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Assessing Relationships Between Deer (Cervidae) Damage and Stand Structure of Scots Pine (*Pinus sylvestris*) Stands in Hemiboreal Latvia

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Abstract: Intensive forest management has promoted an increase in deer (Cervidae) population density. Various silvicultural activities, such as pre-commercial thinning, can change the feeding conditions for deer species, therefore impacting browsing pressure on target tree species. In this study, we analyzed how several factors, including the density of the main tree species, admixture, undergrowth, and forest type, affect deer damage intensity in pine stands, considering deer densities and regional aspects in hemiboreal Latvia. GLMM analysis, based on data from 1238 sample plots, showed that the probability of browsing damage decreases with an increase in the density of undergrowth in young (<20 years) pine stands with a dominant height below 3 m. Also, the probability of pines being damaged by deer was significantly ($p = 0.001$) higher in stands with fresh pre-commercial thinning than in those with no thinning. However, differences in deer density between regions also determined browsing pressure. Results indicated that undergrowth density, pre-commercial thinning, and deer density may be important drivers of damage levels, especially in the winter browsing of young pine stands on wet mineral soils. Therefore, future research should continue to evaluate applied forest management strategies in hemiboreal forests that provide additional natural food base in the form of woody plants and shrubs in winter forage to ensure more deer-adapted practices.

Keywords: browsing damage; moose; red deer; roe deer; pre-commercial thinning; forest types; undergrowth

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1. Introduction

Due to the extensive forest resources in the Nordic–Baltic region, the forestry sector has had a traditionally high economic role within the region, providing wood-based products [1]. As important forests supporting multiple European Union (EU) policies related to climate, biodiversity, and other environmental initiatives [1], over the last three decades, forest management in the Baltic states has focused on maximizing forest productivity [2]. Various management practices have been applied, such as the careful selection of tree species, targeted soil preparation to improve plant growth conditions and survival, and also optimizing planting densities. Additionally, different silvicultural activities are taking place in these intensively managed forests, including site preparation, planting and reforestation, thinning, and others [3].

Intensive forest management has promoted an increase in the proportion of immature stands whose various stages of development provide a preferred food supply for the ungulates [4–6] and, thus, is one of the reasons for the increase in some ungulate populations in Europe, such as red deer (*Cervus elaphus* L.), roe deer (*Capreolus capreolus* L.), and moose (*Alces alces* L.) [7]. In Latvia, wild deer (Cervidae) populations are very high; for example, the estimated number of red deer has tripled between 2000 and 2021 [8]. Dense ungulate populations have led to more frequent contact with humans [7,9], such as collisions with vehicles [10,11] and damage to the agricultural and forestry sectors [12,13]. In Sweden, an analysis of data on how ungulate population density affects the risk of damage to young trees was carried out, and Pfeffer et al. (2021) concluded that regional differences in ungulate population density are essential, as well as food competition between these ungulate species [14].

Interspecies competition among ungulate populations can change the feeding behavior of these animals [5,15]. Under conditions of increased feeding competition during the growing season, moose, which are typical woody plant eaters, may include less-palatable plants, such as grasses, in their diet, while in winter, such conditions increase the consumption of shrubs and undergrowth, which promotes the greater consumption of conifers in the diet [16,17]. Additionally, the presence of large predators, along with human disturbances, affects the feeding areas and habitat choices of ungulates [18–20]. When managing ungulate populations to reduce losses in forestry and other sectors, it is essential to simultaneously evaluate the composition and density of all ungulate species in the deer family [21]. Furthermore, it is crucial to understand changes in deer habitat and browsing damage in response to forest management to combine ungulate and forest management [22] successfully. One of the management practices in young forest stands is pre-commercial thinning, which reduces competition for light, nutrients, and water between target species of the forest stand and undergrowth [23,24]. By thinning out the weaker or less desirable trees, the remaining trees in the stand can achieve better growth rates and health, improving overall forest structure and productivity.

Forest stands dominated by Scots pine (*Pinus sylvestris* L.) cover 33% of all forestland in hemiboreal Latvia. Pine trees growing in the Baltic Sea region have long been known for their straight trunks, slender branches, and high wood quality [25], and, therefore, Scots pine is still a significant tree species economically. The most common undergrowth woody plants in pine stands are *Salix* sp., *Sorbus aucuparia* L., *Betula* sp., *Frangula alnus* Mill., and *Corylus avellane* L. [26]. Most of these plants, along with dwarf shrubs, are essential sources of winter diet for ungulates, particularly deer [15,17]. In young pine stands, early pre-commercial thinning can make pine vulnerable to deer damage. Broken main stems, heavily damaged/stripped bark, and heavily browsed side branches reduce the growth rate of trees [27,28], negatively affect future timber quality [29], and may reduce the potential future monetary income from forest stands [27,30,31]. Therefore, minimizing browsing pressure on pine is one of the main challenges for forest management in Latvia.

In this study, by using data from the National Forest Inventory (NFI), we were looking for answers to how several factors, such as the density of the main tree species, admixture, undergrowth, and forest type, affect deer damage intensity in the young Scots pine stands, considering deer densities and regional aspects in hemiboreal Latvia.

2. Materials and Methods

2.1. Study Area

Latvia (57°14′ N; 22°40′ E) is located in the European hemiboreal forest zone [32,33], which is a transition between boreal and temperate forests. This zone hosts a variable mixture of coniferous and deciduous trees and is characterized by diverse soil and biota [32]. According to Latvian National Forest Inventory (NFI) data, 55% of Latvia is covered by forest (3.6 M ha forest land), and forest growing conditions are highly variable. Overall, two-thirds of forests are on mineral soils (2.505 M ha). Thus, the tree species distribution over edaphic rows is not homogeneous. More than half (56%) of the forests on mineral soils are covered by coniferous trees—Scots pine and Norway spruce (*Picea abies* L. Karst.)—but in deciduous forests on mineral soil, birch (*Betula pendula* Roth, *Betula pubescens* Ehrh.) stands and European aspen (*Populus tremula* L.) stands are the most common. According to NFI data, young forests with an age class of 0–20 years comprise 27.9% (903.01 K ha), while the 0–10 age class alone accounts for 13.8% of the total forest area in Latvia. The proportion of young Scots pine-dominated forests is 1.2% in the 0–10 year age class and 1.9% in the 11–20 year age class, which encompasses more than 105,000 ha (in total, 3.2% of the total forest area).

