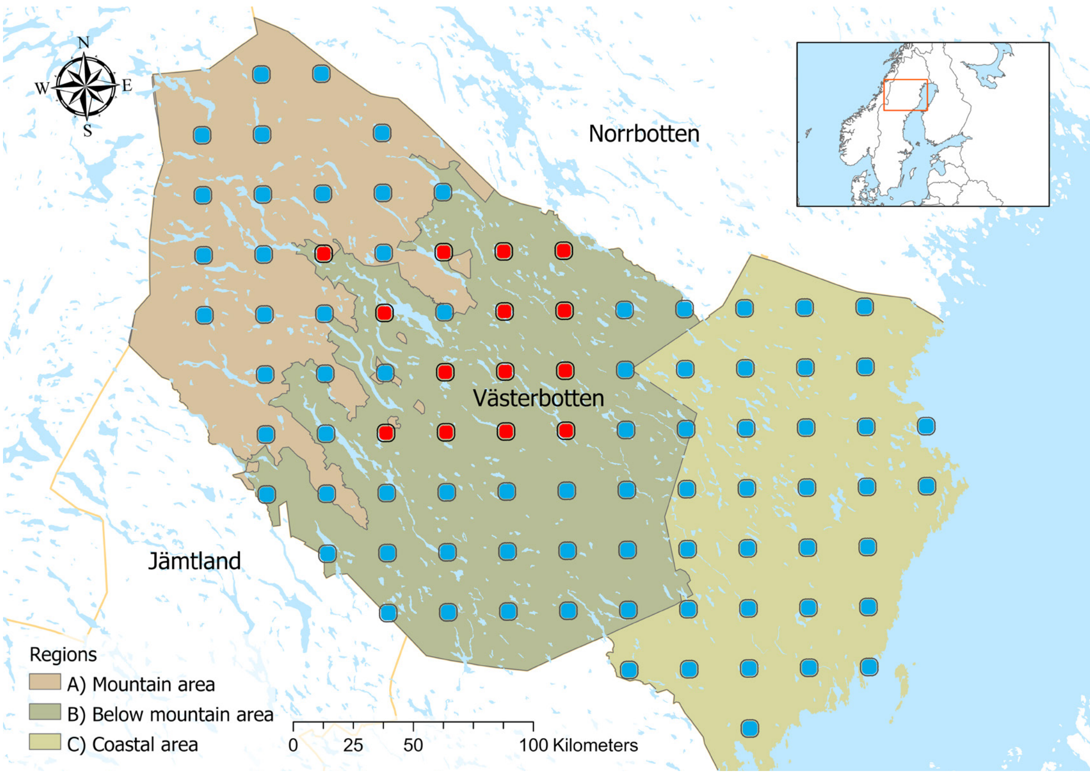

FIGURE 1. Inset: Overview, our study area within the red box (around 65°09'N, 17°13'E). Main image: Detailed map with the three different parts of Västerbotten County used in our analysis; the montane forests, the inland (below the mountain area), and the province of Västerbotten (coastal area). Points (blue and red) show the locations of fixed routes with any proportion of forest cover (n=89). Red points are routes surveyed for sap rows (n=14).

— Infälld bild: Översiktskarta med vårt studieområde inom röd rektangel (cirka 65°09'N, 17°13'E). Huvudkarta: Detaljkarta över Västerbottens län indelat i fjällnära skog, inlandet nedanför den fjällnära skogen (Åsele och Lycksele lappmark nedom fjällen) samt landskapet Västerbotten. Punkter (blå och röda) visar standardrutter där det finns skog i någon omfattning (n=89). Röda punkter är rutter där vi letat efter savrader (n=14).

in June (Green *et al.* 2020). The selected routes are all located in the boreal coniferous forest belt in northern Sweden (see Figure 1). Active forestry has been conducted in the area since the mid-1800s, at first through selective cutting of the largest trees, later gradually more by clear-cutting (Lundmark *et al.* 2013).

We looked for sap rows on the first, southwesternmost, kilometer of the route whenever possible (10 of 14 routes). If the terrain did not allow the observer to cover the first kilometer of the route, we chose the second kilometer, and so on. Along the lines, the observer walked slowly and looked for sap rows within about 10 m in both directions, which means that we covered a corridor of 20x 1000 m. When the full kilometer was done, the observer turned around and went back the same way. Doing this, we searched for sap rows in both directions, and covered an area of about 2 ha per route (20 × 1,000 m) in about 1.5–2 hours (1 km back and forth). The observer only used eyesight, no equipment such as binoculars or ladders, in order to detect sap rows. We examined the tree trunks up to about 8 meters height. All field work was carried out in the autumn of 2020 by the same person (BF). Data was recorded in a smart phone application in ArcGIS Collector. We used a map application where the routes were displayed, and with which it was possible to collect geodata in the field. When a tree with sap holes was found, the following information was recorded: tree species, estimated age of sap rows, and number of sap rows. In addition, the position of the tree was recorded with the GPS of the phone. The age of the sap rows was categorized in three classes: <3 years, 3–7 years and >7 years old.

