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Red wood ant mound densities in managed boreal forests

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Clear-cutting can greatly impact red wood ant (*Formica rufa* group) colonies by changing microclimate, altering forage routes and eliminating aphid colonies as a food source. However, changed forestry practices in Finland, such as smaller clear-cut areas, leaving residual trees, and less intensive site preparation methods used during the last decade may result in less detrimental effects on red wood ants. Therefore, we studied how the number and size of red wood ant mounds varied between mature, 140-year-old, Norway spruce, *Picea abies* (L.) Karst., dominated mixed stands, and in 20-year-old and 5-year-old stands planted with Scots pine (*Pinus sylvestris* L.) in eastern Finland, all originating from similar mature forest stands. No red wood ant mounds were found in the 20-year-old Scots pine stands, which seems to be due to the cutting practices and heavy site preparation used at that time. The mound density in the 5-year-old stands (2.7 mounds per ha) was not different from that in the mature stands (2.9 mounds per ha), which could be a result of lighter harvesting and site preparation practices. However, the mounds in the 5-year-old clear cut areas were smaller in volume and flatter in shape than those in the mature stands. This could be due to accelerated organic matter decomposition in the mounds after timber harvest, or large mounds may have split into smaller ones as a result of changed environmental or food supply conditions. However, five years after clear-cutting and site preparation could be too short a time period to observe the degeneration and eventual disappearance of the still existing red wood ant mounds.

Introduction

Red wood ants (RWA, *Formica rufa* group) are one of the dominant ecosystem elements in the boreal forests of Eurasia. In Finnish forests, ants are the dominant predators, scavengers and turners of soil, and their biomass may comprise up to 10% or more of the animal biomass of that region (Hölldobler & Wilson 1990). RWAs influence the forest food web due to their high abundance and diverse roles in the ecosystem (Laakso & Setälä 2000). The long-lived, robust colonies of RWAs accumulate tree litter (such as coniferous needles, twigs and bark), resin and insects into their mounds (Wisniewski 1967, Maavara *et al*. 1994, Laakso & Setälä 1998). RWAs intensively use as a food source the honeydew excreted from aphids living on trees (Hölldobler & Wilson 1990), and the majority of their diet consists of honeydew (Wellenstein 1952, Rosengren & Sundström 1991). Decomposer microbes are more abundant inside their mounds as compared with the forest soil (Laakso & Setälä 1997, 1998). Extensive studies on RWAs have concentrated on their social structure (Gößwald 1989), geographical distribution and density (Sudd *et al*. 1977, Laine & Niemelä 1989), population dynamics and behaviour (Klimetzek 1981), effects on forest health (Finnegan 1976, Gößwald 1989), and biodiversity (Laakso & Setälä 2000).

In the 1950s, an average RWA mound density of 3 ha^{-1} was found in the most common forest site types in southern Finland (Rosengren *et al*. 1979). These forest site types are dominated by conifers and are of medium fertility. Much lower mound densities (0.005–0.32 mounds per ha) were reported for Irish, French, German or Polish forests (Breen 1979, Klimetzek 1981, Szczepanski & Podkowka 1983, Travan 1990, Nageleisen 1999). Thus the role of RWAs can be more important in boreal forests than in the temperate forests of central Europe (e.g. France, Germany or Poland), where urbanisation, forest fragmentation, forest management, air pollution or pupae collection as food for cage birds or medical purposes may have led to lower mound densities.

Since the 1950s urbanisation and forest management have also intensified in Finland, and could have negative impacts on RWA populations and community structure (Rosengren & Pamilo 1978, Vepsäläinen & Wuorenrinne 1978, Punttila *et al*. 1994). Clear-cutting is a common practice in Finland (approx. 150 000 ha a^{-1}, Peltola 2003), and is harmful for RWAs by changing microclimate, altering forage routes and eliminating aphid colonies as a food source (Rosengren & Pamilo 1978, Rosengren *et al*. 1979, Punttila *et al*. 1991). Mechanical disturbance by forestry practices, such as harvesting and intensive site preparation, may also destroy RWA colonies. However, changed forestry practices in Finland, e.g. use of smaller clear-cut areas, leaving residual living trees and lighter site preparation methods used during the last decade can result in less detrimental effects on RWAs. Therefore, the objectives of our study were (1) to determine the density of RWA mounds in boreal coniferous forest stands of different age, and (2) to discuss the effect of clear-cutting and site preparation on RWA mound densities.

