Ornis Fennica 100: 51–60. 2023

The Mistle Thrush (*Turdus viscivorus*) in a production forestry context: A territory mapping study

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Received 14 July 2022, accepted 25 January 2023

In Northern Europe, the Mistle Thrush (*Turdus viscivorus*) is a relatively poorly studied species inhabiting forested landscapes where it has historically experienced population declines. Those declines have been attributed to the spread of intensive forest management; yet, the populations have stabilized or increased in recent decades. To distinguish the main forestry impacts on its breeding numbers and distribution, a multiple-visit territory-mapping study was carried out over 15 km^2 of production forest landscape in Estonia. At the landscape scale, the breeding distribution was concentrated to conifer forests on bog peat where the densities were five times higher than in other conifer forests and (at least) ten times higher than in non-conifer forests. This reveals a broad distribution pattern where high-density (core) habitats only host a small fraction of the total population; their relative contribution to the recruitment remains unknown. At the breeding territory scale (within 150 m from a nest), Mistle Thrushes avoided recent clear-cuts and preferred larger areas of old stands more than expected from the distribution of suitable stands for nesting. This indicated that, in a short term, clear-cutting reduces nesting habitats of this species disproportionately more than expected from the cut area alone; this is in accordance with the documented 20th century declines of the species in Fennoscandia. The relationship with forestry drainage is more complicated, however, due to delayed effects and covariation with the main breeding habitat. The basic ecology of the species in conifer forest-wetland landscapes, which are subjected to management pressures, warrants future studies and might provide general insights into the dynamics and functioning of these ecosystems.

1. Introduction

Among the Palaearctic thrush species, the Mistle Thrush (*Turdus viscivorus*) has remained relatively poorly studied, although its status has repeatedly raised broader ecological questions. Thus, while it was formerly known as an elusive bird of old conifer forests, it spread to the West-European countryside and urban settlements in the 19th to 20th century (*e.g.*, Peus 1958, Snow 1969). That spread has recently reversed to a partial decline, at least in the British countryside where the Mistle Thrush is becoming confined to urban areas (Mason 2000). During approximately the same time period, the populations in boreal forests declined – but then partly recovered – along with the transformation of near-natural landscapes into production forest. For example, the Finnish Mistle Thrush population declined 2.5-fold between 1945 and 1975, which was attributed to the extensive logging of old stands (Järvinen *et al.* 1977). It has not been explained why this decline was followed by an increase and stabilization (Fraixedas *et al.* 2015).

Despite such intriguing trends and a general understanding of the breeding biology of the Mistle Thrush, its actual breeding densities and their variation across landscape gradients and transformation have been rarely measured. At least in Northern Europe, a challenge is posed by the mobility of the species within its home range, so that single-detection based counts in small plots or narrow strips (*i.e.*, point counts and transect counts) are of uncertain reliability (*e.g.*, Kuus 2018). In turn, multiple-visit territory mapping techniques are laborious at the landscape scale; in European forest birds, these have been used mostly for plot-scale assessment (Mikusiński *et al.* 2018). Thus, actual landscape distributions of breeding Mistle Thrushes based on comprehensive surveys are better documented for the West-European countryside (*e.g.*, Mason 2000, Vowinkel 2009) than in the North-European forest landscapes.

In this paper, I describe a breeding population of Mistle Thrushes in a production forest landscape in Eastern Estonia. The Estonian forests constitute a heterogeneous transition between the boreal (conifer) and temperate (broad-leaved) forest zones, with a strong ecological imprint of clear-cutting based forestry since the 19th century (*e.g.*, Lõhmus *et al.* 2004, 2016). In the second half of the 20th century, this was accompanied by an ecologically controversial expansion of forest land due to broad-scale draining of mires. In these landscape mixtures, Mistle Thrushes are mostly found in Scots pine (*Pinus sylvestris*) dominated stands, but reliable density estimates and an understanding of the forestry pressures are missing (Kuus 2018).

To fill these gaps, I mapped breeding Mistle Thrushes on a large transformed forest landscape, which included drained mires increasingly integrated into the even-aged silvicultural system. I specifically ask how the Mistle Thrushes are distributed in relation to clear-cutting and drainage, which are changing the age structure, landscape pattern, and tree-species composition of the forests.