AGE OF SAP ROWS

Estimating the exact age of sap rows can be challenging. On Norway spruce, the bark is usually first "peeled off" first, and then the holes are pecked. This creates a ginger area on both sides of the sap row (Figure 2a). Sap flowing from the holes and the ginger area around the row is a sign of fresh sap rows (Figure 2b). After a couple of years, the ginger color fades and becomes quite bright. Old sap rows that have been used for a long period become partly overgrown (Figure 2d), previous studies have shown that about 20% of new sap holes are made within the old holes (Pakkala *et al.* 2018). It is, however, difficult to know when they were used. If there is sap flowing in the holes, they are really fresh; if the sap is yellow or white but not flowing anymore (Figure 2e), they are still quite fresh; otherwise, such sap rows are probably older than seven years. There are examples of trees that have been used as sap trees by Three-toed Woodpeckers for more than 100 years (Ruge 1968).

On birches, the sap holes grow as the tree grows. Rows made in the same season as the survey look like narrow cuts, reminiscent of a small cut made with a knife (Figure 2c). Sap holes made a year or two ago are still quite small, but easier to see than fresh rows. The category 3–7 years is usually the easiest to see, as they are clearly visible against the white bark and the width of single holes is about 3–5 mm (Figure 2c). Older holes are usually wider than 5 mm. It is easier to detect sap rows on younger trees with smooth bark compared to older trees with a more complex surface structure. We saw most of the sap rows at a height of 2–8 meters, but on a large, felled birch, we found several sap rows high up in the crown and reaching out on the thick branches. Such sap holes are normally not detectable from the ground. Very fresh holes and holes on older trees located higher up in the crown are the most difficult to detect.

Marks on Scots pines are similar to those on Norway spruces but are in our opinion more difficult to detect, as the color where the bark has been peeled off does not differ much from the rest of the tree. In uncertain cases, we have, regardless of tree species, erred on the side of the older category.

HOME RANGE

Reported home ranges and/or territory sizes of Three-toed Woodpeckers vary from a few tens to several hundred hectares (Glutz von Blotzheim & Bauer 1994, Pechacek 2004). The home range probably varies over the year with the smallest size during the breeding season, especially during the period with young in the nest, and the largest size during the winter. The sap rows are mainly made during the period just before nesting (Pakkala *et al.* 2018) but can be made from early spring to late summer (Turcek 1954, Bailey 2008). For that reason, we want to estimate the home range during the pre-nesting period of the year. As there is a shortage of studies on home range size for Three-toed Woodpeckers in Scandinavia, we used a study from Germany that assessed home ranges/territory

