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ORIGINAL RESEARCH

Non-industrial Private Forest Owners' Knowledge and Forest Management Preferences Regarding Forest Damage in Northern Sweden

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Abstract

In northern Sweden, large forest areas are affected by extensive damage caused by moose, fungi, beetle and other biological pests. For non-industrial private forest (NIPF) owners this leads to large losses of value, not only in economic terms but also in the form of loss of biodiversity and amenity values. Therefore, several research projects are underway to develop new silvicultural methods and other measures to reduce damage. However, a successful implementation of these will often depend on the willingness and knowledge of the forest owners. The objective of this study was, therefore, to elucidate NIPF owners' knowledge about forest damage and their preferences regarding forest management alternatives that potentially could mitigate the damage situation. Data were collected through a questionnaire that was distributed to a random sample of 1,177 NIPF owners in northern Sweden, and the response rate was 31% ($n=368$). The results show that 19% of the NIPF owners did not know the current damage situation in their own forest. In addition, NIPF owners judged that their knowledge to identify damage themselves is quite limited, except for damage caused by moose. Regarding future management options, many were positive towards avoiding clear-cuts in suitable areas, while many were negative towards implementing alternative tree species such as larch and lodgepole pine. The study concludes that there is a clear need to inform and educate NIPF owners about forest damage, but also that there will be challenges in reaching all types of owners.

Keywords Family forest owners · Attitudes · Opinions · Moose · Pests

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Introduction

One third of the Earth's land surface is made up of forests, and it is one of our most important resources, providing work to millions of people globally, essential products for daily life, and maintaining vital ecosystem services (FAO 2022). Caring for and preserving healthy forests that can continue to deliver these benefits is therefore important for both forest owners and other stakeholders worldwide. Because there are several threats to the forest, for example damage caused by insects and other biological pests. The consequences of such attacks on the forest can be great, as they lead to great value losses, not only in money but also loss of biodiversity and amenity values, and effects on ecosystem services can follow (Ramsfield 2016). The risk of suffering severe attacks is also believed to increase as a result of e.g. the ongoing climate change, because warmer weather can favour the reproduction and spread of several species. Moreover, the trees also become more susceptible to attack when exposed to extreme conditions such as drought, flooding or extreme temperatures, which may become more common in the future (Boyd et al. 2013; FAO 2022).

In Sweden, a country with 23.4 million hectares (ha) of productive forestland, which corresponds to 57% of its total land area (Nilsson et al. 2022), forest damage caused by moose, fungi, beetles and other biological pests is already a significant problem. Especially the northern parts of the country, which in this study refers to the counties of Norrbotten and Västerbotten, are troubled by a high proportion of forest damage caused by moose or other pests such as the two-needle pine stem rust fungi *Conartium flaccidum* and *Peridermium pini* (Normark 2019; Wulff et al. 2022). The Swedish Forest Agency's (2022b) inventory for 2022 showed that the proportion of pine trees with annual grazing damage was 10%, which is twice as high as the target of a maximum of 5%. Even the proportion of undamaged pines that had neither fresh damage nor previous damage has for several years been at a level that indicates a severe damage situation. Moreover, inventories that the state-owned forest company Sveaskog (2019) made on their own forestlands have shown that 25% of the examined area had severe damage from moose or fungal attacks. On average, there were only 1,100 healthy stems per ha, while the company's target is 2,000 stems per ha. These results are in line with Normark's (2019) analyses, which showed that roughly a quarter of the young forest (defined as forest between 18 and 28 years old) was in poor condition. They are also in line with Wulff et al. (2022), who found that 28% of the trees in the northern regions of Sweden had severe damages, while just 61% were completely free from damage. Because damage from both moose and fungal attacks is so widespread across northern Sweden, the expression "multi-damaged forest" has been used to describe forests that suffer from several types of damage at the same time (Normark 2019).

Some who are directly affected by the presence of forest damage are the approximately 311,000 non-industrial private forest (NIPF) owners, who own just under half of the country's forestland (Swedish Forest Agency 2022a). For both NIPF and industrial forest owners whose forests are affected by commonly occurring damages (Table 1), this means increased costs when the need for silvicultural measures increases, as well as value losses in the form of lower growth and reduced quality of the wood. This in turn also affects the industry and other actors in the value

Table 1 Description of common pests in Swedish forests (Swedish Forest Agency 2017a,b; Lind 2023; Barklund n.d1., n.d2.). Swedish and Latin names within brackets

Pests	Description	Examples of preventive measures
Moose	Occurs throughout the country except the island of Gotland. Damage occurs when the moose graze on young trees, or otherwise cause physical damage to the trees.	- Choice of tree species for rejuvenation - Reduction of the moose population
Pine stem rust (Törskate (*Conartium flaccidum/Peridermium pini*))	Occurs throughout Sweden. Damage pine trees (*Pinus sylvestris*) by infecting needles or young shoots, after which it grows into the trunk and the branch or top of the tree dies.	- Choice of tree species for rejuvenation - Avoid seeds from trees that are susceptible to infestation as the resulting offspring will be as well.
Pine twist rust (Knäckesjuka (*Melampsora pinitorqua*))	Occurs throughout Sweden and alternates hosts between pines and aspen. Damage pine trees by causing deformations of top shoots and branches.	- Choice of tree species for rejuvenation - Limit the amount of aspen shoots in the pine rejuvenations
Snow blight (Snöskytte (*Phacidium infestans*))	Occurs on pine and lodgepole pine in areas that often have long-term snow cover, i.e. mainly in the north. The fungus occurs on low-lying branches that are covered with snow and causes damage by killing the needles.	- Choice of tree species for rejuvenation - Rejuvenate by planting rather than sowing - Selection of resistant plants - Removal of logging residues if harvest is done during fall
Spruce needle rust *(*Skvattramrost *(Chrysomyxa ledi))*	Occurs throughout the country where there is *Rhododendron tomentosum* as spores are spread from the infected leaves on the ground to the young needles of the spruces, which turn yellow.	- Choice of tree species for rejuvenation
Spruce needle rust (Granrost (*Chrysomyxa abietis*))	Occurs throughout the country. Infects the needles of the spruces and during the summer yellowing areas appear on the needles.	- Choice of tree species for rejuvenation
Gremmeniella *(*Gremmeniella *(Gremmeniella abietina))*	Occurs throughout the northern hemisphere. Causes damage on spruce, pine and lodgepole pine by killing young shoots and buds, as well as by causing wounds on trunks and branches.	- Choice of tree species for rejuvenation - Site selection - Remedial clearing/thinning
Bark beetle (Granbarkborre (*Ips typographus*))	Occurs throughout Sweden, but tree death mainly occurs in the southern and middle parts of the country and to some extent along the coast in the north. Damages the tree by creating passages and nests between the bark and the wood.	- Removal of windfalls and trees with low resilience - Removal of timber and damaged trees from the forest and/or harvesting site storage before summer. A regulatory framework exists for this measure.