The climate is temperate, cool, and moist due to the influence of the Baltic Sea. According to data from the Latvian Environment, Geology, and Meteorology Centre, the mean temperature is +6.8 °C and annual precipitation is 686 mm. However, 2023 became the third-warmest year in observation history, with a mean air temperature of +7.8 °C and an annual precipitation of 761 mm. Significant fluctuations are observed in the characteristics of the snow cover from year to year. According to Latvian Environment, Geology, and Meteorology Centre data, the thickest snow cover in the winter season occurs in the third week of February (from 7 cm in the western part of the territory to 42 cm in the central part). Thaws are a frequent phenomenon in winter, and there are also occasional winters without permanent snow cover.

2.2. Data Overview

We used data collected by the NFI in Latvia, specifically 'Ungulate damage to young pine, spruce and aspen stands', in 2023 from 206 pine stands up to 20 years of age. All data were collected by setting up a total of 1454 circular sample plots (area 100 m^2) distributed regularly within each selected pine stand to represent 5% of each selected stand area (a minimum of 4 sample plots per stand). More than 90% of all pine stands have been planted by seedlings. According to fresh damage level, all live pine trees were classified as follows: (1) Healthy—undamaged and lightly damaged trees (less than 50% of side branches browsed); (2) damaged—at least 50% of stem circumference with stripped bark and/or more than 50% of side branches browsed and/or broken main stem. The third category was dead trees (3) resulting from previous deer damage. The mean height (m) of pine trees in all sample plots was recorded.

To obtain a site-related, comparable relative density index for deer species (red deer, moose, roe deer) that visited forest stands during the winter period [34], the number of pellet groups was counted within the same circular sample plots where pine damage was assessed.

Within these circular sample plots, all admixture species and the number of trunks of each species, as well as undergrowth species and the number of trunks of each species, were counted, and the mean height of each species per sample plot was detected. Also, fresh pre-commercial thinning fact was recorded. This study defines fresh pre-commercial thinning as thinning performed in the last autumn/winter or current spring (the pine needles haven't changed color and fallen off yet and the cut area is still yellowish or light gray and resinous).

All data were collected shortly after the snow melted in late March and April 2023.

2.3. Data

The percentage of damage to the pine was calculated as the number of damaged trees divided by the total tree number per sample plot.

When analyzing the probability of damage to the pine, the following variables were newly calculated from the data collected in the sample plots: (i) height group (based on the average height of trees in the sample plot, two height groups were created—below and above 3 m); (ii) the average height of the undergrowth, which was calculated as the weighted average of the number and height of undergrowth species found in each sample plot; and (iii) sample lot density (the number of all pine trees, admixture, and undergrowth in the sample plot).

Three forest type groups based on soil fertility, stand water regime, and vegetation characteristics [35] were categorized: 'dry'—fresh mineral soils; 'wet'—wet mineral soils; and 'other'—including forests on wet peat soils and drained forests (both on mineral and peat soils). All the information about forest types was gathered from the Forest State register database.

Based on Latvia's cultural and historical regions, forest cover, and ungulate density (according to Latvia State Forest Service data), the analyzed stands were divided into five groups (Figure 1).

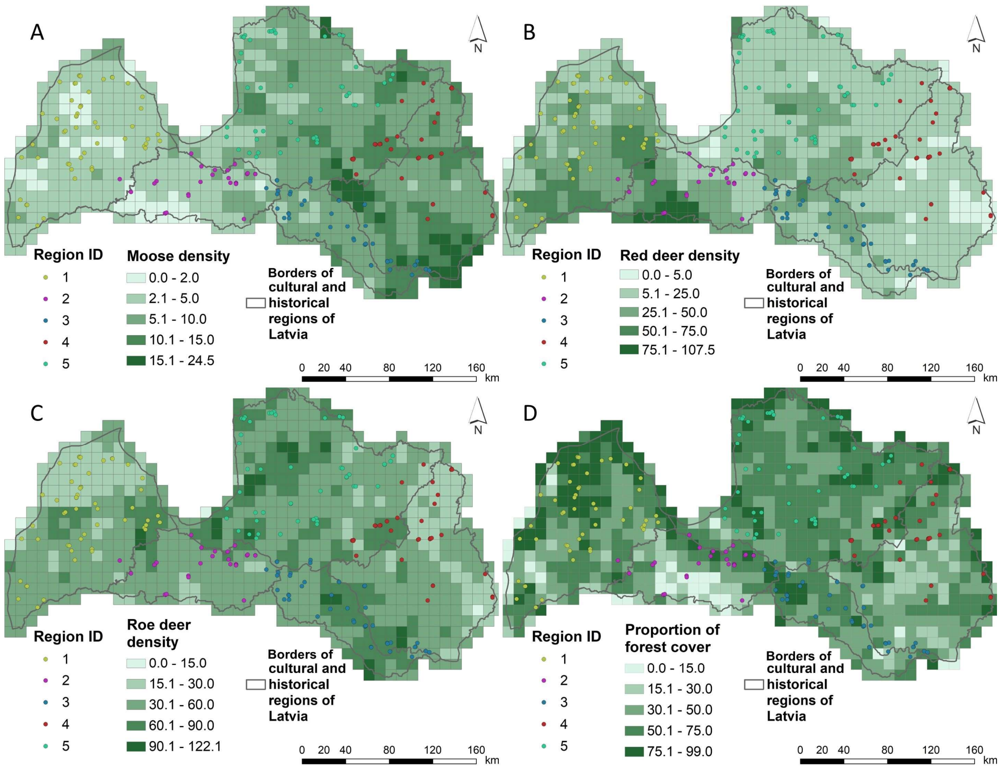

Figure 1. Location and distribution of young pine stands by regions surveyed within framework of National Forest Inventory. Moose (**A**), red deer (**B**), and roe deer (**C**) density (animals per 1000 ha of forest land) within 10 × 10 km grid according to State Forest Service data in year 2023, and forest cover proportion (**D**) within 10 × 10 km grid.