Material and methods

Study area

We inventoried RWA mounds in a forest area of 82 ha in eastern Finland, which comprised of 15 forest stands, representing 3 different age classes: forest stands 5 and 20 years after clear-cutting, and mature, 140-year-old stands (Sotkamo commune, 63°51´N, 28°58´E, 220 m a.s.l.) (Table 1). All the clear-cut stands originated from similar Norway spruce dominated mature stands. The site type was classified as a medium rich *Vaccinium–Myrtillus* type according to the Finnish

Table 1. Description of the stands studied. Statistically significant different averages ($p < 0.05$) between the mature and 5-year-old stands are marked by different letters (a and b).

	5-year-old stands	20-year-old stands	Mature stands (~140 years)
Dominant tree species	Planted Scots pine	Planted Scots pine	Norway spruce
Number of stands	4	3	8
Mean stand area (mean ± S.E.; ha)	5.0 ± 1.3	6.4 ± 3.1	5.4 ± 3.7
Site preparation	Disk ploughing	Deep ploughing	–
Active mound density (mean ± S.E.; ha^{-1})	2.6 ± 0.6a	0	2.9 ± 0.6a
Abandoned mound density (mean ± S.E.; ha^{-1})	0.3 ± 0.1a	0	0.3 ± 0.2a
Abandoned mounds (mean ± S.E.; %)	11.2 ± 4.0a	0	9.5 ± 6.2a

classification system (Cajander 1949). The soils were podzolic, developed on till material (Finér *et al*. 1997). The mature stands were dominated by Norway spruce (*Picea abies* L. Karst.), mixed with Scots pine (*Pinus sylvestris* L.) and white and silver birch (*Betula pubescens* Ehrh. and *B. pendula* Roth.). The 20-year-old stands were clear-cut in the early 1980s with the conventional "stem-only" method which removed all trees from the stand. Site preparation was done by deep ploughing and Scots pine seedlings were subsequently planted. The now 5-year-old stands were also clear-cut with the "stem-only" method in 1996, but some living and all dead trees were left uncut on the area. The site was prepared by disk ploughing in the autumn of 1998, and Scots pine seedlings were planted in the spring of 1999. The annual mean air temperature in the area was 1.8 °C, and the mean average annual precipitation was 700 mm. For more detailed descriptions of the study site *see* Finér *et al*. (1997, 2003).

Field measurements

All RWA mounds in the studied stands were inventoried in September 2001 by measuring their top height and base diameter (north–south and east–west), and categorising them as either active or abandoned. The ant species were not determined, but they were likely to be *Formica aquilonia* Först. or *F. polyctena* Yarr. (Baroni Urbani & Collingwood 1977, Rosengren *et al*. 1979).

Calculations and statistical tests

The above-ground volume of the ant mounds was calculated using the formula for an ellipsoid, and the base area of each mound was calculated using the formula for an ellipse. North–south and east–west diameters were averaged for statistical testing of the diameter. The physical properties of the ant mounds, diameter, height and volume were tested with ANOVA (SPSS 12.0.1) with age class (5-year-old and mature stands) as a grouping variable. Levene's test indicated similar variances between groups. All data were subjected to a logarithmic transformation before statistical analysis.

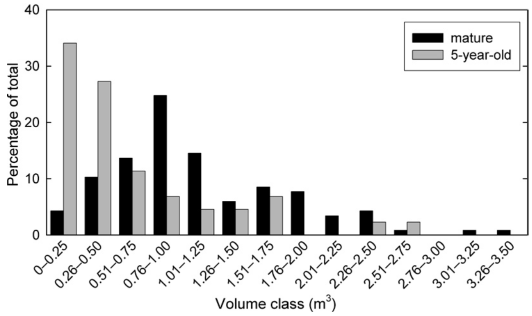

Fig. 1. Relative volume distribution of active RWA mounds in different volume classes in the mature and in 5-year-old forest stands.