chain. In order to find solutions to the problem, several projects are currently underway that investigate suitable forest management measures for this type of forest and what preventive measures can be taken to reduce the proportion of damaged forest in the future (Skogforsk 2019). A number of possible measures to mitigate the damage going forward have also been proposed (Normark 2019). Many of the proposals mentioned have in common that they require the acceptance and participation of the forest owner, either as a direct executor or through the procurement of forest management services.

Understanding what knowledge and forest management preferences NIPF owners have regarding forest damages will therefore be vital for a successful implementation of future policies, services and forest management methods. Especially since previous studies have shown that NIPF owners' awareness of various pests is often low (Simoes at al. 2019). Furthermore, it can be expected that the knowledge and attitudes towards different management alternatives differ between NIPF owners since they are a heterogeneous group of individuals with different forest values, forest management objectives and different relationships to forests (Wiersum et al. 2005; Nordlund and Westin 2011; Häyrinen et al. 2015; Haugen et al. 2016; Ficko et al. 2019; Weiss et al. 2019; Juutinen et al. 2021). Furthermore, it is known from previous studies that socio-demographic factors, forest property characteristics and the NIPF owners' previous experiences of forest management practices often influences their future management strategies and decisions (Ní Dhubháin et al. 2007; Favada et al. 2009; Eggers et al. 2014; Kuuluvainen et al. 2014; Aguilar et al. 2017; Juutinen et al. 2020; Butler et al. 2021; Triplat et al. 2023; Lidestav and Westin 2023). This also applies to how NIPF owners deal with forest damage. For instance, studies in the U.S. have shown that besides the type and severity of the forest damage, owner characteristics such as property size, personal values and whether they have a forest management plan may influence their preventive measures against forest damage (Mayfield et al. 2006; Molnar et al. 2007; Markowski-Lindsay et al. 2020). Different types of owners have also been identified based on their response to insect infestations (Holt et al. 2020). Moreover, membership in a forest owners' association (FOA) has been associated with a greater awareness of forest damage, and these owners often take more actions against the damage (Molnar et al. 2007). Indeed, in order for NIPF owners to take action against forest damage, they must first have an awareness of it as well as an interest and desire to do so. Also in a Swedish context it is reasonable to expect that FOA members have a different approach to forest damage compared to non-members, as they more often are focused on economic returns in the form of timber production (Berlin et al. 2006). The same generally applies to owners of larger properties, just as there is a gender difference where female owners often put higher value on recreational values than male owner do (Molnar et al. 2007; Favada et al. 2009; Nordlund and Westin 2011). In fact, property size often has a strong influence on NIPF owners' choice of management strategies, where the importance of financial values increases with the size of the property (Eggers et al. 2014). When it comes to management preferences in relation to forest damage, this can be assumed to influence, for example, the NIPF owners' choice of tree species when establishing a new forest stand, which has great significance for the type of threat the forest can be exposed to (see Table 1). Commercial tree species in the northern Sweden are mainly pine and spruce, and which one is chosen depends primarily on the growing conditions in the area. However, in areas with a high percentage of forest damage, NIPF owners may have to consider whether a slightly worse growth potential is compensated by a lower risk of damage if choosing alternative tree species for rejuvenation.

As NIPF owners' management decisions affect a significant share of the forest land, many researchers have been interested in investigating their knowledge and attitudes towards current issues with societal relevance. In recent years this includes, for instance, NIPF owners' views on the future use of forests in relation to climate

change and biological diversity (Husa and Kosenius 2021; Koskela and Karppinen 2021), their willingness to utilize forest biomass from young dense forest stands (Kronholm et al. 2020; Triplat et al. 2023), their willingness to harvest timber (Aguilar et al. 2014, 2017; Bashir et al. 2020), and their forest knowledge and value priorities (Eriksson and Fries 2020, 2021). However, the knowledge and forest management preferences of NIPF owners in relation to forest damage has so far received limited attention, especially in the Nordic context. This despite the fact that many countries worldwide experience forests being increasingly damaged by insects, pathogens or other pests, partly as a consequence of ongoing climate change. Therefore, the objective of this study was to elucidate NIPF owners' knowledge and forest management preferences regarding forest damage in northern Sweden. Three research questions were raised to achieve this objective:

(1) To what extent are NIPF owners aware of forest damage on their forest properties?
(2) To what extent do NIPF owners perceive that they have the knowledge to identify forest damage themselves?
(3) What are NIPF owners' perceptions of different management alternatives that can potentially be used to prevent and remedy forest damage?

Materials and Methods

Study Area

The study area covered Norrbotten and Västerbotten counties, which are located in the northernmost part of Sweden. The study area was selected because it has a high share of forest damage (Normark 2019). By geographically delimiting the study area, it was also ensured that the character of the forest is more uniform than if the southern parts of the country were also included. The total land area for these two counties is 151,904 km^2, which corresponds to 37% of Sweden's total land area of 407,284 km^2 (Regionfakta 2022). The study area has 9.6 million ha of forestland, of which 7.1 million ha is productive forestland. The number of NIPF owners is approximately 41,000 and they own about 34% of the forestland in the study area (Nilsson et al. 2022; Swedish Forest Agency 2023).

Sample

From its register, the Swedish mapping, cadastral and land registration authority took a random sample of 1,211 NIPF owners who were at least 18 years old and had a forest property of at least six ha within the study area. The sample size was determined based on the expected response rate and the recommended number of participants needed for a representative sample of the population under investigation (Dillman et al. 2009; Fowler Jr 2009). NIPF owners residing outside of Sweden were excluded from the sample for practical reasons and some cases with missing addresses were also removed. Consequently, the final sample consisted of 1,177 NIPF owners, of which 63% were males and 37% were females. The average age was 62 years and

the average forest property size was 113 ha, with a median of 60 ha. There were no significant differences between male and female owners concerning age or property size.