Those circular plots with admixture above 50 specimens or undergrowth above 300 specimens were excluded from further data analysis (because they were considered as "jumping" on the background of others), as well as sample plots with pine numbers below 6 (as when including observations with very few trees, each damage immediately has a large effect). Excluding all the above-mentioned observations, 1238 sample plots were included in the analysis.

2.4. Statistical Analysis

All analyses were performed in the program R 4.4.1. [36]. To find out how different factors affected the probability that pines would be damaged, the binary logistic generalized linear mixed-effect model (binary logistic GLMM) was used. The analysis was performed with the R package glmmTMB [37]. The ratio of the number of damaged pines was entered as the response variable in the model. Forest type group (a factor with three classes: 'wet', 'dry', and 'other'), dominant height group (a factor with two classes: '<3' and '>3'), pre-commercial thinning (a factor with two classes: pine stands with pre-commercial thinning and pine stands without pre-commercial thinning), number of moose piles, number of red deer piles, number of roe deer piles, total undergrowth density, average undergrowth height, total amount of admixture, and region (a factor with five classes: '1'. . . '5') were entered as independent variables. Interactions between forest type group, dominant height class, and all other variables, as well as interactions between region and pile numbers, were included in the model. The total number of excrement piles of each ungulate species counted per stand was used as a characteristic for each plot. All numerical variables were normalized (scaled). A random factor, 'Stand ID', was included in the model to account for multiple plots per stand. The pattern covariance structure was included in the model to account for possible spatial correlation between the observational units. After creating the model, it was simplified and the most irrelevant variables and their interactions were discarded, comparing the models according to the AIC value. If the interaction terms between the numeric and factor variables were significant, estimated slope values between factor levels were compared using the Tukey test as implemented in the R package emmeans [38]. The R package ggeffects was used to plot the model-based estimates of the damage probabilities for different combinations of predictor variables [39].

3. Results

3.1. Summary Statistics of Main Parameters

In pine stands below 3 m in height, the mean proportion (±standard error) of damage for the main species was 8 ± 1%, and the mean density index (pellet group number per 100 m^2 sample plot) for moose, red deer, and roe deer were 3.9 ± 0.3, 3.5 ± 0.3, and 7.9 ± 0.6, respectively. In pine stands with a main tree species mean height above 3 m, the proportion of damaged pines per sample plot was lower (4 ± 0.4%) than in the previous height group and the density index values for all three deer species were higher (see Table 1 for details). The average density of admixture and undergrowth per 100 m^2 sample plot in pine stands of different height groups was quite similar: 3.8 and 34.1 trees in pine stands up to 3 m, and 3.3 and 42.5 trees in pine stands above 3 m of height, respectively.

Table 1. Descriptive statistics (mean value and standard error (SE)) of main parameters characterizing sample plots by stand height group (n = number of sample plots per each stand group).

Parameter	Forest Type Group	Height < 3 m			Height > 3 m		
		Mean	±SE	n	Mean	±SE	n
Damaged pine proportion	'dry'	6.4	0.9	258	3.8	0.4	633
	'wet'	14.2	3.5	50	5.2	1.1	60
	'others'	7.7	1.3	75	4.6	0.8	162
	Total	7.7	0.8	383	4.1	0.4	855
Moose density index	'dry'	4.0	0.3	258	11.6	1.3	633
	'wet'	4.7	0.7	50	3.7	0.4	60
	'others'	3.0	0.5	75	5.6	0.5	162
	Total	3.9	0.3	383	9.9	0.9	855

Table 1. *Cont.*

Parameter	Forest Type Group	Height < 3 m			Height > 3 m		
		Mean	±SE	n	Mean	±SE	n
Red deer density index	'dry'	2.5	0.3	258	7.9	0.6	633
	'wet'	1.9	0.5	50	1.6	0.4	60
	'others'	7.9	1.1	75	5.1	0.5	162
	Total	3.5	0.3	383	6.9	0.4	855
Roe deer density index	'dry'	7.8	0.7	258	15.7	0.9	633
	'wet'	9.3	1.2	50	10.2	1.4	60
	'others'	7.7	1.7	75	8.5	1.1	162
	Total	7.9	0.6	383	14.0	0.7	855
Admixture density	'dry'	3.5	0.5	258	3.1	0.2	633
	'wet'	9.4	2.0	50	6.5	1.3	60
	'others'	1.2	0.4	75	3.0	0.5	162
	Total	3.8	0.4	383	3.3	0.2	855
Undergrowth density	'dry'	33.2	3.0	258	44.5	2.2	633
	'wet'	21.3	4.1	50	34.7	6.8	60
	'others'	45.7	6.7	75	37.5	3.3	162
	Total	34.1	2.5	383	42.5	1.8	855
Undergrowth height	'dry'	0.89	0.05	258	1.59	0.04	633
	'wet'	0.66	0.12	50	1.05	0.14	60
	'others'	1.26	0.11	75	1.24	0.06	162
	Total	0.93	0.04	383	1.48	0.04	855
Sample plot density	'dry'	57.7	2.9	258	63.4	2.3	633
	'wet'	52.9	4.1	50	57.5	6.3	60
	'others'	67.5	6.8	75	54.6	3.4	162
	Total	59.0	2.4	383	61.4	1.9	855

In stands up to 3 m on 'wet' forest types, there were higher moose and roe deer density indexes, 4.7 ± 0.7 and 9.3 ± 1.2, respectively, while the red deer density index was higher in 'other' forest type stands (7.9 ± 1.1) (Table 1).

In stands below 3 m in height, the main species of sample plot admixture was spruce (26%), followed by birch (13%) and other species (mainly *Quercus robur* L., *Alnus* sp.). In 'wet' forest type stands, the proportion of birch (26%) was slightly higher than spruce (24%). In pine stands above 3 m in height, the main species of sample plot admixture was birch (25%), followed by spruce (18%) and other species (4%).

