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SHORT COMMUNICATION

Distribution of red wood ants (Hymenoptera: Formicidae) in the clear-cut areas of a managed forest in Western Poland

Michał Żmihorski

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Abstract Red wood ants (RWAs) play an important role as predators and competitors in invertebrate communities in forest ecosystems. The abundance of RWAs in managed forest clear-cut areas was investigated in 2007 in Western Poland. The ants were counted in 1 × 1 m squares along transects that led from the edge to the centre of clear-cut areas. Squares that contained RWAs were located significantly closer to the edge as compared with squares without ants. The RWA density decreased significantly from the edge to the centre of clear-cut area. The pattern of the decrease of RWAs towards the clear-cut area centre may have serious consequences for ant-sensitive invertebrates. It can be expected that species richness and species diversity of invertebrates will be affected by forest clear-cut areas, which generate ant-free conditions.

Keywords Clear-cuts · Forest edge · Forest management · *Formica* · Spatial distribution

Introduction

The group of several ant species commonly inhabiting forests in temperate and boreal regions called red wood ants (RWAs) is considered to be an especially important component of forest ecosystems. The species that belong to the RWA group are territorial and aggressive, and form large communities. It has been proven that RWAs have great influence on the distribution and abundance of other ant species, and many other epigeic and arboreal invertebrates (e.g. spiders, carabids; Hawes et al. 2002; Koivula and Niemelä 2003; Reznikova and Dorosheva 2004; Ohashi et al. 2007; but see also Lenoir et al. 2003). It was also observed that these ants may affect the behaviour of carabids, for example forcing them to change their foraging and moving strategies (e.g. Dorosheva and Reznikova 2006). Moreover, as RWAs significantly reduce the abundance of many invertebrate taxa, they may indirectly affect the breeding success of some insectivorous birds (Aho et al. 1999; Jantti et al. 2007). Therefore, it may be assumed that factors affecting the distribution and abundance of RWAs also affect the distribution of many other groups of animals. In the light of the great biocenotic importance of RWAs, knowledge concerning the variability of their densities is crucial for understanding the overall patterns of biodiversity distribution in forest ecosystems (Punttila et al. 1991).

Since only 7% of European forests is protected (Verkerk et al. 2008) and remaining woodland is managed for timber production, one might expect that the distribution and abundance of RWAs are driven by habitat transformations that are related to timber production (clear-cutting, artificial replanting etc.; Domisch et al. 2000; Sorvari and Hakkarainen 2005, 2007). The effect of forest management on RWAs may indirectly affect the spatial distribution of invertebrate communities that are sensitive to predation by and competition with the ants. However, little is known about response of RWAs to clear-cutting in Central European forests. In this study, the distribution of RWAs in clear-cut areas of managed forests was investigated and its ecological consequences are discussed.

M. Żmihorski (✉)
Museum and Institute of Zoology,
Polish Academy of Sciences,
Wilcza 64, 00-679 Warsaw, Poland
e-mail: zmihorski@miiz.waw.pl

Materials and methods

The study was conducted in the spring and summer of 2007, in a managed forest of Western Poland, Central Europe (52°48′N, 14°20′E). The study area was located in the temperate climate zone and its main potential vegetation type was broadleaved forest dominated by oaks (*Quercus* spp.), hornbeams (*Carpinus betulus*) and limes (*Tilia* spp.). The region is affected by mild and wet oceanic climate of Western Europe and by harsh and dry continental climate of Eastern Europe and Asia. The forest was ca. 14,000 ha in size and was managed by National Forest Holding for timber production. As a result of long-lasting forest management tree composition of the stand was dominated by Scots pine (*Pinus sylvestris*), with considerably lower proportion of oaks and birch (*Betula pendula*). The forest comprised semi-rich and poor habitats, with sandy soils and understorey vegetation of the forest floor dominated by mosses (*Polytrichum* spp.), grasses (*Calamagrostis* spp., *Deshampsia flexuosa*) and shrubs (*Rubus* spp., *Vaccinium vitis-idaea*). Plant coverage on clear-cut areas was composed mainly of *Calamagrostis epigejos*, *Convolvulus arvensis*, *Rubus idaeus*, *Senecio vulgaris* and *Dryopteris carthusiana*. Stand age was highly diversified and ranged from 0 years on fresh clear-cuts to 100–150 years in the oldest patches. On the basis of old maps of the region it can be concluded that this forest complex has been managed for timber production for at least 120 years and its area has retained the same shape until nowadays (Żmihorski, unpublished data).