Data Collection

Data were collected through a mixed-mode survey where respondents could either submit their responses on paper or via the online survey tool Netigate, which is a common method of increasing the response rate (Dillman et al. 2009; Fowler Jr 2009). A questionnaire was sent out by postal mail in October 2022 along with a reply envelope in which respondents could return their responses free of charge. In the survey's cover letter, the recipients were informed about the background and purpose of the study, how the data would be used, that their participation was voluntary, as well as log-in information to Netigate. After two weeks, a reminder was sent out to non-responders. Data collection was ended in December 2022, with a response/cooperation rate of 31% ($n=368$). The majority of respondents (80%) submitted their answers by postal mail.

In total, the questionnaire contained 30 questions. However, some of them were outside the scope of this paper. Respondents were first asked to provide background information about themselves, their forest property and their management objectives. They were also asked to what extent they themselves carry out various forest management activities. The second part of the questionnaire focused on the NIPF owners' knowledge and awareness of forest damage. This included, for example, the extent to which their own forest had been damaged by moose and/or other biological pests and how likely it is that they would be able to identify different types of damage themselves with their current knowledge. Furthermore, they were asked to assess their knowledge of how to take care of damaged forest and whether they know how to prevent it from happening. It was not specified that they need to have the practical ability to carry out the forest operations themselves, so it could also mean that they know what needs to be done and then they might hire someone to do it. Most of these questions were formulated as proposals, which were answered on a seven-point scale from "totally disagree" to "totally agree". In the third part of the questionnaire, the respondents were asked if they had participated in any training on forest damage. The final section of the questionnaire focused on the respondents' attitudes to various forest management alternatives that potentially could ease the damage situation, as well as how they perceive different options for treating damaged forest. These questions were based on existing advice to forest owners as well as ongoing research projects around management alternatives for damaged forest (Normark 2019; Skogforsk 2019). Again, most questions were formulated as statements that respondents answered to on a similar seven-point scale as in section two.

During the construction phase, the questionnaire was discussed with a group of experts that is coordinated by the Swedish Forest Agency. Furthermore, the questionnaire was tested on a NIPF owner to ensure that questions were clear and to check how much time it would take for respondents to answer them. Minor adjustments were made based on the provided feedback.

Analysis and Data

When applicable, comparisons between groups were made using t-tests, chi^2 tests, correlations and analysis of variance (ANOVA). SPSS Statistics software was used for the statistical analysis. Examined owner characteristics were age, gender, education, size of forest property, duration of ownership, membership of a FOA, management objectives, frequency of forest visits, possession of a forest management plan, time elapsed since their last forest management activity and level of self-employment in forestry. These variables were selected as they in several studies have been found to influence NIPF owners' management strategies and forest knowledge (Eggers et al. 2014; Eriksson and Fries 2020), which in turn may affect their awareness and management preferences concerning forest damage. For example, it is reasonable to expect that owners who often visit their forest are more likely to be aware of its current health status. Likewise, more active and well-informed owners with stronger economic motives (e.g. FOA members and owners with large properties) may have different approaches towards forest damage compared to other owners (Mayfield et al. 2006; Molnar 2007), promoting alternatives that are good for timber production (Eggers et al. 2014). By studying patterns around how the respondents differed between the investigated questions, it was possible to identify a number of key factors that seem to influence the NIPF owners' knowledge and attitudes about forest damage.

In order to compare differences between NIPF owners based on their level of self-employment in forestry, respondents were given a score based on how much of the work they perform themselves on the following activities: planting, cleaning (pre-commercial thinning), thinning/harvesting, and taking care of windfalls, insect infestations and similar damages. For each activity the respondent was given 2 points if he/she performs that work completely by him/herself, and one point if he/she partly performs the work. In other cases (if they always hired someone to do the work or if the activity had not been relevant during their period of ownership), zero points were given. Since they had graded four types of activities, each respondent could receive a maximum of eight points for self-employment.

Of the respondents, 70% were males and 30% females, which means that males were overrepresented among the participants ($p < 0.001$). With an average age of 64 years, the responders were also significantly older than non-responders ($p = 0.011$). The respondents' average forest property size was 120 ha, which was not significantly different from that of non-responders. Almost half of the respondents (48%) had a forest property between 50 and 200 ha, while 35% had less than 50 ha and 17% had more than 200 ha. On average, they had owned their forest for almost 26 years. In terms of education, about 17% had only finished elementary school, 40% had gone through secondary school and the rest had a university or college education. Some 75% of the respondents stated that they visit their forests often or very often, while the other 25% visit their forests less frequently. Five respondents stated that they never visit their forest. Membership in a FOA was held by 46% of the respondents. A forest management plan that was up-to-date (defined as less than 10 years old) was held by 49% of the respondents. 42% of the respondents considered that timber production and income from timber harvest was their most important management

objective, while 32% consider recreation (hunting, fishing, berry- and mushroom-picking, etc.) to be most important, 21% prioritized amenities (traditions, aesthetics, emotional values, etc.) highest and 6% considered nature conservation and biological diversity to be their main objective. The degree of self-employment in forestry varied between respondents as 37% of the respondents had a self-employment score between 0 and 2, 37% had a score between 3 and 5, and 26% had a score of six or more. Cleaning and taking care of wind-throws, insect damages and similar were the two activities that the respondents most often perform by themselves, which was the case for about half of the respondents, and 33% did all planting by themselves. The majority (63%) always hired someone to do thinning and final-felling.

Results

Awareness about Forest Damage

Respondents were asked to what extent their forests had been affected by damage caused by moose and/or other pests, and 19% of the respondents stated that they do not know. Among male respondents, 12% did not know, while among females it was 37%, which was a significantly higher proportion ($p<0.001$). Furthermore, a relationship was found between respondents' awareness and their duration of forest ownership, with those who did not know having an average tenure of 20 years compared to 27 years for others ($p<0.001$). It was also found that 40% of those who never or quite rarely visit their forest property were unaware of the damage situation, while among those who very often visit their forest, 10% did not know ($p<0.001$). Furthermore, 36% of respondents with a low degree of self-employment in forestry did not know the damage situation, which was a significantly higher proportion compared to those with a medium (13%) or high degree of self-employment (6%) ($p<0.001$). Finally, 9% of those who prioritized timber production were not aware of the damage situation, which was significantly less than among respondents with other management objectives, where the percentage without awareness was 25–39% ($p<0.001$). The group with the lowest degree of awareness were those who prioritized nature conservation.