2. Material and methods

2.1. Study area and field methods

The analyses are based on territory centres (ideally, nests) mapped at the landscape scale using multiple-visit surveys. All the field work, data interpretation and analysis were performed by the author.

The study area was situated in East Estonia, along River Ahja (Fig. 1). The total area was 1473 ha, including 1197 (81%) of forest land that was almost entirely managed for timber production using clear-cutting based approaches. The management exceptions were *ca.* 10 ha of key habitats recently protected in state forests, and some private forests, the owners of which were not focused on timber-related income. In Estonia, typical timber harvest rotations range from *ca.* 60 years in deciduous or mixed stands on the most productive sites to *ca*. 120 years in pine forests on the poorest soils; this produces an unbalanced site type representation within stand age classes.

The landscape included several bog areas embedded in the forest (Fig. 1), which had been densely ditched in the 1960s; the drainage systems were renovated again in the 2010s. The total area of those bogs (ombrotrophic and mixotrophic combined) was 353 ha (23% of the total) and no open bog remained at the time of the study: 273 ha was categorized as ‘forest’ on the Estonian base map and the rest was transitional wooded bog. The woodland cover of the bogs was mostly Scots pine; the pine was also more common than Norway spruce (*Picea abies*) in other conifer forests outside the bogs (824 ha). In contrast, the spruce was more common in mixtures with deciduous trees on productive soils.

The study area was surveyed in three adjacent parts (Fig. 1). The central part (413 ha) was mapped in each year, 2020–2022; an analysis of its total breeding bird assemblage in 2020 has been published (Lõhmus 2020). The northern area