Results

No RWA mounds were found in the 20-year-old Scots pine stands, while the mound density between the mature forest and the 5-year-old stands was not significantly different (Table 1, df = 1, $F = 0.016$, $p = 0.901$). The mounds in the 5-year-old stands were smaller (df = 1, $F = 7.68$, $p = 0.020$) and flatter (df = 1, $F = 10.38$, $p = 0.009$) than those in the mature ones (Table 2), although their diameter did not differ (df = 1, $F = 3.75$, $p = 0.082$). The smallest volume class (< 0.25 m^3) had the highest frequency in the 5-year-old stands, whereas mound size in the mature stands showed a more normal distribution (Fig. 1). The mounds covered 4.0 m^2 per ha both in the mature and the 5-year-old stands, which was only 0.04% of the total area. There was no difference in the

Table 2. Physical characteristics (mean ± S.E.) of active RWA mounds in the mature Norway spruce stands (n = 8) and the 5-year-old Scots pine stands (n = 4). Statistically significant different averages (p < 0.05) between the mature and the 5-year-old stands are marked by different letters (a and b).

	5-year-old stands	Mature stands
Diameter (m)	1.13 ± 0.12a	1.45 ± 0.16a
Height (m)	0.47 ± 0.05a	0.77 ± 0.05b
Volume (m^3)	0.68 ± 0.13a	1.23 ± 0.19b
Base area (m^2)	1.26 ± 0.28a	1.83 ± 0.42a

functioning (active or abandoned) of mounds between the mature and the 5-year-old stands (df = 1, $F = 1.008$, $p = 0.339$).

Discussion

The RWA mound density in the mature and 5-year-old stands was consistent with that found in other studies carried out in Finland. Using the National Forest Inventory data collected during the early 1950s, Rosengren *et al*. (1979) reported an average density of three RWA mounds per ha in the most common forest type (*Myrtillus* type). Similar mound densities have been reported for planted coniferous forest stands in northern England (Sudd *et al*. 1977), while studies conducted in Ireland, Germany and Poland found much lower mound densities (Breen 1979, Klimetzek 1981, Szczepanski & Podkowka 1983, Travan 1990). However, these studies reported mound densities for large forest areas (hundreds or thousands of hectares), and were not grouped by forest-site types or compartments, as were those of Sudd *et al*. (1977) and Rosengren *et al*. (1979). If the Finnish data from the 1950s were reported for the total forest area of southern Finland, the RWA mound density would be 1.2 mounds ha^{-1} (Wuorenrinne 1975), which is still considerably higher than the densities found in Ireland or Germany. Reasons for the low RWA mound densities in central Europe could be combinations of forest fragmentation, nest destruction (e.g. Gößwald 1971), recreational pressure (e.g. Nageleisen 1999) or air pollution and heavy metal deposition (Migula & Głowacka 1996, Rabitsch 1997). Another reason for the low mound densities in Germany could be collection of ant pupae as food for cage birds or for medical purposes, thus reducing the vitality of RWA colonies (Gößwald 1944, Wuorenrinne 1978).

No RWA mounds were found in the 20-year-old Scots pine stands. The mounds originally present on these sites may have been destroyed by clear-cutting and site preparation (ploughing) used when these stands were regenerated. Clear-cutting is known to have detrimental effects on RWA colonies, as foraging distances become longer or change (Rosengren & Pamilo 1978), and aphid colonies disappear (Rosengren & Pamilo 1978, Rosengren *et al*. 1979). Scots pine seedlings were also planted, and the changed stand composition from Norway spruce dominance to Scots pine dominance could have affected ant colony vitality, since RWAs live in a close symbiosis with aphids, and intensively tend them for honeydew. Since aphids are host tree species specific (e.g. Dixon 1973), a change in aphid species could have broken the specific symbiosis between aphids and RWAs. Other ant species, such as two of the most abundant ant species in mature boreal forests, *Camponotus herculeanus* and *Myrmica ruginodis*, benefit from the disappearance of RWAs and the microclimatic changes after clear-cutting (Punttila *et al*. 1991). However, when forest succession proceeds, these areas will presumably be colonised again by the shade-tolerant RWA species *Formica aquilonia* (Punttila *et al*. 1994, Punttila 1996).