Among those who had rated the extent to which their forest had been affected by damage from moose and/or other biological pests, 15% stated that the forest had not been affected at all, while the majority considered that the level of damage was low or moderate (Fig. 1). On average, the respondents rated the extent of damage on their properties as 2.9, on a scale from one (=not at all) to seven (=to a very high extent).

Respondents with nature conservation as their highest-ranked management objective perceived that their forest had been damaged to a significantly greater extent (avg. 4.4) than those prioritizing recreation (avg. 2.6), amenities (avg. 2.8) or timber production (avg. 3.1) ($p<0.05$). Furthermore, there was a significant correlation between how often the respondent visited their forest and the extent of forest damage they perceived existed ($r=0.17$, $p=0.004$).

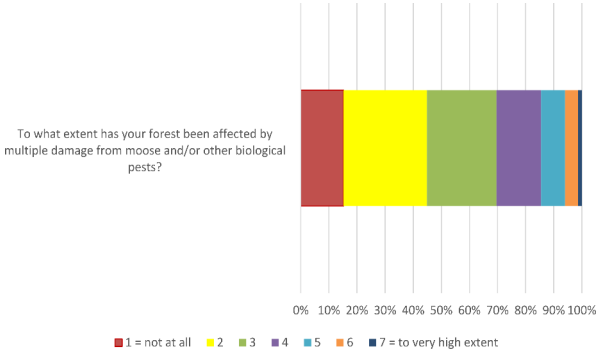

Fig. 1 Distribution of respondents according to the extent to which they perceive that their forest has been affected by forest damage

Type of Damage

Grazing damage caused by moose was by far the most common type of damage, which 77% of the respondents had experienced in their forest, followed by pine stem rust which had been noticed by 33% of the respondents. Other common types of damages were from snow blight, pine twist rust and bark beetle, which were reported by 19%, 15% and 9%, respectively.

The respondents were asked to rate the probability that they could identify certain types of forest damage by themselves, based on their current knowledge. The respondents were most confident that they could identify moose grazing damage. As shown in Table 2, male respondents consistently rated their ability to identify damage significantly higher than female respondents did for all damage types except moose grazing damage.

Another identified difference was that members of FOAs rated their ability to identify pine stem rust by themselves significantly higher (avg. 3.2) than non-members did (avg. 2.5) ($p=0.014$). Furthermore, as shown in Table 3, for five out of the eight damage types there was a small but significant positive correlation between forest property size and the respondents' perceived ability to identify the damage. A somewhat stronger correlation was found between the respondents' degree of self-employment and ability to identify damage, and here the correlation was significant for all eight damage types. In addition, on six of the damage types, a significant negative correlation was found between the time that had passed since the respondents' last forest management activity and their perceived ability to identify the damage. Finally, concerning pine twist rust, a difference was found in relation to the respondents' primary management objective ($p=0.015$), which those prioritizing timber production considered themselves significantly more likely to identify (avg. 3.3) compared to those who prioritized recreation (avg. 2.4).

Knowledge to Prevent and Take Care of Damage

Respondents were asked about their knowledge on how to prevent and how to take care of forest damage caused by moose or other pests and the proportion of respondents who considered themselves to have little knowledge was greater than the proportion who considered themselves to have great knowledge (Fig. 2).

Table 2 Respondents' perception of the likeliness that they with their current knowledge could identify the damage by themselves, measured on a scale from one (low) to seven (high). Swedish names (as they were presented in the survey) and Latin names in brackets

Damage type	Perceived ability to identify the damage by themselves			
	Males (avg.)	Females (avg.)	Total (avg.)	p-value
Moose grazing (Älgbete)	5.7	5.2	5.5	0.089
Pine stem rust (Törskate (*Conartium flaccidum/Peridermium pini*))	3.8	2.7	3.5	<0.001
Snow blight (Snöskytte (*Phacidium infestans*))	3.1	2.5	2.9	0.042
Pine twist rust (Knäckesjuka (*Melampsora pinitorqua*))	3.0	2.3	2.8	0.009
Bark beetle (Granbarkborre (*Ips typographus*))	4.1	2.6	3.6	<0.001
Spruce needle rust (Granrost (*Chrysomyxa abietis*))	2.6	2.1	2.5	0.033
Gremmeniella (Gremmeniella *(Gremmeniella abietina))*	2.5	1.8	2.3	0.001
Spruce needle rust (Skvattramrost *(Chrysomyxa ledi))*	2.3	1.8	2.2	0.013

On average, respondents rated their knowledge of forest damage prevention to be 3.15, on a seven-point scale, and 3.4 concerning their knowledge of taking care of damage. Male respondents considered themselves significantly more knowledgeable than female respondents ($p<0.001$). Regarding their knowledge of taking care of forest damage, their respective average scores were 3.7 and 2.6, and regarding knowledge of how to prevent damage, their respective scores were 3.5 and 2.4.

There was a significant negative correlation between the time elapsed since the respondents' last forest management activity and their perceived knowledge of how to take care of forest damage (r = -0.22, $p<0.001$), and also concerning knowledge of preventing forest damage (r = -0.19, $p<0.001$). Furthermore, there was a significant positive correlation between forest property size and the respondents' knowledge of how to take care of forest damage (r=0.12, $p=0.022$), and there was a tendency that the knowledge of how to prevent forest damage correlated in a similar way (r=0.10, $p=0.056$). Especially those with forest properties smaller than 50 ha perceived that they had less knowledge than others ($p<0.01$). Regarding prevention, this group scored significantly lower (avg. 2.7) than both those with 50–200 ha (avg. 3.3) and those with more than 200 ha (avg. 3.7) and regarding treatment of damaged forest there was a significant difference between those with the smallest (avg. 3.0) and largest properties (avg. 4.0).