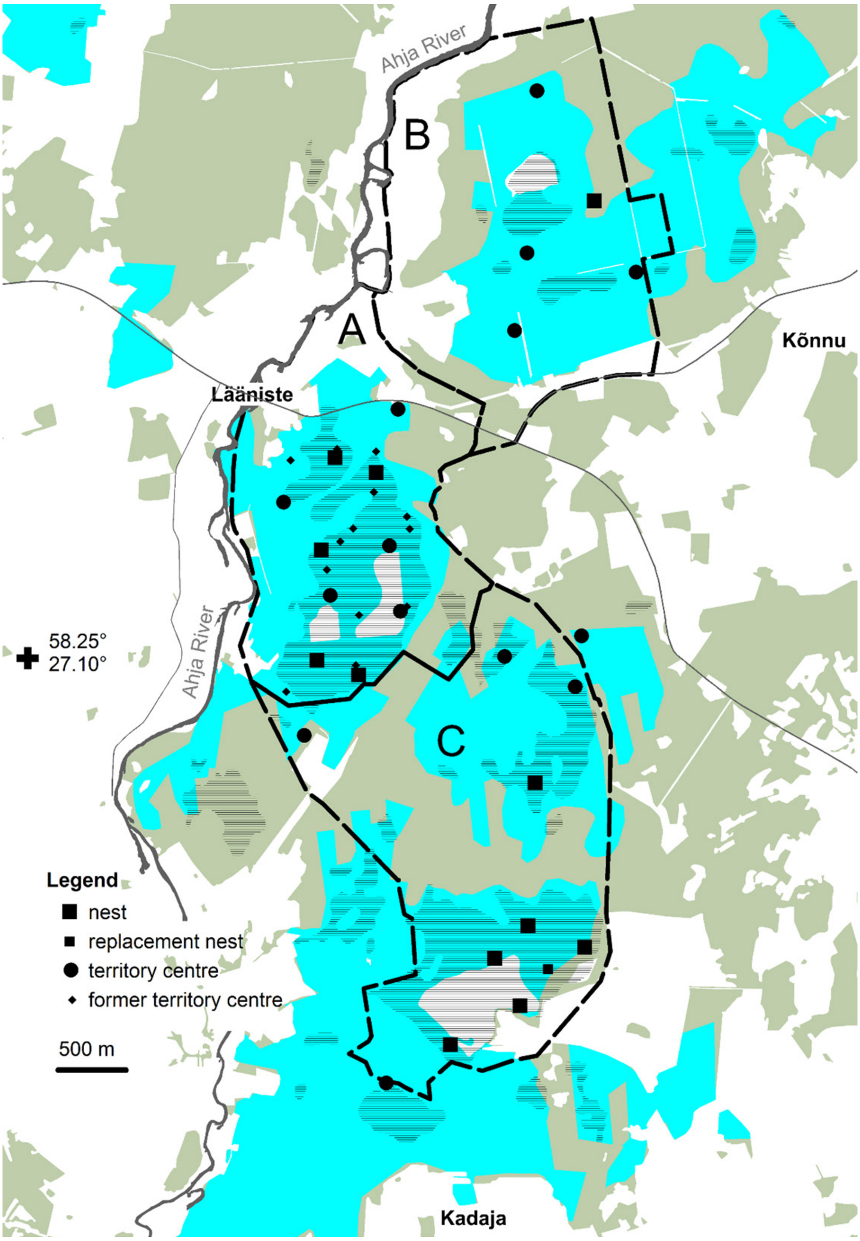

Fig. 1. The study areas and breeding territory distribution of *Turdus viscivorus* in three adjacent East-Estonian landscapes. For the area A, the large symbols depict 2022 results; the small symbols are from 2020–2021. For the areas B and C, the symbols refer to years 2021 and 2022, respectively. The coloured areas are forests, with conifer forests (source: CORINE 2018 land cover) distinguished in blue colour and bog areas shaded (Fibric and Hemic Histosols; source: Estonian soil map).

(483 ha) was only mapped in 2021 and the southern area (576 ha) in 2022. The basic method was a multiple-survey mapping of all breeding birds based on conventional techniques (Tomiałojć 1980) with an average 7–8 visits from mid-April to late June. Specifically, in the Mistle Thrush, this was accompanied by nest searching also after the nesting season, which allowed to roughly

establish survey effectiveness. Thus, in two years in the central area, six pairs were detected in the basic surveys and one pair was added after re-interpretation of the nests found (Lõhmus 2022a). Also, each landscape was briefly visited in late March and early April to detect early presence of singing birds. For the paper, those additional observations and nest records have been included, and I consider total survey errors exceeding 10% unlikely in any landscape.

I followed conservative rules when assigning territories because Mistle Thrushes can be highly mobile even during a single survey, its spring migration partly overlaps with the early breeding season, and there is uncertainty about the presence of second clutches in Estonia (see below). Thus, without nests or simultaneous observations, I did not consider inter-observation distances <300 m sufficient for distinguishing territories even if these seemed to form separate clusters. Most recorded territories were eventually based on at least 4–5 observations, the type and spatial arrangement of which was used to assign a territory (activity) centre when no nest was found.

2.2. Data processing

All the observations and territory delineations were digitalized in a geographical information system. The subsequent map analysis was performed at two spatial scales, using MapInfo Professional version 10.5 (Pitney Bowes Software Inc. 2010) and publicly available data sources. In the case of recent forest management operations, the latter were updated based on my field records.

2.2.1. Landscape-scale distribution

A landscape-scale assessment was based on breeding densities (no. of nests and territory centres) among some major land cover types, replicated among the three study area parts (Fig. 1). For the central part, I only used the last (2022) field mapping. The aim of the assessment was to characterize broad density variation of the species by land cover classes across the landscape. Based on the species' biology, I distinguished: (i) 'forests' based on the Estonian 1:10,000 basic map provided by the Land Board (accessible at https://geoportaal.maaamet.ee); on this map, clear-cuts, forest rides and small forest roads are included in the forest area; (ii) 'coniferous forests' as the overlap of forests and the relevant land cover type (312) of the CORINE Land Cover 2018 map (accessible at https://land.copernicus.eu); (iii) bog areas based on the Estonian soil map (provided by the Land Board) as Fibric Histosol (ombrotrophic bog) or Hemic Histosol areas (mixotrophic bog). This assessment was obviously constrained by the actual areas mapped (sample sizes; presence and configuration of certain land cover types). Thus it could not be fully formalized beforehand – it is rather a post-hoc interpretation of the distribution map, which should be tested elsewhere.