The RWA mound density did not differ between the mature and the 5-year-old forest stands, but the mounds in the latter ones had a smaller volume. A more extreme microclimate on clear-cut areas aggravates temperature regulation in the mound (Rosengren *et al*. 1979). Clear-cutting results in higher soil surface temperature and increased precipitation reaching the forest floor. This may result in a faster decomposition of mound material, as there are already more decomposer microbes in the mound than in the soil (Laakso & Setälä 1997, 1998). This, and possible compaction of the mound material (since RWAs no more maintain the porous mound structure) could decrease mound height, as was indicated in Table 2. Clear-cutting can also cause the splitting of large mounds into smaller colonies (Rosengren & Pamilo 1978), which could explain the high number of smaller mounds in the 5-year-old stands (Fig. 1). Current logging practices and site preparation in Finland are less intensive (Forestry environment guide 1994, Korhonen *et al*. 1998) than some 20 years ago. When the stands which are now five years old were cut, some living and all dead trees were left and the sites were disk ploughed, which is less destructive than the deep ploughing that was practiced when the now 20-year-old stands were regenerated. This could account for the presence of RWA mounds in the 5-year-old stands. However, five years after logging and subsequent site preparation may not be long enough to observe the degeneration and eventual disappearance of the RWA mounds.

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References

Baroni Urbani, C. & Collingwood, C. A. 1977: The zoogeography of ants (Hymenoptera, Formicidae) in northern Europe. — *Acta Zoologica Fennica* 152: 1–34.

Breen, J. 1979: Nest sites of *Formica lugubris* (Hymenoptera, Formicidae) in Irish plantation woods. — *Journal of Life Sciences, Royal Dublin Society* 1: 13–32.

Cajander, A. K. 1949: Forest types and their significance. — *Acta Forestalia Fennica* 56.

Dixon, A. F. G. 1973: *Biology of aphids*. — The Institute of Biology's Studies in Biology no. 44, Edward Arnold Publishers Ltd. London.

Finér, L., Ahtiainen, M., Mannerkoski, H., Möttönen, V., Piirainen, S., Seuna, P. & Starr, M. 1997: Effects of harvesting and scarification on water and nutrient fluxes. A description of catchments and methods, and results from the pretreatment calibration method. — *Finnish Forest Research Institute, Research Papers* 648: 1–38.

Finér, L., Mannerkoski, H., Piirainen, S. & Starr, M. 2003: Carbon and nitrogen pools in an old-growth, Norway spruce mixed forest in eastern Finland and changes associated with clear-cutting. — *Forest Ecology and Management* 174: 51–63.

Finnegan, R. J. 1976: Umsiedlung der nützlichen Waldameisenart *Formica lugubris* Zett. (*Hymenoptera, Formicidae*) von Italien nach Kanada (Quebéc). — *Waldhygiene* 11: 161–166.

Folgarait, P. J. 1998: Ant biodiversity and its relationship to ecosystem functioning: a review. — *Biodiversity and Conservation* 7: 1221–1244.

Forestry environment guide 1994: *Finnish Forest and Park Service*. — Tuokionprint, Helsinki.

Gößwald, K. 1944: Einwirkung des Puppensammelns bei den verschiedenen Waldameisenarten. — *Zeitschrift für Angewandte Entomologie* 30: 317–335.

Gößwald, K. 1971: Über den Schutz von Nestern der Waldameisen. — *Waldhygiene* 9: 1–24.

Gößwald, K. 1989: *Die Waldameise*. — AULA-Verlag, Wiesbaden.

Hölldobler, B. & Wilson, E. O. 1990: *The ants*. — Springer Verlag, Heidelberg Berlin.

Klimetzek, D. 1981: Population studies on hill building wood-ants of the *Formica rufa*-group. — *Oecologia* 48: 418–421.

Korhonen, K.-M., Laamanen, R. & Savonmäki, S. 1998: *Finnish Forest and Park Service*. — Environmental guidelines to practical forest management. Edita, Helsinki.

Laakso, J. & Setälä, H. 1997: Nest mounds of red wood ants (*Formica aquilonia*): hot spots for litter-dwelling earthworms. — *Oecologia* 111: 565–569.