Table 3 Correlation between ownership characteristics and respondents' perceived ability to identify the forest damage by themselves based on their current knowledge. Swedish names (as they were presented in the survey) and Latin names in brackets

Damage Type	Degree of Self-employment	Frequency of Forest Visits	Size of Forest Property	Time Since Last Forest Management Activity
Moose grazing (Älgbete)	0.16**	0.19**	0.05	-0.19**
Pine stem rust (Törskate (*Conartium flaccidum/Peridermium pini*))	0.33**	0.36**	0.20**	-0.21**
Pine twist rust (Knäckesjuka (*Melampsora pinitorqua*))	0.32**	0.30**	0.16**	-0.23**
Snow blight (Snöskytte (*Phacidium infestans*))	0.27**	0.29**	0.13*	-0.20**
Spruce needle rust (Skvattramrost *(Chrysomyxa ledi))*	0.27**	0.25**	0.16**	-0.18**
Spruce needle rust (Granrost (*Chrysomyxa abietis*))	0.21**	0.21**	0.07	-0.11
Gremmeniella (Gremmeniella *(Gremmeniella abietina))*	0.21**	0,24**	0.12*	-0.14*
Bark beetle (Granbarkborre (*Ips typographus*))	0.31**	0,25**	0.09	-0.10

* $p<0.05$; ** $p<0.01$

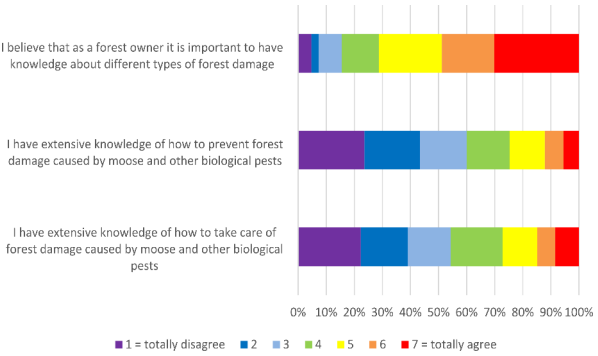

Fig. 2 Proportion of respondents agreeing or disagreeing with statements concerning their knowledge of forest damage prevention and how to take care of damage, as well as to what extent they believe it is important to have such knowledge

There were significant relationships between how often the respondents visit their forest and their knowledge of preventing forest damage, as well as how to take care of forest damage, and the correlations were equally strong in both cases (r=0.35, $p<0.001$). Also the level of self-employment correlated with their knowledge of forest damage prevention (r=0.38, $p<0.001$) and treatment of forest damage (r=0.42, $p<0.001$). Additionally, those with an updated forest management plan considered themselves significantly more knowledgeable about these things than those without one, as their average scores were 3.6 for treatment and 3.5 for prevention compared to 3.1 and 2.9, respectively ($p<0.01$). Finally, differences were found in relation to the respondents' management objectives ($p<0.05$). Regarding treatment of damages, those who prioritized recreation rated their knowledge significantly lower (avg. 2.8) than those prioritizing timber production (avg. 3.7) or nature conservation (avg. 4.1).

Also concerning damage prevention they rated their knowledge significantly lower (avg. 2.8) than those prioritizing timber production (3.5).

As shown in Fig. 2, many respondents expressed that as a forest owner it is important to have knowledge about forest damage (avg. 5.2). There was a significant positive correlation between the perceived importance of knowledge and the respondents' degree of self-employment ($r=0.23$, $p<0.001$), as well as how often they visit their forest ($r=0.27$, $p<0.001$). In addition, those who had implemented a forest management activity more recently were more inclined than others to believe that it is important to forest owner to have knowledge on forest damages, as there was a negative correlation between elapsed time and the respondents' rating on this issue ($r = -0.15$, $p=0.007$).

Education about Forest Damage

A minority of the respondents had participated in some form of training on forest damage. Some 4% of the respondents stated that they had taken part in the Swedish Forest Agency's online course on multi-damaged forests, 12% stated that they had taken part in other training on forest damage and some had taken part in both the online course and other training, which means that the total percentage of those trained was 15%. The most frequently mentioned organization that had provided their training was a FOA, but also other organizations such as forest companies, forestry schools, and the Swedish Forest Agency were mentioned. Respondents who had taken part of training activities had a higher degree of self-employment in forestry ($p<0.001$), they had to a higher extent an updated forest management plan ($p=0.016$), and the time that had elapsed since their last management activity was shorter ($p=0.047$). Furthermore, those who never or rarely visit their forest were less likely to have taken part of any training than those who visit it very often ($p=0.002$). In the first group, the share of respondents with training was 6%, while it in the latter was 22%.

Attitudes Towards Future Management Alternatives

Seedling Selection

Respondents were asked to rank three hypothetical seedling types with different growth characteristics and resistance to pests based on how they would choose in a future forest regeneration if having the choice. A seedling with medium resistance and growth characteristics was ranked highest by 55% of respondents, while 34% ranked a seedling with strong resistance but somewhat poorer growth characteristics as their first choice, and 11% prioritized a seedling with good growth characteristics but poorer resistance to pests. A relationship between the respondents' choice of seedling and their main management goal was found ($p=0.023$). The seedling with good growth but low resistance was chosen to the greatest extent by those with timber production as their primary management objective (19%), while none of the respondents focusing on nature conservation ranked this seedling as their first option. The opposite relationship was found for the seedling with high resistance but poorer growth, which half of the respondents with nature conservation as their primary man-

agement objective ranked highest, while 25% of those the timber production oriented respondents preferred this option. In the groups with recreation or amenities as their main management objective, it was the first choice for 37% in each group. The preference of the medium seedling alternative was roughly the same irrespective of management objective, varying between 50 and 58% in each group.

Reduction of the Moose Population

When asked if the moose population in northern Sweden should be reduced in order to reduce forest damage, the share of respondents who strongly opposed this was greater than those who largely agreed (Fig. 3). Compared to female respondents (avg. 2.9), male respondents agreed to a significantly higher extent to this claim (avg. 3.3), although both groups were more often against than for this alternative ($p=0.036$). A difference between respondents was also found in relation to their management objectives ($p=0.003$), as those who prioritized timber production agreed to a higher extent (avg. 3.7) than those with recreation (avg. 2.6) as their main objective. Furthermore, members of FOAs agreed more often (avg. 3.4) with the statement concerning reduction of moose population than non-members (avg. 3.0) ($p=0.042$). Finally, there were significant positive correlations between the respondents' opinion and their age (r=0.14) and duration of ownership (r=0.18) ($p<0.01$).