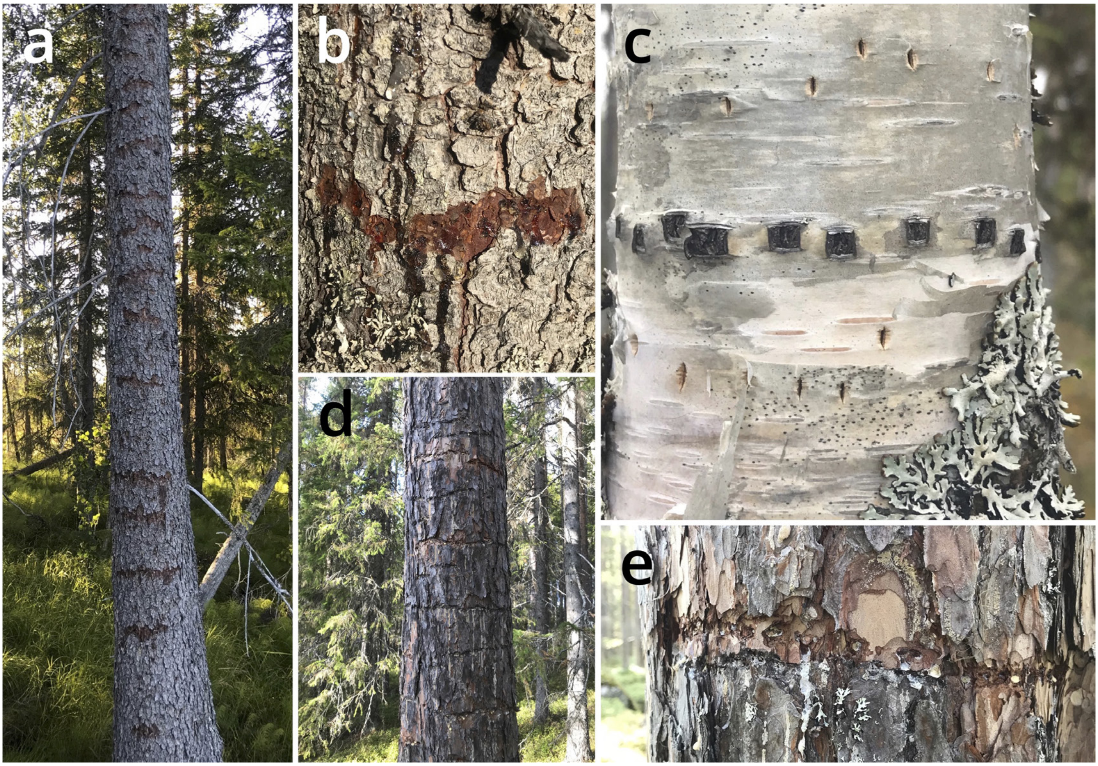

FIGURE 2. Sap rows of different ages and on different tree species, presumably made by Eurasian Three-toed Woodpeckers *Picoides tridactylus*. (**a**) Typical fairly fresh marks (<3 years) on Norway spruce *Picea abies*, where the bark is first peeled off, and holes are then pecked. There are ginger areas on each side of the sap holes. The color of these areas fade over time and they become brighter and then gradually overgrown by new bark. (**b**) Norway spruce. Sap/resin flowing out of the sap holes is a clear sign of recently made sap holes (<3 years). (**c**) A downy birch *Betula pubescens* with sap holes from the current season (small, "sharp" cuts) and sap holes that are about 5 years old (larger, darker, "squares"). (**d**) Partially overgrown sap rows on Scots pine *Pinus sylvestris*. This pine has been used for a long period of time; a closer look is needed to determine the age of the latest visit to these sap rows. (**e**) A close-up of the same pine reveals that old sap holes have been reopened, a bark flake has also been peeled off recently. The sap/resin is visible in the holes, but is not flowing, indicating it does not have to be from current season, but definitely not from very long ago (<3 years).
— *Rader med savhål i olika åldrar och på olika trädslag, förmodligen orsakade av födosökande tretåiga hackspettar* Picoides tridactylus. *(**a**) Typiska ganska färska märken (<3 år) på gran* Picea abies*, där barken först skalats av följt av hackande av hål. Det blir brunröda områden på vardera sidan om savhålen. Färgen på dessa områden bleknar med tiden och de blir ljusare och sedan gradvis övervallade av ny bark. (**b**) Gran. Sav/kåda som rinner ut ur savhålen är ett tydligt tecken på nyligen gjorda savhål (<3 år). (**c**) En glasbjörk* Betula pubescens *som visar savhål från nuvarande säsong (små, vassa snitt) och savhål som är cirka 5 år gamla (större, mörkare, fyrkantiga). (**d**) Delvis övervallade savrader på tall* Pinus sylvestris. *Denna tall har använts under lång tid, men det krävs en närmare titt för att avgöra tidpunkt för senaste besök. (**e**) Närmare inspektion av samma tall visar att de gamla savhålen öppnats igen, en barkflaga har också nyligen skalats bort. Sav/kåda är synlig i hålen, men rinner inte, så det behöver inte vara från nuvarande säsong, men definitivt inte så länge sedan (<3 år).*

sizes for Three-toed Woodpeckers using radio-tagged birds (Pechacek 2004). During the pre-nesting season, the home range varied between 42.6 and 381.7 ha. We chose to use the average of these two extremes, 212 ha, as the average home range during the season in focus here. The German study included 15 radio-tagged birds and the average recorded home range in that study was 115 ha. However, home ranges are probably generally larger in northern Sweden compared to the German Alps due to lower biological productivity, more intensively managed forests, and lower volume of dead wood in northern Sweden (Schmitz *et al.* 2015, Nilsson *et al.* 2020). The Swedish woodpeckers probably need a larger area to find the food they need. In order not to overestimate the densities, we therefore used the estimate of 212 ha as the average home range for Three-toed Woodpeckers in our calculations.

PROPORTION OF ACTIVE TERRITORIES PER YEAR

To determine the proportion of active territories in any given year of the territories found over a longer time period, we looked at data from two areas that have been carefully surveyed over several years. In a 340 km^2 (270 km^2 forest land) area in southern Finland, 195 territories were found between 1987 and 2000 (Pakkala *et al.* 2002). The proportion of active territories in a single year was on average 40% in this area. In a 100 km^2 (70 km^2 forest land) area around Forsmark, Uppland, in central Sweden, eight territories were found between 2015 and 2019, with an average of 48% active territories in a single year (own unpublished data). The area in Finland has relatively high densities (0.29 pairs per km^2) of Three-toed Woodpeckers, while the Forsmark area is located at the southern limit of the breeding distribution and holds about 0.04 pairs per km^2. We chose to use the lower of these values in our calculations, 40%, as this was based on a larger data set from areas more similar to northern Sweden than the Forsmark data. Note however, the similarity between the two studies in the recorded proportions.