2.2.2. Nest-site preferences

At a smaller scale, I compared clearcutting- and drainage-related variables within 150 m radius around 22 Mistle Thrush nests and accompanying background points. The analysis was based on nests only because of the uncertainty of the locations of those territory centres, which are based solely on observations of singing or calling birds (Lõhmus 2022a). Also, although repeated observations can roughly indicate territory borders, such delineation is unreliable due to multiple sources of error. The 150-m radius approaches half of the shortest observed nearest neighbour distances as recorded in the central and southern areas where I had multiple nest founds. From the nests of different years in the same area, I also included only those that were at least 150 m apart or in another forest stand.

Because the nest-site analysis aimed at complementing the landscape analysis, each background point location was restricted to a site similar to the nest in terms of its broad habitat type. The locations were established through the same procedure: the point closest to 300 m (but no less) and to a cardinal direction in a potentially suitable stand and at least 300 m away from any other nest or background point. 'Potentially suitable stand' was defined as of the same broad land cover class (conifer on peatland; other conifer; non-conifer; wooded mire) and at least

90% of the age of the actual nest stand. In the case of multiple options, I selected the location away from the plots selected for other nests. Overall, it was a conservative approach to habitat selectivity, since at least two background points were situated close to probable territory centres where the nests had not been found.

In a 150-m circle (7 ha) surrounding each nest or background point, I analyzed the age structure of surrounding forest stands, the total length of the ditch network (including straightened streams) and distance to the nearest ditch using SQL queries and the Distance Calculator tool of the MapInfo software. The age structure was expressed as the relative area of four stand-age classes, with post-clearcut open areas (0–15 years of age) and stands above minimum rotation age (>80 years) as extremes, and approximate end of self-thinning (*ca.* 40 years) distinguishing the two classes in between. Area of wooded mire was initially considered, but omitted from multi-factor analysis due to its strong relationship with the distance to the nearest ditch ($r = 0.71$, $n = 44$, $p < 0.001$). I updated the original stand age data (age of the dominant tree layer in the breeding year) provided by the Estonian Forest Registry with fresh logging data. The ditches were analyzed as revealed on the Estonian base map.

After checking for the collinearity of the measurements (factor variables), I looked for the best logistic model (factor variable subset) for explaining nesting probability, *i.e.*, difference between the nest plots and background plots (binomial dependent variable). The prioritization was based on AICc values of alternative models, which were calculated using the function dredge (MuMIn package; Barton & Barton 2019); factor significance was estimated based on the likelihood ratios. The relationship between the nesting probability and the best explanatory factor variable was plotted using visreg (Breheny & Burchett 2017).

3. Results

3.1. Landscape-scale distribution

In total, I registered 24 Mistle Thrush breeding territories in the landscapes in 2021 (northern part) and 2022 (central and southern part) (Fig. 1). Based on territory centres, the landscape-scale density variation was more than ten-fold in forests: from 0.5 territories km^{-2} in non-conifer forests to 5.5 territories km^{-2} in conifer forests in bogs (Table 1). In the central and southern parts of the area, where the latter (optimal) habitat covered >100 ha, the density estimates were consistent: 6.6 and 5.4 territories km^{-2}, respectively. Outside forests, the Mistle Thrush only inhabited wooded bogs for which my sample was very small – the two pairs recorded in a total of 80 ha provided a tentative estimate 2.5 pairs km^{-2}.

Three shortest nearest-neighbour distances,

Table 1. Recorded breeding densities of the Mistle Thrush by land cover classes and study area part (not shown for <100 ha areas marked with asterisks). See Fig. 1 for the distribution of the pairs on the landscape.

		Territories/km^2 (total no. of territories)				Total area (ha)
	Land cover class	Central	Northern	Southern	Total	
	Total area	2.4 (10)	1.0 (5)	1.6 (9)	1.6 (24)	1472.6
1	Forest land	2.8 (9)	1.4 (5)	1.6 (8)	1.8 (22)	1197.4
1a	Conifer forest	3.4 (9)	1.7 (4)	2.1 (7)	2.4 (20)	824.3
	Non-bog conifer forest	0.7 (1)	1.9 (4)	0 (0)	0.9 (5)	551.4
1b	Non-conifer forest	(0)*	0.8 (1)	0.5 (1)	0.5 (2)	373.1
2	Area on bog soils	6.2 (9)	(0)*	4.5 (8)	4.8 (17)	353.0
2a	Conifer bog forest (1a∩2)	6.6 (8)	(0)*	5.4 (7)	5.5 (15)	272.9
2b	Wooded mire (2–2a)	(1)*	(0)*	(1)*	2.5 (2)	80.1