Continuous Cover Forestry

Regarding the question of whether the respondents want to practice forestry without clearcutting (i.e. continuous cover forestry) on forest lands suitable for this, almost a third of respondents totally agreed with this statement while a tenth completely disagreed (Fig. 3). Female respondents were significantly more positive (avg. 5.3) towards this management alternative compared to male respondents (avg. 4.8) ($p=0.015$). There was a positive correlation between the time elapsed since the last management activity and the willingness to implement continuous cover forestry (r=0.11, $p=0.037$). Furthermore, respondents who had no management plan that was up to date agreed to higher extent (avg. 5.1) with the statement than those who had

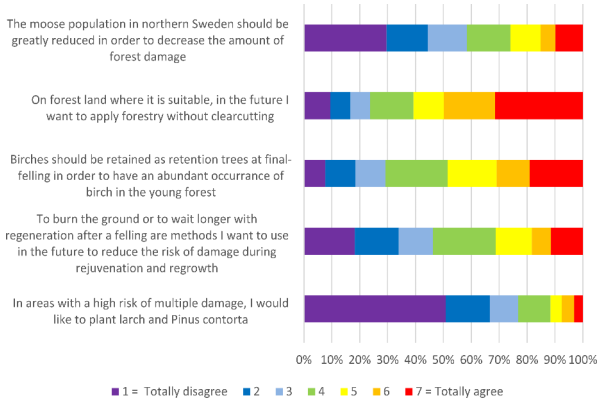

Fig. 3 Distributions of the respondents' opinions regarding their willingness to use different forest management alternatives in their own forests in the future to prevent forest damages caused by pests

a management plan (avg. 4.7) ($p=0.024$). Finally, there were significant differences between respondents in relation to their management objectives ($p<0.001$). Respondents who prioritized timber production were the least positive (avg. 4.3) about this measure and those who prioritized nature conservation were the most positive (avg. 6.6). In between were those prioritizing recreation (avg. 5.3) or amenities (avg. 5.2). All differences between these groups were significant except between recreation and amenities.

Retain Birches as Retention Trees

Almost half of the respondents were completely (19%) or to some extent (30%) willing to retain birches as retention trees at final-felling in order to have an abundant occurrence of birch in the rejuvenation, while 29% completely or to some extent opposed this (Fig. 3). FOA members were less likely (avg. 4.2) to be willing to retain birch as retention trees compared to non-members (avg. 4.7) ($p=0.012$). Furthermore, a negative correlation was found between respondents' level of self-employment and their willingness to retain birch as retention trees (r = -0.12, $p=0.025$). A difference was found in relation to respondents' management objectives ($p<0.001$). Respondents prioritizing timber production were the least positive towards this measure (avg. 4.0), and those prioritizing nature conservation were most positive (avg. 5.7). Respondents focusing on nature conservation were also significantly more willing to retain birch than those prioritizing recreation (avg. 4.5). The opinion of those who prioritized amenities (avg. 4.7) was not significantly different compared to others. Finally, a positive correlation was found between the preference to retain birch as retention trees and the time elapsed since the respondents' last management activity (r=0.16, $p=0.003$).

Rest Period or Burning After Felling

Almost half of the respondents were completely (19%) or to some extent (28%) unwilling to burn the ground or wait longer with planting after a felling in order to reduce the risk of damage in connection to the regeneration, while a third (31%) were completely or to some extent willing to do so (Fig. 3). FOA members were less likely (avg. 3.4) to want to implement these measures compared to non-members (avg. 3.8) ($p=0.022$). There was also a positive correlation between the respondents' willingness to implement rest periods or burning and the time elapsed since their last management activity (r=0.15, $p=0.007$). Furthermore, a difference was found in relation to the respondents' management objectives ($p=0.047$), where those prioritizing recreation (avg. 3.9) were more willing to implement these measures than those focusing on timber production (avg. 3.3). Respondents who prioritized amenities (avg. 3.7) or nature conservation (avg. 4.1) did not differ significantly from others.

Use of Other than Traditional Tree Species

The respondents were asked if they would like to plant larch trees and lodgepole pine (*Pinus contorta*) in areas with high risk for damage and the majority of respondents

(51%) completely disagreed with this proposition, and only small proportion (12%) agreed with this proposal completely or to some extent (Fig. 3). A significant relationship was found in relation to the respondents' management objectives ($p=0.005$), where those focusing on timber production opposed the proposal to less extent (avg. 2.6) than those prioritizing recreation (avg. 1.9). Respondents prioritizing amenities (avg. 2.5) or nature conservation (avg. 1.9) did not differ significantly from others.

Relationship Between Attitudes to Future Management Alternatives

As shown in Table 4, there were significant correlations between some of the proposed management alternatives for the future. It was found that those who were more willing to apply continuous cover forestry in suitable areas also had a stronger desire to retain birches as retention trees in order to have more birch after regeneration, as well as to apply burning or longer rest periods after a felling. Moreover, those who wanted to reduce the moose population were also more often interested in planting larch or lodgepole pine. In addition, there was a correlation between the willingness to retain birches as retention trees and the willingness to apply burning or longer rest periods after felling.

[1] A = Reduce moose population in order to decrease the amount of forest damage; B = When suitable, I want to apply forestry without clearcutting; C = Birches should be retained as retention trees in order to have more birch in the young forest; D = To burn the ground or wait longer with regeneration after a felling are methods I want to use in the future; E = In areas with high risk of damage, I would like to plant larch and Pinus contorta.

Treatment Preference for Forest Stand Affected by Pine Stem Rust

The respondents were asked about their opinion regarding three potential treatment alternatives for young pine forests that have been infested by pine stem rust (Fig. 4). To remove the infested pine trees and let remaining hardwoods and spruces stand for the future growth was the most preferred alternative (avg. 5.4), followed by leaving a denser stand than normal after thinning and cleaning in order to have more healthy trees in reserve (avg. 4.0). The least preferred option was to retain spruce and hardwood where there are larger gaps between the pine trees but otherwise give no attention to the fact that the pines had been infested by pine stem rust if they are considered viable (avg. 3.0). In other words, pines are largely retained during thinning even if they are damaged. No significant differences between the respondents were found regarding their attitude towards leaving the stand denser after thinning. Regarding retaining viable pines although they are infested, there was a signifi-

Table 4 Relationship between respondents' attitudes to the proposed management alternatives for the future. Significant correlations ($p<0.01$) are marked with an asterisk