SAP ROW BASED DENSITY CALCULATIONS

We calculated densities (pairs per km^2) based on sap row data as follows. Presence of fresh sap rows (<3 years old) on a route were regarded as one active territory (one pair) during any of the last three years. If the pair had been present during every year this would together with the estimated home range of 212 ha (2.12 km^2) give a density of $1/2.12=0.47$ pairs per km^2.

With on average 40% of existing territories being active in a single year this gives an annual density of $0.47 \times 0.40=0.19$ pairs per km^2. Should average proportion of occupied territories be higher than 40%, then resulting annual densities will be higher as well.

To get overall densities we then multiplied the annual density with the found proportion of routes with fresh sap rows (<3 years old). This means that if sap rows were found on all routes, the resulting density is 0.19 pairs per km^2. If sap rows were found on any other proportion of surveyed routes, the resulting density will be lower than this.

Since Three-toed Woodpeckers are well-known for making sap rows on conifers (Ruge 1968, Glutz von Blotzheim & Bauer 1980, Hess 1983, Cramp 1985, Pakkala *et al.* 2018) while there are few sources on sap rows made by Three-toed Woodpeckers on deciduous trees, we chose to calculate densities based on sap rows found on conifers only (as a minimum value) and on all trees (as a maximum value).

DENSITY CALCULATIONS BASED ON BIRD OBSERVATION DATA

It is possible to calculate densities from line transect (fixed route) data if one knows something about detectability and can correct the observed number of birds because not all birds present will be observed at any survey. In Finland, such correction factors have been developed. Within the Finnish Bird Survey, birds along line transects are recorded within and outside of a 50 m wide belt ("the main belt", 25 m on each side of the line). From data collected in this way it is possible to calculate lateral detectability. Lateral detectability is used for adjusting for the fact that an observer detects a higher proportion of the present birds close to the observer (line) than farther away from the line. Correction factors for lateral detectability were first published by Järvinen & Väisänen (1983), and the factors were updated by Lehikoinen (2014). We have used the updated factors here.

However, in order to get closer to real densities one must also correct for not all birds present being observed even very close to the observer, so-called basic detectability. We employed correction factors for basic detectability that were calculated by comparing territory mapping data with line transect data from the same areas in Finland (Rajasärkkä 2010). In Finland, birds counted along the line transect are recorded in "pair equivalents". Thus, a singing male is counted as one pair, as is a seen female (even if no male is seen or heard), while one male and one female at the same place is counted as one pair, and two males and one female are counted as two pairs, and so on. We have chosen to be somewhat more restrictive. In cases where more than one woodpecker was observed during a single km along the fixed routes, we have counted this as a maximum of one pair anyway, even if, for example, three individual birds were recorded. We did this to avoid double-counting of birds and in the end to avoid overestimation of densities and overall population size.

We calculated densities of Three-toed Woodpeckers at three different geographical scales based on observations from the fixed routes:

1) All routes within Åsele and Lycksele lappmarker (Sorsele, Malå, Storuman, Lycksele, Vilhelmina, and Åsele municipalities) below the montane forest. This corresponds to the area where we actively surveyed sap rows. We used a larger area than our actual study area in order to get a larger data set on bird observations (n=37).
2) All routes containing montane forest, i.e. both coniferous forest and montane birch forest (n=22). Here we used the border for montane forest as classified by the Swedish Forest Agency (Skogsstyrelsen 2020).
3) All routes in the province of Västerbotten, representing routes relatively close (within 125 km) to the coast (n=30).

We calculated densities for all three regions based on data from the period 2010–2019 in order both to be representative of the present situation and to be able to include enough observations. Density was calculated following Svensson (2016) as average number of recorded pairs per survey kilometer × lateral detectability [7.03] × basal detectability [1.5] = pairs per km².

CALCULATIONS OF POPULATION SIZE

Since the fixed routes are systematically spaced all over the country, including Västerbotten County, they also cover all major habitats in a proportional way. We used this relationship to calculate the forest areas for different parts of Västerbotten County. The total area of forest land in the county is 40,680 km² (Nilsson *et al.* 2020). With 22 fixed routes in the montane forest this means that almost 25% (24.7%) of the forest in Västerbotten County is montane forest, corresponding to an area of 10 048 km². The equivalent forested areas in Åsele and Lycksele lappmarker below the montane forest (41.6% of the total forest area in the county) was 16,923 km² and in the province of Västerbotten (33.7% of the total forest area in the county) 13,709 km².

We then calculated the population size of Three-toed Woodpeckers for these separate parts of Västerbotten County by multiplying the observed and calculated densities (pairs per km²) with the above-mentioned areas of forest land. We calculated population size for Åsele and Lycksele lappmarker below the montane forest both based on densities from our sap row observations and on densities based on bird observations. From the montane forest and the province of Västerbotten (coastal area) we calculated population size from densities based on bird observations. Overall population size for the whole of Västerbotten County was finally calculated by summing the observation-based population estimates for the three separate parts of the county.