The undergrowth was dominated by birch (42%), followed by different willow species (10%), *Frangula alnus* Mill. (3%), and *Sorbus aucuparia* L. (2%). There was a high proportion of other shrub species as well, such as *Corylus avellana* L., *Prunus padus* L., *Euonymus europaeus* L., *Lonicera xylosteum* L., and others. Birch was the most dominant understory species in all forest types and stands in both height groups (Figure 2). The undergrowth species proportion in pine stands with taller trees (height > 3 m) was higher in all forest type groups when compared with stands up to 3 m in height.

The proportion of damaged pines in thinned stand sample plots was higher than in un-thinned stands, at 9 ± 1% and 5 ± 0.4%, respectively. The moose and roe deer density indexes were higher in un-thinned stands, whereas the density index of red deer was higher in thinned stands (Figure 3).

There were some differences in damaged pine proportion and deer density index between different regions (Table 2), with the highest proportion of damaged pines in the eastern part of Latvia (region '4') and the lowest in the western part (region '1'), at 12 ± 2% and 2 ± 1%, respectively. According to pellet counts in the sample plots, the highest density index for all three deer species was in the southeastern part of Latvia (region '3'). The smallest moose and roe deer density index were in the southern part (region '2'), and red deer–in the eastern part of Latvia (region '4').

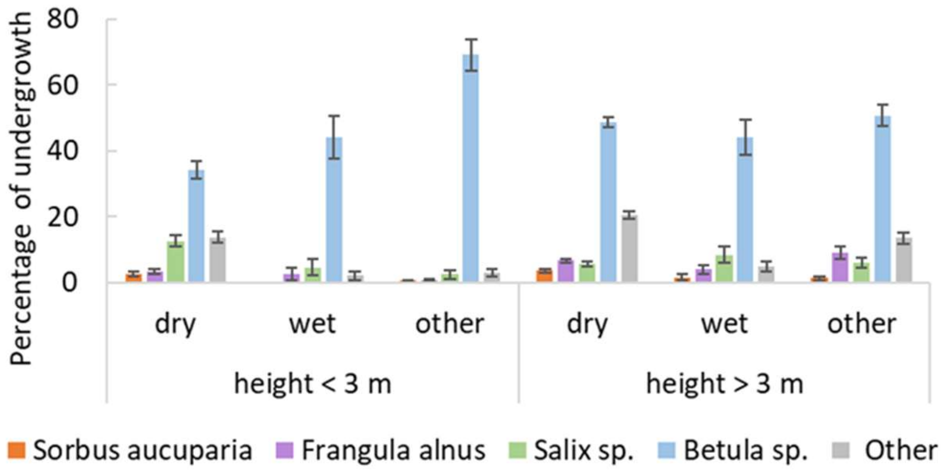

Figure 2. The mean proportion of the most common undergrowth species in pine stands of different heights and forest type groups (the number of trunks of the relevant species per sample plot is related to the number of trunks of all trees/shrubs listed in the undergrowth in the same 100 m^2 sample plot). Error bars show ± standard error.

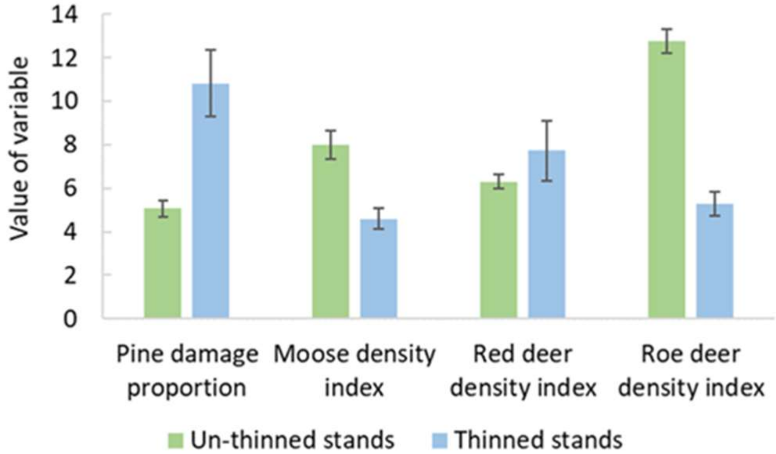

Figure 3. Damaged pine proportion and deer density index values in pine stands with and without pre-commercial thinning. Error bars show ± standard error.

Table 2. Proportion of damaged pines and mean deer density indexes (mean value and standard error (SE)) in sample plots (number of pellet groups per 100 m^2 sample plot), and number of sample plots per forest type by region.

Region	Proportion of Damaged Pines	Deer Density Index			No of Sample Plots per Forest Type Group		
		Moose	Red Deer	Roe Deer	'Wet'	'Dry'	'Others'
1	4.62 ± 0.58	4.11 ± 0.88	6.89 ± 0.51	6.92 ± 0.42	187	40	61
2	1.71 ± 0.5	1.44 ± 0.17	7.89 ± 1.32	5.18 ± 0.59	127		23
3	4.93 ± 0.69	20.76 ± 2.55	8.57 ± 1.03	21.56 ± 1.76	251	16	25
4	11.75 ± 1.58	7.28 ± 0.5	1.2 ± 0.13	9.54 ± 0.94	114	19	59
5	3.61 ± 0.56	3.67 ± 0.3	4.39 ± 0.39	13.18 ± 0.88	212	35	69

3.2. GLMM Test Results

The results of the GLMM model (Table 3) indicate that the probability of pine damage is significantly influenced by several interacting factors. The significant two-factor interactions are the effect of the region and the moose density index ($p < 0.001$), the forest type group and the undergrowth height (p = 0.034), the dominant height group and the total admixture density (p < 0.001), and the dominant height class and the moose density index (p = 0.016). The interaction among three variables is also significant when considering the forest type group and the dominant height group with the total density of the undergrowth. The "pre-commercial thinning" factor does not interact with any other factors included in the analysis; it should be viewed as a one-variable influence (p = 0.001).

Table 3. Factors affecting probability of pine damage (summary of GLMM test results).