Variable[1]	A	B	C	D	E
A	1.0	-0.08	-0.06	-0.04	0.33*
B		1.0	0.47*	0.14*	-0.03
C			1.0	0.23*	0.01
D				1.0	0.06
E					1.0

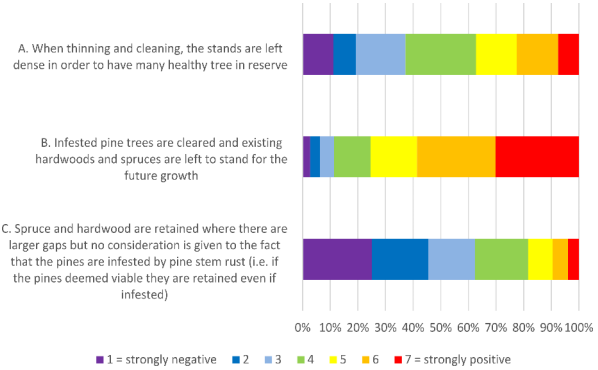

Fig. 4 Distributions of the respondents' opinions regarding their willingness to use different management alternatives for young pine forests infested by pine stem rust

cant negative correlation between the respondents' degree of self-employment and approval of the proposal (r = -0.122, $p=0.028$). Regarding the alternative to remove infested pines and instead focus on spruce and hardwood for future growth, there was a positive relationship between self-employment and the respondents' willingness to do so (r=0.186, $p<0.001$), and there was a difference in the respondents' willingness to implement this thinning alternative depending on how often they visited their forest ($p=0.002$), where those who very often visit their forest were more positive (avg. 5.8) than those who rarely visit their forest (avg. 5.0). Finally, there was a negative correlation between the respondents' willingness to implement this alternative and the time elapsed since they had performed a management activity in their forest (r = -0.174, $p=0.002$).

Discussion

Through a survey, this study investigated NIPF owners' knowledge and forest management preferences regarding forest damage in northern Sweden. The results show that a large share of NIPF owners have experienced damage in their forests, which is not surprising since the area has extensive damage caused by moose and other pests (Wulff et al. 2022). More striking is the discovery that one in five NIPF owners are completely unaware if they have or not have damage in their own forest. Consequently, there are many NIPF owners who are unlikely to take action even if their forest currently has damage that should be addressed. For these owners, it will lead to value losses when the future growth and timber quality decreases, as well as in other form of losses such as biodiversity and amenity values (Ramsfield et al. 2016). Not taking care of damage might also affect their neighbours, as the harmful fungi or insects spread in the area. Moreover, the results indicate that the level of knowledge about how to identify different types of forest damage is generally relatively low, except for moose grazing damage. That moose grazing damage is more easily identified may be due to the fact that it is the most common damage type in the area. To large extent, the level of knowledge expressed by respondents correlated with the presence of the damage reported. However, one exception was damage caused by bark beetle, which was ranked considerably higher in respondents' ability to identify it compared to its presence in their forests. Damage from bark beetle is a problem

especially in the southern parts of the country (Wulff and Roberge 2020), but this topic has received relatively much attention in the national media which could have increased NIPF owners knowledge about it. The effect of media coverage is also pointed out in Simoes et al. (2019), which strengthens this assumption. Another factor that to some extent can explain the greater awareness of damage caused by moose and bark beetles is that these are visible for a greater part of the year, while e.g. pine stem rust is most easily seen in June (Lind 2023).

Related to the above, the majority of NIPF owners perceive themselves to have limited knowledge of how to take care of forest damage and how to prevent it from occurring. Furthermore, only a minority of NIPF owners had participated in courses or other training in order to increase their knowledge of forest damage, although the majority of them believe that it is important to have knowledge about, for instance, forest damage. Traditionally, NIPF owners have mainly gained their forestry knowledge from their fathers via a learning-by-doing approach (Häggqvist et al. 2014). However, as NIPF owners' level of self-employment in forestry has decreased (Swedish Forest Agency 2018), and the expectations on modern youths to participate in forest work has changed (Kronholm and Staal Wästerlund 2017), present and future owners may need other type of education in order to get the relevant knowledge. Examples of this is that FOAs, which have an interest in having active members, have developed a number of courses during the last years (Kronholm 2016), and also the Swedish Forest Agency provides several training activities and courses. The challenge is thus how to get more NIPF owners to participate. Because, for many of them, there seem to be a barrier to go to courses or similar activities in order to learn more about it. Especially among those who have a low level of self-employment. In other words, those who already have some knowledge and interest in performing forestry activities are also those who actively look for opportunities to learn more. The respondents were not asked about the reasons for why they had not attended courses, so it is not possible to say whether the biggest obstacles are lack of time or interest, practical possibility to get to the courses or something else. For those who offer courses, this would be interesting to study in more detail in the future. As suggested by Häggqvist et al. (2014), better tailored information and study circles can be effective ways if they are marketed in a proper way so that many different types of owners can find them attractive.

There was a clear gender difference in NIPF owners' awareness of forest damage and the perception of their own level of knowledge on how to deal with forest damage. That female NIPF owners subjectively judge their own forestry knowledge to be lower than male owners do is in line with previous studies (Eggers et al. 2014; Häggqvist et al. 2014), but how much of this is due to differences in actual knowledge and how much is due to their own judgment and confidence is hard to say (Eriksson and Fries 2020, 2021). For instance, it is not uncommon that female owners can feel an uncertainty and have a lack of confidence in their role as forest owners (Hamunen et al. 2020). Such sentiments were also expressed by some of the female NIPF owners in this study, who communicated that it would have been better if their husbands or another male relative had been asked instead of them. Furthermore, female owners have traditionally been less active in terms of harvesting and silvicultural activities (Lidestav and Berg Lejon 2013). As seen in this study, the level of knowledge

concerning forest damage was higher among NIPF owners who had a high level of self-employment in forestry. In addition, those with timber production as their main objective expressed a higher level of knowledge about forest damage. In summary, it thus appears that the traditional self-employed male owner with timber production as the main priority and who therefore often visits the forest has the highest awareness and feels more knowledgeable about forest damage than less active and distant owners. This is in line with previous studies on NIPF owners' forestry knowledge in general (cf. Eriksson and Fries 2021).