Results

We found a total of 98 trees with fresh sap rows made during the last three years. Fresh sap rows on conifers were found on 21% of the routes, and fresh sap rows on birches were found on all routes (100%). On average, we found 7 (1–21) sap trees with fresh sap rows per route (Table 1).

TABLE 1. The proportion of routes, the total number of sap trees, and the number of trees per surveyed route with fresh (<3 years old) sap rows, presumably made by Eurasian Three-toed Woodpeckers *Picoides tridactylus*, on conifers, birches, and in total.
— Andelen rutter, antalet träd och antalet träd per inventerad rutt med färska (<3 år gamla) rader av savhål förmodat gjorda av tretåig hackspett Picoides tridactylus *i barrträd, björk och totalt.*

Variable *Variabel*	Conifers *Barrträd*	Birch *Björk*	Total *Totalt*
Proportion of routes with fresh sap rows *Andel rutter med färska savrader*	21%	100%	100%
Number of trees with fresh sap rows *Antal träd med färska savrader*	5	93	98
Average number of trees with fresh sap rows per route and observed range *Genomsnittligt antal träd med färska savrader per rutt och observerat intervall*	0.36 (0–2)	6.6 (1–21)	7.0 (1–21)

TABLE 2. Calculated densities (pairs per km²) and estimated overall population size (pairs) for Eurasian Three-toed Woodpeckers *Picoides tridactylus* (TTWP) in different parts of Västerbotten County.
— Beräknade tätheter (par per km²) samt skattningar av total populationsstorlek (par) för tretåig hackspett Picoides tridactylus *(TH) i olika delar av Västerbottens län.*

Area *Område*	Method *Metod*	N TTWP *Antal TH*	N routes *Antal rutter*	Pairs per km² *Par per km²*	Population size *Populationsstorlek*
Åsele och Lycksele lappmarker below montane forest *Åsele och Lycksele lappmarker, nedanför fjällnära skog*	Sap rows, only conifers *Savrader, endast barrträd*	–	14	0.040	676
Åsele och Lycksele lappmarker below montane forest *Åsele och Lycksele lappmarker, nedanför fjällnära skog*	Sap rows, all trees *Savrader, alla trädslag*	–	14	0.189	3,196
Åsele och Lycksele lappmarker below montane forest *Åsele och Lycksele lappmarker, nedanför fjällnära skog*	Fixed route bird observations *Fågelobservationer standardrutter*	20	201	0.131	2,215
Montane forest, Västerbotten County *Fjällnära skogar i Västerbottens län*	Fixed route bird observations *Fågelobservationer standardrutter*	39	136	0.378	3,801
Province of Västerbotten, coastal area *Västerbottens landskap, kustområdet*	Fixed route bird observations *Fågelobservationer standardrutter*	16	156	0.135	1,851
Västerbotten County *Västerbottens län*	Fixed route bird observations *Fågelobservationer standardrutter*				7,867

DENSITIES OF THREE-TOED WOODPECKERS

If we assume that Three-toed Woodpeckers only make sap rows on conifers, the calculated density in our study area is 0.04 pairs per km². If we assume that Three-toed Woodpeckers also make the sap rows on birches, the resulting density is 0.19 pairs per km².

When we used observations of birds on the fixed routes and applied the Finnish correction factors for lateral and basal detectability, the density in Åsele and Lycksele lappmarker below the montane forest (corresponding to our study area) was 0.13 pairs per km². The area covered by montane forest held much higher densities of Three-toed Woodpeckers, 0.38 pairs per km². In the area closer to the coast, in the province of Västerbotten, the calculated density based on observations on the fixed routes was 0.14 pairs per km² (Table 2).

THREE-TOED WOODPECKER POPULATION SIZES IN DIFFERENT PARTS OF VÄSTERBOTTEN COUNTY

The population size for Åsele and Lycksle lappmarker below the montane forest, calculated from densities of sap rows, was 700–3,200 pairs, depending on whether we use densities based on sap rows on conifers only (lower limit) or on all trees (upper limit).

The population size calculated from observations of birds on the fixed routes in the same region was 2,200 pairs. Based on the high densities, the montane forests seemingly hold the highest number of Three-toed Woodpeckers in the county: observations on the fixed routes result in a population size of about 3,800 pairs. Finally, we calculated that almost 1,900 pairs could occur in the province of Västerbotten (coastal area). Altogether, this gives an total population size of 7,900 pairs for the whole county, based on observations on the fixed routes (Table 2).