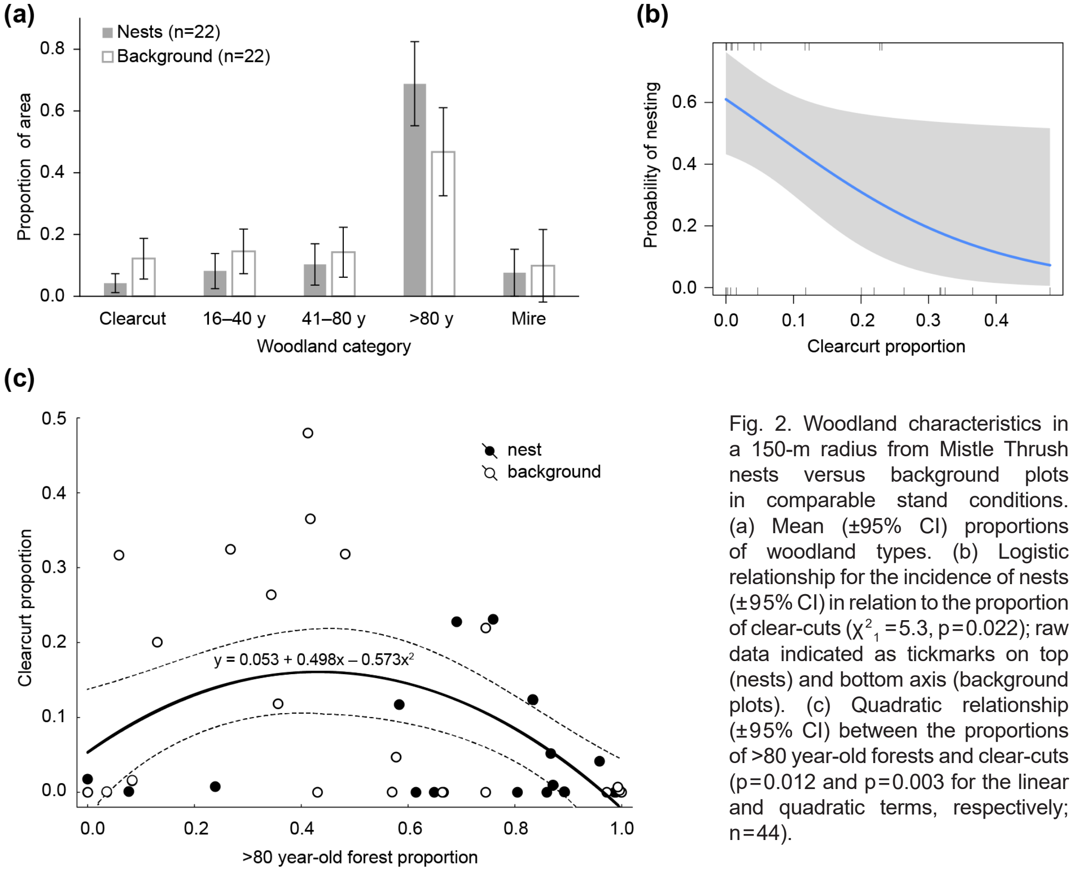

Fig. 2. Woodland characteristics in a 150-m radius from Mistle Thrush nests versus background plots in comparable stand conditions. (a) Mean (±95% CI) proportions of woodland types. (b) Logistic relationship for the incidence of nests (±95% CI) in relation to the proportion of clear-cuts ($\chi^2_1 = 5.3$, $p = 0.022$); raw data indicated as tickmarks on top (nests) and bottom axis (background plots). (c) Quadratic relationship (±95% CI) between the proportions of >80 year-old forests and clear-cuts ($p = 0.012$ and $p = 0.003$ for the linear and quadratic terms, respectively; $n = 44$).

as measured between nests found, were within a range of 300–350 m. Yet, according to the observations, neither defended territories nor foraging areas were located symmetrically around nests.