Factor	Statistics	df	*p* Value
Pre-commercial thinning	10.916	1	0.001
Forest type group	4.1000	2	0.129
Height group	5.436	1	0.020
scale(Moose density index)	11.340	1	0.001
scale(Undergrowth density)	0.128	1	0.721
scale(Admixture density)	4.126	1	0.042
scale(Undergrowth height)	1.384	1	0.239
Region	13.730	4	0.008
Forest type group–Height group	4.393	2	0.111
Height group–scale(Moose density index)	5.765	1	0.016
Forest type group–scale(Undergrowth density)	0.620	2	0.734
Height group–scale(Undergrowth density)	0.021	1	0.884
Height group–scale(Admixture density)	17.475	1	<0.001
Forest type group–scale(Undergrowth height)	6.746	2	0.034
scale(Moose density index)–Region	27.931	4	<0.001
Forest type group–Height group–scale(Undergrowth density)	5.789	2	0.055

In pine stands with a dominant height below 3 m, the probability of damage decreases with an increase in the density of undergrowth for 'dry' and 'wet' forest types. In stands with a dominant height above 3 m, the probability of pine damage decreases as the undergrowth increases in 'other' forest types, but increases in 'wet' and 'dry' ones (Figure 4).

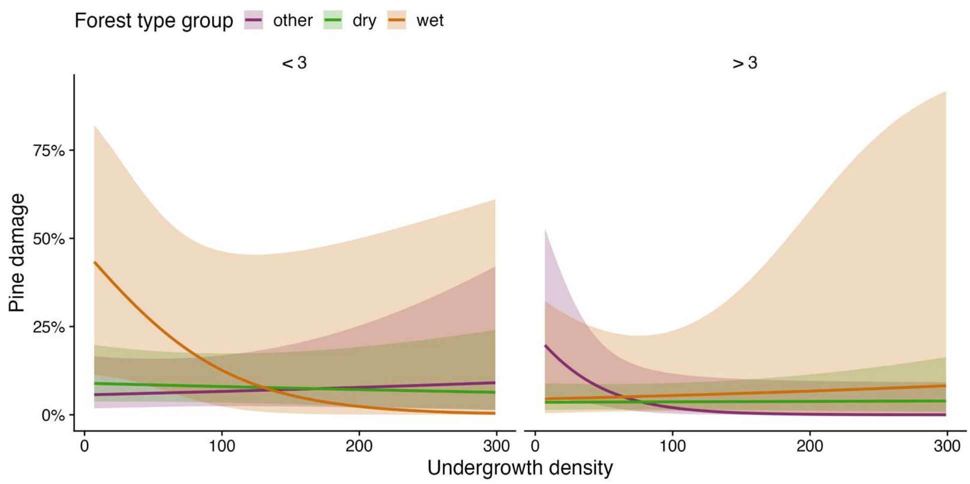

Figure 4. Estimated probability of pine damage according to undergrowth density, dominant stand height class, and forest type group (results of GLMM model (±95% confidence band)).

In all regions, the presence of moose significantly impacts damaged pines (Figure 5). There were statistically significant differences in the effects between regions 1 and 4 (p = 0.0137), 1 and 5 (p = 0.0204), 3 and 4 (p = 0.0045), and 3 and 5 (p = 0.0091).

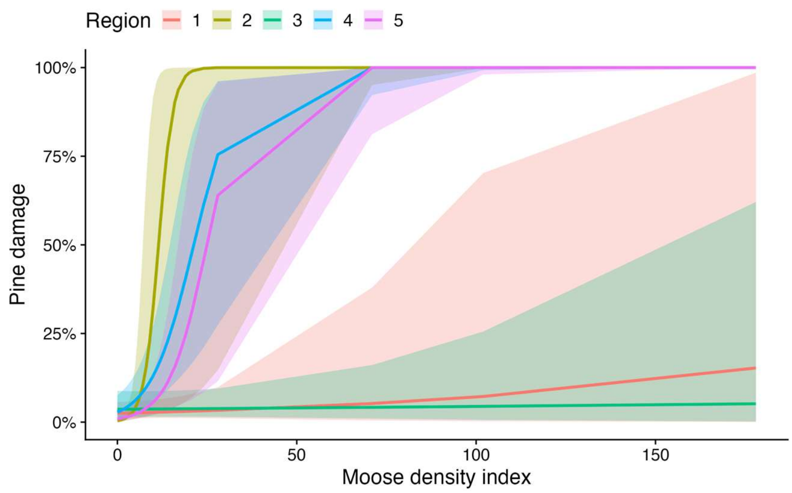

Figure 5. Estimated probability of pine damage depending on region and moose density index (pellet group number per 100 m^2 sample plot (±95% confidence band)).

In both height groups, an increase in the moose density index increases pine damage, which is statistically significantly more pronounced in the stands with a mean height below 3 m (p = 0.0164) (Figure 6).

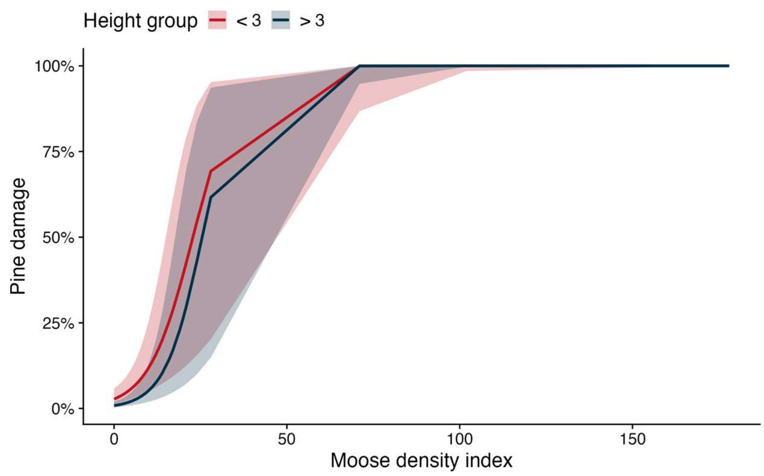

Figure 6. Estimated probability of pine damage depending on height group and moose density index (pellet group number per 100 m^2 sample plot (±95% confidence band)).

4. Discussion

This study illustrated how stand structure and applied forest management practices affect the intensity of deer damage in young pine stands in hemiboreal Latvia. We found that the proportion of damaged pines is significantly higher in pine stands below 3 m in height, and damages to pines in such stands (height < 3 m) increased with decreasing undergrowth density.