Discussion

The densities we calculated based on sap rows corresponded relatively well with the densities based on observed birds on the fixed routes in Åsele and Lycksele lappmarker below the montane forests. The densities based only on sap rows on coniferous trees were, however, markedly lower than those based on observed birds or those based on sap rows on all trees. It is well-known that Three-toed Woodpeckers make sap rows on conifers (Ruge 1968, Glutz von Blotzheim & Bauer 1980, Hess 1983, Cramp 1985, Pakkala *et al.* 2018), but we have only found one publication showing intensive use of birches for sap drinking (Bailey 2008). This study regards the North American sister species *P. dorsalis*, previously considered conspecific with the Eurasian species *P. tridactylus*. We have made own observations from the montane birch forest at Ammarnäs in Västerbotten County of Three-toed Woodpeckers making sap rows on birches, but no direct observations of the behavior in other areas. Sap rows on birches found by us so far do, however, correspond very well with the distribution of Three-toed Woodpeckers (own unpublished data), but there are of course still some uncertainties about whether all sap rows found on birches in our study area were made by this species alone.

Other woodpeckers, especially the Great Spotted Woodpecker, are also known to make sap rows, and they also do so at least occasionally on birches in Finland (Pakkala *et al.* 2018). In Sweden, however, we have not found any reports of sap rows on birches made by Great Spotted Woodpeckers. We have also not observed the specifically longer distances between sap holes made by Great Spotted Woodpeckers, proposed as a species characteristic by Pakkala *et al.* (2018). More detailed studies are needed to find out more about the making of sap rows on different tree species in northern Sweden. The similarities between densities based on sap rows and observed birds do, however, indicate that at least in the northern parts of Sweden, Three-toed Woodpeckers may primarily be responsible for the sap rows also on birches.

Presuming that most or all of the sap rows we found were made by Three-toed Woodpeckers, this also means that looking for sap rows is a more efficient way of surveying the presence of Three-toed Woodpeckers than looking for the birds themselves. We noticed that Three-toed Woodpeckers have only been observed on two of the 14 routes we searched for sap rows between 2010 and 2019, while we found fresh sap rows on all routes. It is well known that Three-toed Woodpeckers are hard to find, even in an occupied breeding territory. Therefore, using observations of sap rows could be an easier way of collecting data on the occurrence of the species. It also has the advantage that it could be done at all times of the year and also without real knowledge about the sounds made by the birds. The method could for example be used by conservationists or forest owner who want to know if Three-toed Woodpeckers occur in specific areas.

The densities based on bird observation data that we found in different parts of the county below the montane forests were relatively similar, indicating rather low but evenly distributed numbers of Three-toed Woodpeckers through a large part of the county. We could, for example, not see any signs of successively increasing densities with increasing distance from the coast. Densities in the province of Västerbotten relatively close to the coast were very similar to those further inland in Åsele and Lycksele lappmarker below the montane forest. This indicates that in the parts of the county with long-term active forestry, densities over larger areas are more or less the same. At the same time, recorded densities based on fixed route observations in the montane forests were clearly higher. The latter finding was expected, as the mountain region holds large continuous areas of intact old forest areas (Svensson *et al.* 2018), much less affected by forestry. Densities in the montane forests were about three times higher than those in other parts of Västerbotten County.

Another recent analysis (Svensson 2016) also used the Finnish correction factors and suggested that earlier calculation methods show reliable results for common species (>100,000 pairs in the whole of Sweden) but usually underestimate less common species (<100,000 pairs in Sweden), such as Three-toed Woodpeckers. Svensson (2016) suggested that the size of the Swedish population of Three-toed Woodpeckers could be five times larger than the one reported in Ottosson *et al.* (2012). Our calculations also result in higher estimates for Västerbotten County and the province of Västerbotten than those in Ottosson *et al.* (2012). Even though we used a more conservative approach when interpreting the number of observed pair equivalents per km on the fixed routes, our results indicate a regional population size that could be about three to five (2.6–4.9) times larger than the earlier estimate for the county and almost four (3.7) times larger for the province. For Åsele and Lycksele lappmarker, including the montane forest, our estimate is 3.5 times higher than the estimate by Ottosson *et al.* (2012).

The new, partly higher estimates presented here should not be interpreted as a recent increase in population size of Three-toed Woodpeckers in Västerbotten County. The difference between ours and earlier estimates instead depends on different ways of estimating the population size. It remains to be shown which estimate is closest to the true number, but we argue that the methods and calculations that we have used here are more likely to reflect reality than the partly simpler calculations made by Ottosson *et al.* (2012).

Interestingly, our estimates of regional population size are very close to what can be calculated as the possible carrying capacity for the county, based on the Three-toed Woodpecker's requirements for dead wood. An analysis of data from both Sweden and Switzerland concluded that the threshold value for a 95-percent probability of Three-toed Woodpecker occurrence is 15 m^3 of standing dead wood per ha within an area of 1 km^2 (Bütler *et al.* 2004). Using this threshold together with data on general levels of standing dead wood in Västerbotten County (approximately 11,000,000 m^3; Skogsdata, 2020) indicate a regional population capacity of 7,300 of Three-toed Woodpecker pairs.