In this study, only half of the respondents had an up-to-date forestry management plan, which is fairly in line with other recent studies (Lidestav and Westin 2023). From a policy perspective, it would thus be worth considering how to get more NIPF owners to draw up and regularly update their management plan, either on voluntary basis or through regulations, as previous studies have shown that the existence of a written plan affects their propensity to prevent damage (Molnar et al. 2007). In addition, for remote owners who visit their forest less often, more digital and easily accessible information services where they can find reports (or report themselves) of discovered forest damage in the area where their forest is located could be an interesting option. In fact, a need for better information services for NIPF owners does not only apply to forest damage (Kärhä et al. 2020). A challenge, however, is to get any organization to want to develop and maintain such services. Forest companies that buy timber from NIPF owners have a lot of data about the forests, but may not have the incentive to provide the service and this would also likely be limited to those who they do business with. Therefore, for greater coverage and more neutral advice, it would be appropriate that a public body (e.g. the Swedish Forest Agency or the Swedish University of Agricultural Sciences who regularly do forest inventories) would uphold these services. However, this might require new funds and directives from the state. Regarding education and services, it should also be taken into account that the needs may differ between different parts of the country, e.g. due to different damage types and varying rotation times.

Future Management Alternatives

NIPF owners' attitudes towards forest management alternatives that potentially could counteract future forest damage were investigated and the results show that for some of the options opinions were fairly uniform, while in others they were more divided. To some extent, the attitudes of NIPF owners towards different management alternatives correlated. This is no surprise, because for those who have problems with moose grazing, both a reduction of the moose population and the selection of other tree species than pine can ease the problem.

One question on which many agreed was whether they want to avoid clearcutting on suitable areas, as almost a third of the NIPF owners definitely want to do this. Compared to the findings of Juutinen et al. (2020), this is a slightly higher percentage that shows great interest in applying continuous cover forestry. However, this may to some extent be related to differences in how the questions were asked. In this case, the question concerned specific areas and not the NIPF owners' general management intention. As previous studies have shown, NIPF owners can have a positive attitude

towards continuous cover forestry as a complement to clear-felling, even if they do not fully embrace it (Axelsson and Angelstam 2011). Furthermore, the present public debate in Sweden about the effects of continuous cover forestry versus clearcutting may have influenced some NIPF owners' views on the method. In the Swedish forestry context, however, there are still several barriers that limit a wider implementation of continuous cover forestry (Hertog et al. 2022).

The results also clearly show that most NIPF owners have little interest in choosing alternative tree species such as larch and lodgepole pine for future regeneration. One reason for this may be that in northern Sweden larch and lodgepole pine are considered by some to be a threat to reindeer herding, as they can reduce accessibility to the forest and also threaten the growth of lichens (Lindkvist et al. 2012). Another fear might be that it would have a negative effect on recreational activities, for instance hunting. This could also be a reason why a large percentage of respondents were negatively disposed to reducing the moose population in order to reduce the amount of forest damage. Against the background of the high proportion of forest damage caused by moose and the fact that Sweden today has the world's densest population of moose calculated as the number of moose in relation to the forest land area (Wallgren 2022; Wulff et al. 2022), the resistance of the NIPF owners to reducing the number of moose can be seen as somewhat surprising. It is unknown how many of the respondents were hunters, but from previous studies it is known that hunters may perceive forest damage differently than other forest owners because they have different incentives (Ezebilo et al. 2012).

The size of the forest property has often been pointed out as a factor with strong influence on NIPF owners' management strategies (Eggers et al. 2014), but in this study opinions were rarely related to the forest size. Nor were there large differences between male and female owners, except for a couple of the suggested management alternatives. For instance, female NIPF owners were more often certain that they would like to avoid clear-cutting and thereby have uneven-aged forest on suitable areas, which is in line with previous studies (Juutinen et al. 2020). Furthermore, they were also more strongly against reducing the moose population. As shown by Nordlund and Westin (2011), ecological and recreational forest values are more important for women than for men, which could be one factor behind these differences. This assumption is supported by the fact that the NIPF owners' attitudes in several cases were related to their prioritized management objective, where those who prioritized timber production often had different views compared to those prioritizing recreation of nature conservation.

Study Limitations

A limitation of NIPF owner surveys is that some groups are often more reluctant than others to participate. The overall response rate of 31% is considered satisfactory in comparison with other recent surveys, but the participation rate for male owners was higher than for female owners, which is often the case for surveys aimed at Swedish NIPF owners (Nordlund and Westin 2011; Staal Wästerlund and Kronholm 2017; Kronholm et al. 2020; Triplat et al. 2023). However, since the share of female NIPF owners in Sweden is about 38% (Swedish Forest Agency 2022a), the share of

female respondents (30%) is not hugely deviant from the population. Furthermore, elder owners were overrepresented, which is also in line with previous studies (Staal Wästerlund and Kronholm 2017; Lidestav and Westin 2023). For future studies, however, it should be noted that, in order to increase the response rate, it may still be worth investing the extra time and money that a mail survey requires. As seen in this study, when respondents could choose between handing in their responses by mail or online, the majority of them chose to return the questionnaire by mail. In some surveys where NIPF owners have only been offered an online option, response rates have been as low as 10% (Kärhä et al. 2020).

Another limitation of this study is that the NIPF owners' knowledge about forest damage was measured through their self-evaluation. Therefore, as mentioned above, the results may not fully reflect their actual knowledge, but to some extent also reflect the NIPF owners' level of confidence as in their role as forest owners. In order to get a more objective evaluation of their knowledge about forest damage, future studies could, for example, test their skills by showing pictures of different types of damage.

Conclusions

The study highlights that a significant share of NIPF owners are unaware of the possible damages caused by pests in their own forest, and that many have a low ability to identify damage caused by pests other than moose with their current knowledge. Therefore, from both an industrial and societal perspective it would be highly important to reach out to NIPF owners with more information and education activities in order to increase their ability to prevent and take care of forest damage in their forest. Further efforts are also needed to increase the willingness of NIPF owners to obtain a forest management plan, as this can be a good tool to counteract forest damage. It can also be concluded that NIPF owners are generally not very interested in some of the management options currently proposed by experts, such as the use of alternative tree species. By elucidating the NIPF owners' management preferences and knowledge gaps in relation to forest damage, this paper contributes to an increased understanding of which measures forest sector actors should focus on to increase forest owners' opportunities to reduce the amount of forest damage.

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Declarations

Conflict of Interest None to declare.

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