3.2. Nest sites

Of the 22 found nests that were considered spatially independent data points, only two were situated in non-bog sites. These two were also the only nests in mid-aged stands: a 28 year-old *Vaccinium myrtillus*-type pure pine stand and a 41 year-old drained *Filipendula*-type spruce-pine mixture; both of high productivity (estimated annual increment 10–12 m^3 ha^{-1}; the Estonian site productivity index Ia–I). Among the 20 bog sites, 17 nests were located in drained mixotrophic bog forests, with a mean age 98 ±13 (SD) years (range 83–128 years). Those sites were of variable timber productivity: seven were poor sites (annual increment 1.5–2.9 m^3 ha^{-1}; productivity index V–Va) and the rest were medium-productivity sites (2.7–4.9 m^3 ha^{-1}; III–IV). Finally, three nests were at the edges of the wooded ombrotrophic bog of the southern area, no more than 50 m from what was categorized as bog forest (age range 106–119 years) on the base map.

There was only one active nest that was apparently a replacement clutch after the first clutch was lost early in the breeding season. I obtained no evidence of 2nd broods but, in some breeding territories, the males were heard actively singing in late June. The nests themselves were distinct from those of the other thrush species in the area, for they were abundantly camouflaged with fruticose and pendulous lichens. Another peculiarity was frequent nesting in drained pine bogs on suppressed (smaller) dead pines and pine stumps, 3.4 ±1.5 (SD) m from the ground

Table 2. The most informative logistic regression models (ΔAICc < 2; no. 1–5) distinguishing Mistle Thrush nest plots (n=22) from otherwise similar background stands (n=22). Model p-values are based on log-likelihood (LL) differences from the null model (0; no fixed variables).

Model no.	Parameter estimates					Model performance		
	Intercept	Relative forest area within 150 m			Distance to ditch (m)	LL (df)	AIC_c	p
		Clearcut	>80 yr	16–40 yr				
0	0.00					–30.5 (1)	63.1	
1	–0.59	–5.360	1.679			–26.3 (3)	59.2	0.015
2	0.83	–6.511		–3.231		–26.6 (3)	59.9	0.021
3	0.45	–6.247				–27.9 (2)	60.0	0.022
4	–1.21		2.061			–28.0 (2)	60.3	0.025
5	–2.19		2.950		0.009	–27.0 (3)	60.8	0.033

(nine nests), which were prone to fall either due to heavy lean or partly rotten base (Fig. S1 in the online only supplementary materials). Twelve nests were on live pines, with a mean diameter at breast height 23.6 ±6.2 cm, at height 5.9 ±2.2 m from the ground. One nest was on a live birch and one on a live spruce.

Woodland areas within 150 m from nests contained less clearcut and more old-forest area than background plots in otherwise similar stands (Fig. 2). Their univariate relationships also comprised two of the best five logistic regression models (within ΔAICc<2); the overall top model was based on both of these factors (each contributing at $p<0.1$; likelihood-ratio test); and one of these was alternatively present in each of the two remaining top models (Table 2). Accounting for the (non-linear) relationship between these two main factors revealed that the thrushes tolerated some clear-cut area around nest only at simultaneously high proportion of old forest (Fig. 2c). The only other effects included in the top models, each once, were a negative relationship with the area of 16–40 year-old stands (combined with the area of clear-cuts) and a positive relationship with the distance to the nearest ditch (combined with the area of old stands). The total length of the ditch network did not contribute to the top models.

For the area of >80 year-old stands (the main and preferred nesting habitat), the factor collinearity analysis revealed two ecologically notable patterns. (i) This variable had a stronger negative relationship with the area of mires (omitted from the multi-factor modelling) among the nest plots ($r=-0.53$, $n=22$, $p=0.011$) than among the background plots ($r=-0.38$, $n=22$, $p=0.080$). (ii) The >80 year-old stands were generally situated in more densely drained parts of the landscape, as their areas in background plots were larger where ditches were closer ($r=-0.44$, $n=22$, $p=0.040$). However, that relationship was even clearer in the nest plots ($r=-0.70$, $n=22$, $p<0.001$). A similar contrast was seen for the old-forest correlation with the density of the ditch network ($r=0.12$, p=n.s. and $r=0.50$, $p=0.018$, respectively).