We would like to encourage more detailed studies on both the occurrence of sap rows and of the woodpeckers themselves. This can be done, for example, through more surveys for sap rows also in parts of the county closer to the coast, as well as in forests in the mountain area. We believe that home range sizes in the mountain area are smaller compared to our study area, which is more affected by forestry. In order to find out more about woodpecker presence at a general level, the fixed routes could be used for more detailed investigations during the time of year when drumming activity is high. Using playback of species-specific drumming sounds in April, for example, could yield interesting data to be used in comparison with data from the ordinary surveys of the routes as well as findings of sap rows.

In conclusion, we find that systematic observations of sap rows can be used for calculating credible densities of Three-toed Woodpeckers. The fact that we found sap rows on all surveyed routes indicates that the Three-toed Woodpecker is well spread, albeit sparsely distributed, throughout the study area. Our density calculations based on sap rows are in good agreement with other methods, such as those based on observations of birds. The advantages of surveying sap rows instead of actual Three-toed Woodpeckers are simplicity and speed. Our method can be used by basically anyone, at any time of the year, and quickly provides densities of Three-toed Woodpeckers in any geographical area. The method can thus be valuable for both conservation and forestry.

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Svensk sammanfattning

En global nyckelfråga är hur vi kan hantera markanvändningen så att den bidrar till människors välbefinnande utan att äventyra resten av livet på jorden. Att övervaka populationsutvecklingen för hotade fågelarter är en viktig del av det arbetet. En del arter är kända för att vara diskreta och svåra att inventera – för dessa arter kan det vara värdefullt att hitta alternativa inventeringsmetoder. Tretåig hackspett *Picoides tridactylus* är en sådan art.

Tretåig hackspett trivs i äldre barrdominerade skogar rika på död ved (Hogstad 1970, Cramp 1985, Virkkala 1991, Stenberg 1996, Hagemeier & Blair 1997, Fayt 1999, Pechacek & Kristin 2004). Arten är värdefull för skogsbruket eftersom den kan ha en reglerande effekt på antalet barkborrar (Coleoptera: Curculionidae, Scolytinae), och speciellt granbarkborren *Ips typographus*, i skogen (Fayt *et al.* 2004). Tretåig hackspett anses vara svårinventerad (Winkler *et al.* 1995, Winkler & Christie 2002). Etablerade par av tretåig hackspett kan vara tysta och tillbakadragna och om de varken trummar eller lockar på varandra är de mycket svåra att hitta (Amcoff & Eriksson 1996). Tretåig hackspett är dock känd för att hacka rader av små hål, så kallade savrader, runt trädstammar på våren för att komma åt

den näringsrika saven. Här använder vi systematiskt registrerade observationer av savrader för att beräkna tätheter av tretåiga hackspettar i norra Sverige. Vi jämför sedan dessa med tätheter beräknade utifrån observerade fåglar på Svensk fågeltaxerings standardrutter (se figur 1).

Vi inventerade savrader under hösten 2020 på 14 av de 716 standardrutterna inom Svensk fågeltaxering (Green *et al.* 2020). På varje rutt gick vi en kilometer och tittade efter savrader ca 10 m åt båda håll, utan andra hjälpmedel än synen. När vi gått en kilometer vände vi och gick samma väg tillbaka. Vi dokumenterade ålder på savrader i tre olika kategorier: <3 år, 3–7 år och äldre än 7 år. Vi använde sedan andelen rutter med färska savrader (<3 år), tillsammans med genomsnittlig revirstorlek och andelen aktiva revir per år härledd från litteraturen, för att beräkna tätheter för tretåig hackspett.

Att bedöma ålder på hackmärken kan vara utmanande. På björk *Betula* sp. växer savhålen i takt med att trädet växer. Savhål gjorda innevarande säsong ser bara ut som smala jack, lite som ett kort snitt med en kniv (se figur 2c). Savhål gjorda för ett eller två år sedan är fortfarande ganska små, men klart lättare att se än helt färska savhål. Kategorin 3–7 år är oftast de lättaste att se, de syns tydligt mot den vita barken på björk, bredden på sådana savhål är cirka 3–5 mm (se figur 2c). Äldre savhål är ofta bredare än 5 mm.

Det är lättare att få syn på savrader på yngre träd med slät bark jämfört med äldre träd med mer komplex ytstruktur. Helt färska savrader och savrader på äldre träd som sitter högre upp i kronan är svårast att se.

På granar *Picea abies* ”skalas” oftast barken av först och sen hackas hålen. Detta medför att det blir ett brunrött band på båda sidor om savraden (se figur 2a). Att det kommer sav eller kåda ur hålen eller att området kring raden är brunrött är tydliga tecken på färska savhål (se figur 2b). Efter ett antal år övergår den brunröda färgen till att bli ganska ljus. Gamla savrader övervallas (se figur 2d), det är svårt att veta när de användes senast, men kommer det sav eller kåda ur hålen så har någon hackspett varit där nyligen – annars är sådana savrader troligen äldre än 7 år (se figur 2e). Det finns exempel på träd som nyttjats som savträd av tretåig hackspett i mer än hundra år (Ruge 1968).