In our study, the highest ungulate density index was in the pine stands above 3 m in height, where the density of the undergrowth, as well as the density of the entire sample plot and, consequently, the density of the entire stand, was greater. We believe that, most likely, such stands are useful as good hiding places and sleeping places. Previous studies show that dense coniferous stands can provide good shelter during winter in deep-snow conditions [4,40,41], as the crown of trees reduces the amount of snow in the understory, making access to dwarf shrubs and other trees and shrubs growing in the undergrowth easier. However, since the density of ungulates is high, it is most likely that the food base available in these higher stands is not sufficient in the winter period. Previous studies in

Latvia show that the wolf population remains stable [42], which can also impact ungulates' feeding and hiding behavior; therefore, dense stands can be a hiding place from predators as well [19,20].

The results of our research align well with the findings from other studies, indicating that damage intensity changes with the availability of food in the stand. We assume that since the density of ungulates is high, it is most likely that the food base available in these higher stands is not sufficient in winter, and therefore ungulates also feed in the lower pine stands, not only on the woody plants found in the undergrowth, but also on the dominant species of the stand. In pine stands below 3 m in height on wet soils, the proportion of damaged pines was the highest at the same time as the density of the undergrowth and tree density in sample plots were lowest, while the density of admixture was highest. The estimated density indexes of moose and roe deer in these stands were higher than those evaluated in the other forest type groups. The stands on wet forest types are characterized by more difficult growing conditions—high soil moisture and low oxygen—which make them suitable for relatively undemanding undergrowth species like *Frangula alnus* L. and *Salix* sp. For example, it has been observed that when food availability and quality are lower (meaning less palatable species in the undergrowth), moose tend to browse larger biomass quantities [3,29]. On the other hand, browsing damage is reduced in highly dense stands, as they are less accessible for ungulates [3].

Thinning is one of the sustainable forest management tools that improves tree growth rate and health, thereby increasing tolerance to environmental pressures, providing plant diversity and creating wildlife habitats [24]. It also significantly alters the natural food supply for ungulates and impacts browsing pressure on the target tree species [27]. Previous studies show that successfully combining ungulates and forest management practices can reduce browsing damage by providing good quality and sufficient quantities of forage and, for example, creating barriers from thinned material to limit ungulate movement into the stand [40,43]. For example, Pfeffer et al. [14] concluded that tree density, especially pine density, influenced winter damage. In our study, we also found a similar result: after the thinning of the stand, during which undergrowth species were removed and less desirable pine trees thinned, the proportion of fresh damage was significantly higher than in stands without pre-commercial thinning. On the other hand, Huuskonen et al. [44] found that increasing the proportion of cervids' preferred species may lead to a greater risk of damage to other, less preferred tree species growing in the same stand. However, differences in deer density between regions can also affect browsing pressure.

We found significant differences in the proportion of damaged pines and deer density index between different regions. The results of the GLMM model (Table 3) indicate that the highest proportion of deer damage was observed in the southeastern part of Latvia (region '3'), and, in all regions, the moose density index had a greater impact on pine damage. Also, in red deer-dominated regions ('1' and '2'), modeling showed that if moose were present in the stand, a much stronger correlation between moose density and pine damage were observed. However, this does not exclude the influence of other deer species on the proportion of pine damage, which has also been confirmed by studies by other authors, stating that not only each individual species, but the total species composition and density of ungulates in the area are important [17,45]. To further assess all deer species impact, additional data are required, along with adjustments to the research methodology. Overall, our findings align well with previous studies' results, showing that deer density is the most critical factor affecting pine damage [46,47].

The presence of specific deer species is important, as well as the species composition and overall density. Although moose, red deer, and roe deer are quite different body-sized species, their feeding niches overlap, especially in winter [15,17,48]. As the population density of a species increases—mainly if it is the smallest species—the others are pushed out of their usual feeding niches [17]. Thus, browsing damage can appear on economically important tree species.

5. Conclusions

Considering our results, it is clear that undergrowth density, and, therefore, pre-commercial thinning, together with deer density, may be important drivers of damage levels, especially winter browsing, in Scots pine stands. Although not studied here, a broader perspective on managing young pine forests by choosing the right timing for various management actions, which may include strategies for providing supplementary winter forage (avoiding thinning in late autumn or winter), may be a way to ensure more efficient and ungulate-adapted forest management under current conditions.

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References

1. Högbom, L.; Abbas, D.; Armolaitis, K.; Baders, E.; Futter, M.; Jansons, A.; Jögiste, K.; Lazdins, A.; Lukminė, D.; Mustonen, M.; et al. Trilemma of Nordic–Baltic Forestry—How to Implement UN Sustainable Development Goals. *Sustainability* **2021**, *13*, 5643. [CrossRef]
2. Rytter, L.; Ingerslev, M.; Kilpelainen, A.; Torssonen, P.; Lazdina, D.; Löf, M.; Madsen, P.; Muiste, P.; Stener, L.G. Increased forest biomass production in the Nordic and Baltic countries -a review on current and future opportunities. *Silva Fenn.* **2016**, *50*, 1e33. [CrossRef]
3. Jactel, H.S.; Nicoll, B.M.; Gonzalez-Olabarria, J.R.; Grodzki, W.; Långström, B.; Moreira, F.; Netherer, B.; Orazio, C.; Piou, D.; Santos, H.; et al. The influences of forest stand management on biotic and abiotic risks of damage. *Ann. For. Sci.* **2009**, *66*, 701. [CrossRef]
4. Roberge, J.M.; Laudon, H.; Björkman, C.; Ranius, T.; Sandström, C.; Felton, A.; Sténs, A.; Nordin, A.; Granström, A.; Widemo, F.; et al. Socio-ecological implications of modifying rotation lengths in forestry. *Ambio* **2016**, *45*, 109–123. [CrossRef]
5. Felton, A.M.; Holmström, E.; Malmsten, J.; Felton, A.; Cromsigt, J.P.G.M.; Edenius, L.; Ericsson, G.; Widemo, F.; Wam, K. Varied diets, including broadleaved forage, are important for a large herbivore species inhabiting highly modified landscapes. *Sci. Rep.* **2020**, *10*, 1904. [CrossRef]
6. Landry, S.; Villard, M.A.; Pelletier, G.; St-Laurent, M.H. Harvest block aggregation as a driver of intensive moose browsing pressure on hardwood regeneration in a temperate forest. *For. Ecol. Manag.* **2024**, *552*, 121562. [CrossRef]
7. Linnell, J.D.C.; Cretois, B.; Nilsen, E.B.; Rolandsen, C.M.; Solberg, E.J.; Veiberg, V.; Kaczensky, P.; van Moorter, B.; Panzacchi, M.; Rauset, G.R.; et al. The challenges and opportunities of coexisting with wild ungulates in the human-dominated landscapes of Europe's Anthropocene. *Biol. Conserv.* **2020**, *244*, 108500. [CrossRef]
8. Done, G.; Ozoliņš, J.; Bagrade, G.; Jansons, J.; Baumanis, J.; Vecvanags, A.; Jakovels, D. A case study for best suitable methods of monitoring demographic structure in cervid populations to predict increasing forest damages. *Silva Fenn.* **2024**, *58*, 23025. [CrossRef]
9. Pascual-Rico, R.; López-Martín, B.; Sánchez-Zapata, J.A.; Morales-Reyes, Z. Scientific priorities and shepherds' perceptions of ungulate's contributions to people in rewilding landscapes. *Sci. Total Environ.* **2020**, *705*, 135876. [CrossRef]