Laakso, J. & Setälä, H. 1998: Composition and trophic structure of detrital food web in ant nest mounds of *Formica aquilonia* and in the surrounding forest soil. — *Oikos* 81: 266–278.

Laakso, J. & Setälä, H. 2000: Impacts of red wood ants (*Formica aquilonia* Yarr.) on the invertebrate food web of the boreal forest floor. — *Ann. Zool. Fennici* 37: 93–100.

Laine, K. J. & Niemelä, P. 1989: Nests and nest sites of red wood ants (*Hymenoptera, Formicidae*) in subarctic Finland. — *Annales Entomologici Fennici* 55: 81–87.

Maavara, V., Martin, A.-J., Oja, A. & Nuorteva, P. 1994: Sampling of different social categories of red wood ants (*Formica s. str.*) for biomonitoring. — In: Markert, B. (ed.), *Environmental sampling for trace analysis*: 465–489. VCH Verlagsgesellschaft mbH, Weinheim.

Nageleisen, L.-M. 1999: Étude de la densité et du rôle bioindicateur des fourmis rousses dans les forêts du nord-est. — *Revue Forestière Française* 51: 487–495.

Peltola, A. (ed.) 2003: *Finnish statistical yearbook of Forestry*. — Finnish Forest Research Institute, SVT Agriculture, Forestry and Fishery.

Punttila, P. 1996: Succession, forest fragmentation, and the distribution of wood ants. — *Oikos* 75: 291–298.

Punttila, P., Haila, Y., Pajunen, T. & Tukia, H. 1991: Colonisation of clearcut forests by ants in the southern Finnish taiga: a quantitative survey. — *Oikos* 61: 250–262.

Punttila, P., Haila, Y., Niemelä, J. & Pajunen, T. 1994: Ant communities in fragments of old-growth taiga and managed surroundings. — *Ann. Zool. Fennici* 31: 131–144.

Rabitsch, W. B. 1997: Seasonal metal accumulation patterns in the red wood ant *Formica pratensis* (Hymenoptera) at contaminated and reference sites. — *Journal of Applied Ecology* 34: 1455–1461.

Rosengren, R. & Pamilo, P. 1978: Effect of winter timber felling on behaviour of foraging red wood ants (*Formica rufa* group) in early spring. — *Memorabilia Zoologica* 29: 143–155.

Rosengren, R. & Sundström, L. 1991: The interaction between red wood ants, *Cinara* aphids, and pines. A ghost of mutualism past? — In: Huzley, C. R. & Cutler, D. F. (eds.), *Ant–plant interactions*: 80–91. Oxford University Press.

Rosengren, R., Vepsäläinen, K. & Wuorenrinne, H. 1979: Distribution, nest densities and ecological significance of red wood ants (the *Formica rufa* group) in Finland. — *O.I.L.B Bulletin SROP II*, 3: 181–213.

Sudd, J. H., Douglas, J. M., Gaynard, T., Murray, D. M. & Stockdale, J. M. 1977: The distribution of wood-ants (*Formica lugubris* Zetterstedt) in a northern English forest. — *Ecological Entomology* 2: 301–313.

Szczepanski, W. & Podkowka, T. 1983: Census of ant nests from the *Formica rufa* group within the Forest Protective Belt of the upper Silesian industrial region. — *Sylwan* 127: 271–281.

Travan, J. 1990: Bestandsaufnahme der Waldameisennester im Staatswald Oberbayerns. Teil. I: Flachlandforstämter. — *Waldhygiene* 18: 119–142.

Vepsäläinen, K. & Wuorenrinne, H. 1978: Ecological effects of urbanization on the mound-building *Formica* L. species. — *Memorabilia Zoologica* 29: 191–202.

Wellenstein, G. 1952: Zur Ernährungsbiologie der Roten Waldameise. — *Zeitschrift für Pflanzenkrankheiten, Pflanzenpathologie und Pflanzenschutz* 59: 430–459.

Wuorenrinne, H. 1975: Über die Notwendigkeit und die Möglichkeiten des Waldameisenschutze in Finnland. — *Waldhygiene* 11: 48–50.

Wuorenrinne, H. 1978: The influence of collection of ant pupas upon ant populations in Finland (Hymenoptera, Formiciade). — *Notulae Entomologicae* 85: 5–11.