Sixteen transects were selected in 4 clear-cut areas not older than 3 years (3–5 transects per clear-cut area, at least 30 m away from each other). The transects started at the edge of clear-cut area and led towards its centre. Each transect was ca. 30 m long and consisted of ca. 15 separate squares where RWAs were sampled. However, because of some local disturbances some squares were omitted. Squares were distributed evenly every 2 m along the transect; the last square (fifteenth) was 30 m away from the clear-cut area edge. The boundary of each square was delineated by a 1 × 1 m wooden frame. Individuals of RWA in each square were directly counted during 1–3 min. The RWA group in the study area was composed mainly of *Formica rufa* Linnaeus, *F. sanguinea* Latreille, *F. exsecta* Nylander and *F. polyctena* Förster (Włodarczyk et al. 2009; Włodarczyk, unpublished data). Great care was taken to avoid double counting. Moreover, for each square, plant coverage (0–100%) was visually assessed as a factor potentially affecting the ants. All counts were conducted in good weather conditions, mainly in afternoon. In total, RWAs were counted in 196 squares.

The number of RWAs in the sampled squares was not normally distributed, due to a considerable proportion of squares where no RWAs were recorded. Therefore, two statistical analyses were performed. First, mean distance to clear-cut edge was compared between squares with and without red wood ants by using t test. Second, for all squares with RWAs ($n = 53$) a univariate analysis of covariance was conducted, with clear-cut area as a random categorical factor, distance to the edge of clear-cut area and plant coverage as covariates, and log-transformed number of RWAs as the dependent variable. Variance homogeneity was checked with Levene's test, which tests the null hypothesis that the error variance of the dependent variable is equal across groups. All statistical analyses were performed with SPSS 13.0 (SPSS 2004).

Results

Squares containing ants were found to be closer to clear-cut area edges (mean 10.57 m ± 7.24 SD; $n = 53$) than squares without ants (mean 17.70 m ± 8.62; $n = 143$), and the difference was statistically significant (t test, $t_{194} = 5.39$, $P < 0.0001$). The abundance of RWAs differed significantly among four clear-cut areas ($P = 0.005$), whereas the effect of plant coverage was not statistically significant ($P = 0.095$, Table 1). The number of ants recorded in the squares was significantly affected by distance to clear-cut area edge (Table 1; Fig. 1). The latter relationship was best explained by an exponential function (Fig. 1).

Discussion

Because the presented results are based on ca. 200 squares distributed on 4 clear-cut areas, the results should be treated with caution. Also, the analysis concerns only the youngest clear-cut areas, whereas patterns of RWAs abundance and distribution in older ones may be different. Despite these shortcomings, the study generated significant and reliable results. It should be mentioned that in the study

Table 1 Results of univariate analysis of covariance testing of the effect of clear-cut area, distance to clear-cut area edge and plant coverage on density of red wood ants in 1-m^2 squares in a managed forest in Western Poland

Source	*df*	*F*-value	*P*
Intercept	1	40.05	0.003
Distance to clear-cut area edge	1	25.17	<0.001
Plant coverage	1	2.91	0.095
Clear-cut	2	6.01	0.005

The assumption of equal variances across groups was met (Levene's test: $F = 0.93$; $P = 0.400$)

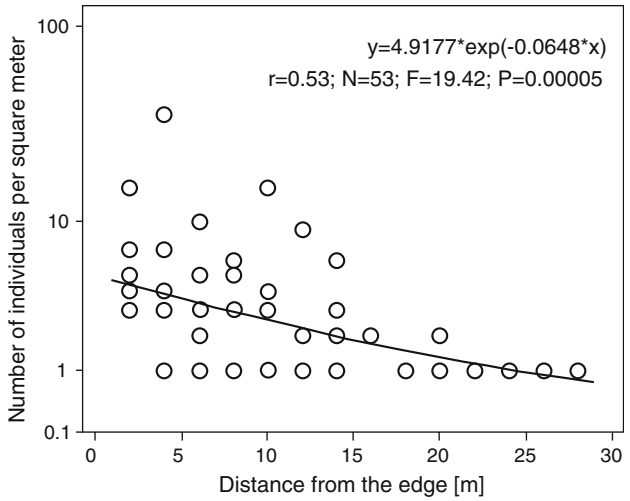

Fig. 1 Number of red wood ants (RWAs) in 1-m^2 squares in managed forest clear-cut areas in Western Poland, plotted against distance to clear-cut area edge. Note that the abundance of RWAs is not adjusted for the clear-cut area effect (Table 1)

area forest management, habitat features, replanting techniques and clear-cut characteristics are typical of most managed forests in Poland. Therefore, it can be suspected that the obtained pattern of RWAs distribution in clear-cut areas is similar in other Polish managed forests. Since managed forests comprise nearly 80% of the overall forested area in Poland (Budna et al. 2006), the results can have wide application.