4. Discussion

In the Estonian production forest landscape, Mistle Thrushes were nesting in habitats vulnerable to intensive forest management. The specific patterns detected were: (i) the importance of old pine-dominated bog forests and (ii) avoidance of adjacent clear-cuts, while (iii) no direct negative influence of the forestry drainage was detected. Instead, (iv) the drainage systems co-varied with the nesting areas on the landscape and their vicinity was specifically preferred by the thrush. Thus, the short-term effect of the bog drainage on this species is positive and can create high-density patches (see below). The mechanisms involved may be the functioning of ditch banks as foraging grounds and better shade provided by the denser post-drainage stand. Independent data supporting this hypothesis comes from a Finnish mire restoration study where the species was absent in pristine areas, but several pairs were found in degraded areas, also in a short time perspective after restoration (Alsila *et al.* 2021).

However, those positive forestry drainage impacts are probably partly transient, which introduces instability and uncertainty to the Mistle Thrush population dynamics. First, during the first decades after bog drainage, the overgrown open areas do not yet provide nesting habitat and may lose some value as foraging grounds. This is supported by a Finnish landscape-scale survey where any possible positive drainage effects were far outweighed by negative clear-cutting effects on this species (Väisänen & Rauhala 1983). Also, my study confirmed that the clear-cutting effects extend beyond the area logged and are pronounced within at least the 150 m distance measured. Both these effects are also plausible for explaining the large historical decline of the Fennoscandian populations (Järvinen *et al.* 1977). Secondly, long-drained pine mires on more fertile soils typically undergo an irreversible regime shift after clear-cutting, transforming these into spruce-deciduous mixtures on decayed peat (Lõhmus *et al.* 2015). Such transformation-prone sites formed half of all the nest sites on bog soils in my study. Their perspective is to be lost as nesting habitat for the species during the coming decades.

Such ecological characteristics of the Estonian breeding population of the Mistle Thrush are clearly closer to its conspecifics in Fennoscandia than those in West Europe (see also Introduction). How exactly the coniferous and bog habitats shape its ecology in North Europe is still poorly known. Apparently, the Mistle Thrush has a distinct diet there. A study in different biomes in European Russia distinguished large beetles as the main prey in the breeding season, with minor shares of large moths and other insects (Prokofyeva 2006). In Estonia, pine-dominated production forests on mineral land are not poorer than other forest types in such insect biomass, but calcium availability (snails) may be limiting birds there (Rosenvald *et al.* 2011). However, the food base in (drained) bog forests has not been specifically studied. According to my observations, Mistle Thrushes often forage on ground in clearcuts and thinned forests, particularly since the second half of the breeding period. Its breeding performance in (hemi)boreal bogs and conifer forests may be thus limited by early-season conditions, which may be further linked to why second clutches are rare (not confirmed by me; mentioned as likely by Rootsmäe & Veroman 1974). For comparison, Blackbirds (*Turdus merula*) in the same study landscape (but nesting in much more productive sites) usually had two and, rarely, even three clutches (Lõhmus 2022a).

In terms of population distribution, my key finding was that conifer forests on bog peat had Mistle Thrush densities five times higher than other conifer forests and (at least) ten times higher than non-conifer forests. Such unequal distribution is supported by some other Estonian surveys (unfortunately based on small samples). Thus, my estimate 5.5 pairs/km^2 for drained bog forest is close to the 5 pairs/km^2 in similar forests in south-western Estonia (Kiis 2020). The estimate 0.9 pairs/km^2 for non-bog conifer forests matches a line-transect estimate in Hiiumaa Island (Väli & Laurits 2006). At the landscape scale, a line transect study suggested 2,200 pairs in the forest-rich Pärnu county, Southwest Estonia (Ellermaa 2003), which has 831 km^2 of conifer forest (as defined in the current study). At 2.4 pairs/km^2, the latter implies *ca.* 2,000 pairs in conifer forests (and perhaps 3,000 pairs altogether) – estimates reasonably close to Ellermaa's (2003).