Märken på tall *Pinus sylvestris* liknar de på gran men är enligt vår bedömning svårare att upptäcka då färgskillnaden där barken skalats bort inte skiljer sig så mycket från resten av trädet. Tidigare studier har visat att cirka 20 % av nya savhål görs i de gamla hålen (Pakkala *et al.* 2018). Sådana hål är ofta svåra att upptäcka. I osäkra fall har vi valt en äldre kategori för observationerna.

Vi hittade färska savrader (<3 år) på barrträd (gran och tall) på 3 av 14 rutter (21 %), medan samtliga rutter hade färska savrader på björkar (tabell 1). Om tretåig hackspett bara gör savrader på barrträd var den beräknade tätheten 0,04 par per km^2. Om tretåig hackspett också gör savraderna på björk var den beräknade tätheten 0,19 par per km^2 (tabell 2). Vi jämförde våra beräknade tätheter baserade på observerade savrader med tätheter baserade på observationer av själva fågeln från den ordinarie inventeringen av standardrutterna, som görs i juni månad varje år.

Vi beräknade tätheter för tre olika delar av Västerbottens län. Baserat på observationer av fåglar på standardrutterna, korrigerade med faktorer för upptäckbarhet (beräknade i finska studier), var tätheten inom Åsele och Lycksele lappmarker men nedanför den fjällnära skogen (där vårt studieområde ligger) 0,13 par per km^2 för perioden 2010–2019. De högsta tätheterna fann vi som förväntat i den fjällnära skogen, där det var 0,38 par per km^2 2010–2019. I det mer kustnära landskapet Västerbotten var motsvarande resultat 0,14 par per km^2.

Det är fortfarande osäkert om alla hittade savrader på björkar i vårt studieområde verkligen har gjorts av tretåig hackspett. Även andra hackspettar, särskilt den större hackspetten *Dendrocopos major*, gör savrader, och större hackspett gör det också ibland på björkar i Finland (Pakkala *et al.* 2018). Mer detaljerade studier behövs för att ta reda på mer om vilka arter som kan göra savrader på olika trädarter i norra Sverige. Likheterna mellan tätheter baserade på savrader och observerade fåglar tyder dock på att tretåig hackspett är ansvarig för huvuddelen av savraderna även på björkar i norra Sverige.

Vi beräknade även populationsstorlekar av tretåig hackspett för de tre delarna av Västerbottens län. För Åsele och Lycksele lappmarker nedanför de fjällnära skogarna beräknade vi total populationsstorlek både baserat på observationer av savrader (700–3 200 par) och bokförda fåglar på standardrutterna (2 200 par). För övriga delar använde vi enbart tätheter baserade på observationer av fåglar på standardrutterna. I de fjällnära skogarna beräknar vi att det bör finnas 3 800 par av tretåig hackspett. I det mer kustnära landskapet Västerbotten gav våra beräkningar en total populationsstorlek på knappt 1 900 par. Sammantaget innebär detta att det kan finns ca 7 900 par tretåig hackspett i hela Västerbottens län (tabell 2). Denna skattning kan jämföras med tidigare skattningar på 1 600–3 000 par i Västerbottens län av Ottosson *et al.* (2012). De nya, högre skattningen som presenteras här ska inte tolkas som om antalet tretåiga hackspettar har ökat i Västerbottens län under senare år. Skillnaden beror i stället på olika sätt att beräkna den totala populationsstorleken. Vilken beräkning som ligger närmast verkligheten återstår att se, men vi tror att de metoder och beräkningar vi har använt ligger närmare sanningen än de delvis enklare beräkningarna gjorda i Ottosson *et al.* (2012).

Det vore intressant att göra mer detaljerade studier av frågorna i fokus här. Detta kan till exempel göras genom fler inventeringar av savrader, både närmare kusten och i mer fjällnära skogar. Ett annat sätt kunde vara att använda standardrutterna för mer detaljerade undersökningar av förekomsten av själva fåglarna under den tid på året när trumaktiviteten är högre. Att använda förinspelade trumljud i april skulle exempelvis kunna vara värt att prova.

Sammanfattningsvis har vi visat ett det går att bedöma tätheter av tretåig hackspett på ett trovärdigt sätt genom systematiska observationer av savrader. Våra resultat indikerar att den tretåiga hackspetten är ganska jämnt spridd, om än glest förekommande, över hela Västerbottens län men med betydligt högre tätheter i den fjällnära skogen. Våra beräknade tätheter med olika metoder stämmer relativt väl överens med varandra, men fördelen med att räkna savrader istället för tretåiga hackspettar är enkelhet och snabbhet. Metoden kan i praktiken utföras av vem som helst, under alla tider på året och ger snabbt uppgifter om tätheter av tretåig hackspett över stora geografiska områden, vilket är värdefullt för både naturvården och skogsbruket.