10. Vetter, S.G.; Arnold, W. Effects of population structure and density on calf sex ratio in red deer (*Cervus elaphus*)—Implications for management. *Eur. J. Wildl. Res.* **2018**, *64*, 30. [CrossRef]
11. Pascual-Rico, R.; Morales-Reyes, Z.; Aguilera-Alcalá, N.; Olszańska, A.; Sebastián-González, E.; Naidoo, R.; Moleón, M.; Lozano, J.; Botella, F.; von Wehrden, H.; et al. Usually hated, sometimes loved: A review of wild ungulates' contributions to people. *Sci. Total Environ.* **2021**, *801*, 149652. [CrossRef] [PubMed]
12. Harada, K.; Ang Meng Ann, J.; Suzuki, M. Legacy effects of sika deer overpopulation on ground vegetation and soil physical properties. *For. Ecol. Manag.* **2020**, *474*, 118346. [CrossRef]
13. Šebeň, V.; Konôpka, B. Assessing the influence of ruminating ungulates on forest regeneration and young stands in Slovakia: Results from the National Forest Inventory. *Cent. Eur. Fore J.* **2024**, *70*, 222–234. [CrossRef]
14. Pfeffer, S.E.; Singh, N.J.; Cromsigt, J.P.G.M.; Kalén, C.; Widemo, F. Predictors of browsing damage on commercial forests—A study linking nationwide management data. *For. Ecol. Manag.* **2021**, *479*, 118597. [CrossRef]
15. Ratkiewicz, M.; Coissac, E.; Świsłocka, M.; Czajkowska, M.; Kowalczyk, R.; Czernik, M.; Taberlet, P. Winter diet overlap among moose, roe deer and red deer in coniferous and mixed forests depends on snow cover depth. *For. Ecol. Manag.* **2024**, *556*, 121710. [CrossRef]
16. Spitzer, R.; Felton, A.; Landman, M.; Singh, N.J.; Widemo, F.; Cromsigt, J.P.G.M. Fifty years of European ungulate dietary studies: A synthesis. *Oikos* **2020**, *129*, 1668–1680. [CrossRef]
17. Spitzer, R.; Coissac, E.; Felton, A.; Fohringer, C.; Juvany, L.; Landman, M.; Singh, N.J.; Taberlet, P.; Widemo, F.; Cromsigt, J.P.G.M. Small shrubs with large importance? Smaller deer may increase the moose-forestry conflict through feeding competition over *Vaccinium* shrubs in the field layer. *For. Ecol. Manag.* **2021**, *480*, 118768. [CrossRef]
18. Kuijper, D.P.J. Lack of natural control mechanisms increase wildlife-forestry conflict in managed temperate European forest systems. *Eur. J. For. Res.* **2011**, *130*, 895–909. [CrossRef]
19. Gicquel, M.; Sand, H.; Månsson, J.; Wallgren, M.; Wikenros, C. Does recolonization of wolves affect moose browsing damage on young Scots pine? *For. Ecol. Manag.* **2020**, *473*, 118298. [CrossRef]
20. Churski, M.; Spitzer, R.; Coissac, E.; Taberlet, P.; Lescinskaite, J.; van Ginkel, H.A.L.; Kuijper, D.P.J.; Cromsigt, J.P.G.M. How do forest management and wolf space-use affect diet composition of the wolf's main prey, the red deer versus a non-prey species, the European bison? *For. Ecol. Manag.* **2021**, *479*, 118620. [CrossRef]
21. Zini, V.; Wäber, K.; Dolman, P.M. Relation of pine crop damage to species—Specific density in a multi-ungulate assemblage. *Eur. J. For. Res.* **2022**, *141*, 489–502. [CrossRef]
22. Vospernik, S.; Reimoser, S. Modelling changes in roe deer habitat in response to forest management. *For. Ecol. Manag.* **2008**, *255*, 530–545. [CrossRef]
23. Saksa, T.; Miina, J. Cleaning methods in planted Scots pine stands in southern Finland: 4-year results on survival, growth and whipping damage of pines. *Silva Fenn.* **2007**, *41*, 274. [CrossRef]
24. Moreau, G.; Chagnon, C.; Achim, A.; Caspersen, J.; D'Orangeville, L.; Sánchez-Pinillos, M.; Thiffault, N. Opportunities and limitations of thinning to increase resistance and resilience of trees and forests to global change. *Forestry* **2022**, *95*, 595–615. [CrossRef]
25. Baumanis, I.; Jansons, Ā.; Neimane, U. Selection, genetics and seeding in Latvia. In *LSFRI Silava*; UD Academic Press 'Saule': Daugavpils, Latvia, 2014; p. 328. (In Latvian)
26. Šilingas, M.; Suchockas, V.; Varnagirytė-Kabašinskienė, I. Evaluation of Undergrowth under the Canopy of Deciduous Forests on Very Fertile Soils in the Lithuanian Hemiboreal Forest. *Forests* **2022**, *13*, 2172. [CrossRef]
27. Herfindal, I.; Tremblay, J.P.; Hester, A.J.; Lande, U.S.; Wam, H.K. Associational relationships at multiple spatial scales affect forest damage by moose. *For. Ecol. Manag.* **2015**, *348*, 97–107. [CrossRef]
28. Mathisen, K.M.; Milner, J.M.; Skarpe, C. Moose—Tree interactions: Rebrowsing is common across tree species. *BMC Ecol.* **2017**, *17*, 12. [CrossRef]
29. Wallgren, M.; Bergström, R.; Bergqvist, G.; Olsson, M. Spatial distribution of browsing and tree damage by moose in young pine forests, with implications for the forest industry. *For. Ecol. Manag.* **2013**, *305*, 229–238. [CrossRef]
30. Lavsund, S. Moose relationship to forestry in Finland, Norway and Sweden. *Swed. Wildl. Res.* **1987**, Supplement 1, 229–244.
31. Reimoser, F.; Putman, R. Impact of wild ungulates on vegetation: Costs and benefits. In *Ungulate Management in Europe, Problems and Practices*; Putman, R., Apollonio, M., Andersen, R., Eds.; Cambridge University Press: Cambridge, UK, 2011; pp. 144–192.
32. Lõhmus, A.; Kraut, A. Stand structure of hemiboreal old-growth forests: Characteristic features, variation among site types, and a comparison with FSC-certified mature stands in Estonia. *For. Ecol. Manag.* **2010**, *260*, 155–165. [CrossRef]
33. Jõgiste, K.; Frelich, L.E.; Laarmann, D.; Vodde, F.; Baders, E.; Donis, J.; Jansons, A.; Kangur, A.; Korjus, H.; Köster, K.; et al. Imprints of management history on hemiboreal forest ecosystems in the Baltic States. *Ecosphere* **2018**, *9*, e02503. [CrossRef]
34. Alves, J.; Alves da Silva, A.; Soares, A.M.V.M.; Fonseca, C. Pellet group count methods to estimate red deer densities: Precision, potential accuracy and efficiency. *Mamm. Biol.* **2013**, *78*, 134–141. [CrossRef]
35. Bušs, K. Forest ecosystem classification in Latvia. *Proc. Latv. Acad. Sci. Sect. B* **1997**, *51*, 204–218.