Extrapolating these habitat-specific densities all over Estonia indicates that only a small proportion of Mistle Thrushes currently nest in distinct high-density habitats. Thus, conifer forests on bog peat cover only *ca.* 760 km^2 (*ca.* 4000 pairs), while other conifer forests encompass at least 6,700 km^2 (> 6,000 pairs?) and non-conifer forests *ca.* 16,000 km^2. Adding transitional wooded mires, where local densities probably vary much, supports the current national population assessment, 15,000–25,000 pairs (Kuus 2018). High-density habitats might provide *ca.* 20% of this. It is not clear how common such ratio might be in this species or in other bird species with sparse distributions (Bernstein *et al.* 1991), and what is the share of recruitment of the Mistle Thrush in the high-density habitats (*cf.* Johnson 2007). For example, in Poland, the species remains by far the most fragmentation prone thrush species (minimum forest size needed estimated at 25 ha;

Cieslak 1991), but its breeding densities are much more stable throughout pine-forest succession after 30 years of age (Zawadzka *et al.* 2018) than in my study. Again, the reason of weaker stand-age dependence is unclear but it may be related to a more abundant prey base at southern latitudes. Weaker food limitation, accompanied with higher reproduction rates (multiple clutches), may have also supported the historical adaptation of the southern populations to landscape transformation.

In conclusion, northern populations of the Mistle Thrush constitute an interesting model of species responses to the two regionally dominant forestry-related drivers of the landscape change – logging and artificial drainage. Even in this simple system, their impacts on populations are not independent and straightforward, particularly over longer (decadal) time frames. While peatland drainage can support high-density habitats for the Mistle Thrush for many decades, these can be irreversibly lost later. In contrast, logging may cause rapid habitat loss, but the dynamics may reveal alternative outcomes after 30–40 years depending on the silvicultural focus on conifer species, rotation lengths, and the set-aside system. Understanding the mechanisms and rates of such population responses can significantly improve the current assemblage-scale models of those changes (Lõhmus 2022b).

Kartläggning av dubbeltrastens (*Turdus viscivorus*) revir i ett skogsbrukslandskap

I norra Europa är dubbeltrasten (*Turdus viscivorus*) en relativt undermåligt studerad art som bor i skogslandskap och vars populationer historiskt sett har minskat. Populationsminskningarna har kopplats till intensifieringen av skogsbruket, men minskningarna har avtagit eller stabiliserats under de senaste årtiondena. För att urskilja skogsbrukets effekter på dubbeltrastens häckande par och deras distribution har jag gjort en revirkartläggningsstudie i en 15 km^2 stor produktionsskog i Estland. På landskapsnivå var häckningsdistributionen koncentrerad till barrskogar på torvmyrar där tätheterna var fem gånger högre än i andra barrskogar och (minst) tio gånger högre än i andra skogstyper. Detta innebär att häckningsdistributionen är bred men där kärnhabitat med höga densiteter bara utgör en en liten del av hela populationen och deras relativa kontribution till rekrytering av nya häckare är fortfarande oklar. På häckningsrevirnivå (inom 150 m från boet) undviker dubbeltrastar kalhyggen och föredrar större områden med äldre trädbestånd mer än vad som förväntas baserat på distributionen av passande bestånd för häckning. Det här innebär att kalhyggen minskar andelen lämpliga häckningsrevir oproportionerligt mycket mer än vad som förväntas baserat på kalhyggets storlek, i enlighet med dokumenterade populationsminskningar i Fennoskandien under 1900-talet. Kopplingen till skogsdikning är mer komplicerad på grund av fördröjningseffekter och samvariation med habitatet i själva häckningsreviret. Fortsatta studier av dubbeltrastens ekologi i barrskogsvåtmarker under olika typer av användningsgrad kan ge generella insikter om dessa ekosystems funktioner och dynamik.

Acknowledgements. The Estonian Environmental Agency provided access to the National Forest Register. Kadri Runnel helped with the procedures in R. Emma Vatka, Patrik Karell and an anonymous reviewer constructively commented on the manuscript. The Estonian Research Council provided financial support (grant PRG1121).

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Online supplementary material

Supplementary material available in the online version of the article includes Figure S1.