36. R Core Team. A Language and Environment for Statistical Computing. R Foundation for Statistics Computing. Vienna, Austria. Available online: https://www.R-project.org/ (accessed on 10 October 2024).
37. Brooks, M.E.; Kristensen, K.; Benthem, K.J.; Magnusson, A.; Berg, C.W.; Nielsen, A.; Skaug, H.J.; Maechler, M.; Bolker, B.M. glmmTMB Balances Speed and Flexibility Among Packages for Zero-inflated Generalized Linear Mixed Modeling. *R J.* **2017**, *9*, 378–400. [CrossRef]
38. Lenth, R. Emmeans: Estimated Marginal Means, Aka Least-Square Means. R Package Version 1.2.1. Available online: https://CRAN.R-project.org/package=emmeans (accessed on 10 October 2024).
39. Lüdecke, D. ggeffects: Tidy Data Frames of Marginal Effects from Regression Models. *J. Open Source Softw.* **2018**, *3*, 772. [CrossRef]
40. Vospernik, S. Probability of bark stripping damage by red deer (*Cervus elaphus*) in Austria. *Silva Fenn.* **2006**, *40*, 589–601. [CrossRef]
41. Brault, B.; Tremblay, J.P.; Thiffault, N.; Royo, A.A.; Côté, S.D. Successful forest restoration using plantation at high deer density: How neighboring vegetation drives browsing pressure and tree growth. *For. Ecol. Manag.* **2023**, *549*, 121458. [CrossRef]
42. Žunna, A.; Runģis, D.E.; Ozoliņš, J.; Stepanova, A.; Done, G. Genetic Monitoring of Grey Wolves in Latvia Shows Adverse Reproductive and Social Consequences of Hunting. *Biology* **2023**, *12*, 1255. [CrossRef]
43. Schwegmann, S.; Hendel, A.L.; Frey, J.; Bhardwaj, M.; Storch, I. Forage, forest structure or landscape: What drives roe deer habitat use in a fragmented multiple-use forest ecosystem? *For. Ecol. Manag.* **2023**, *532*, 120830. [CrossRef]
44. Huuskonen, S.; Domisch, T.; Finér, L.; Hantula, J.; Hynynen, J.; Matala, J.; Miina, J.; Neuvonen, S.; Nevalainen, S.; Niemistö, P.; et al. What is the potential for replacing monocultures with mixed-species stands to enhance ecosystem services in boreal forests in Fennoscandia? *For. Ecol. Manag.* **2021**, *479*, 118558. [CrossRef]
45. Donini, V.; Corlatti, L.; Ferretti, F.; Carmignola, G.; Pedrotti, L. Browsing intensity as an index of ungulate density across multiple spatial scales. *Ecol. Indic.* **2024**, *163*, 112131. [CrossRef]
46. Ward, A.I.; White, P.C.L.; Walker, N.J.; Critchley, C.H. Conifer leader browsing by roe deer in English upland forests: Effects of deer density and understorey vegetation. *For. Ecol. Manag.* **2008**, *256*, 1333–1338. [CrossRef]
47. Borowski, Z.; Gil, W.; Bartoń, K.; Zajączkowski, G.; Łukaszewicz, J.; Tittenbrun, A.; Radliński, B. Density-related effect of red deer browsing on palatable and unpalatable tree species and forest regeneration dynamics. *For. Ecol. Manag.* **2021**, *496*, 119442. [CrossRef]
48. Heinze, E.; Boch, S.; Fischer, M.; Hessenmöller, D.; Klenk, B.; Müller, J.; Prati, D.; Schulze, E.D.; Seele, C.; Socher, S.; et al. Habitat use of large ungulates in northeastern Germany in relation to forest management. *For. Ecol. Manag.* **2011**, *261*, 288–296. [CrossRef]