It was found that the density of RWAs decreased significantly from the edge of the clear-cut area toward its centre. This result seems to be consistent with other findings, which showed negative effects of anthropogenic changes of forest habitat on *Formica* species (Domisch et al. 2000; Sorvari and Hakkarainen 2005, 2007). As a consequence, the clear-cut area centre lacks RWAs. This pattern can be explained by several factors. First, abiotic conditions, such as insolation, ambient temperature amplitude, soil and air moisture are significantly more variable in clear-cut areas than in closed-canopy forest (e.g. Aussenac 2000). Because of these specific microclimate conditions, clear-cut areas may be avoided by most ant species that belong to the RWA group (Rosengren and Pamilo 1978; Domisch et al. 2000). Second, the activity of RWAs in clear-cut areas may be limited by food resources, for instance scarcity of aphids (Punttila et al. 1991; Sorvari and Hakkarainen 2007).

Factors driving the decrease of RWAs density towards the centres of the analysed clear-cut areas remain unknown. Nevertheless, because RWAs have a strong impact on many other invertebrates (Hawes et al. 2002; Koivula and Niemelä 2003; Reznikova and Dorosheva 2004; Dorosheva and Reznikova 2006; Ohashi et al. 2007), their distribution pattern can have serious consequences. The decrease of the number of RWAs towards the clear-cut area centre may result in a change of the density of other invertebrates that suffer from predation by and/or competition with RWAs. If this is the case, clear-cut area centres may act as refugia for some epigeic invertebrates. On the other hand, some other species may decrease on the clear-cut areas because the release from RWAs predation may simplify the invertebrate community through strengthened interspecific competition that RWAs usually alleviate and through loss of niches that are usually provided by RWAs (e.g. Laakso and Setälä 1997). The predictions need further research, since their verification may help to explain the effect of timber harvesting on forest biodiversity.

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References

Aho T, Kuitunen M, Suhonen J, Jantti A, Hakkari T (1999) Reproductive success of Eurasian Treecreepers, *Certhia familiaris*, lower in territories with wood ants. Ecology 80:998–1007

Aussenac G (2000) Interactions between forest stands and microclimate: ecophysiological aspects and consequences for silviculture. Ann For Sci 57:287–301

Budna E, Grzybowska L, Karczewicz A (2006) Leśnictwo. Central statistical office in Poland, Warsaw

Domisch T, Finér L, Jurgensen MF (2000) Red wood ant mound densities in managed boreal forests. Ann Zool Fenn 42:277–282

Dorosheva EA, Reznikova ZI (2006) Behavioral mechanisms of spatial competition between red wood ants (*Formica aquilonia*) and ground beetles (Carabidae). Zh Obshch Biol 67:344–360

Hawes C, Stewart AJA, Evans HF (2002) The impact of wood ants (*Formica rufa*) on the distribution and abundance of ground beetles (Coleoptera: Carabidae) in a Scots pine plantation. Oecologia 131:612–619

Jantti A, Suorsa P, Hakkarainen H, Sorvari J, Huhta E, Kuitunen M (2007) Within territory abundance of red wood ants *Formica rufa* is associated with the body condition of nestlings in the Eurasian treecreeper *Certhia familiaris*. J Avian Biol 38:619–624

Koivula M, Niemelä J (2003) Gap felling as a forest harvesting method in boreal forests: responses of carabid beetles (Coleoptera, Carabidae). Ecography 26:179–187

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

Lenoir L, Bengtsson J, Persson T (2003) Effects of Formica ants on soil fauna-results from a short-term exclusion and a long-term natural experiment. Oecologia 134:423–430

Ohashi M, Kilpelainen J, Finer L, Risch AC, Domisch T, Neuvonen S, Niemelä P (2007) The effect of red wood ant (*Formica rufa* group) mounds on root biomass, density, and nutrient concentrations in boreal managed forests. J For Res 12:113–119

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

Reznikova Z, Dorosheva H (2004) Impacts of red wood ants *Formica polyctena* on the spatial distribution and behavioural patterns of ground beetles (Carabidae). Pedobiologia 48:15–21

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

Sorvari J, Hakkarainen H (2005) Deforestation reduces nest mound size and decreases the production of sexual offspring in the wood ant *Formica aquilonia*. Ann Zool Fenn 42:259–267

Sorvari J, Hakkarainen H (2007) Wood ants are wood ants: deforestation causes population declines in the polydomous wood ant *Formica aquilonia*. Ecol Entomol 32:707–711

SPSS (2004) SPSS 13.0 for Windows. SPSS, Chicago

Verkerk PJ, Zanchi G, Lindner M (2008) Impacts of biological and landscape diversity protection on the wood supply in Europe. EFI Tech Rep 27:1–27

Włodarczyk T, Żmihorski M, Olczyk A (2009) Ants inhabiting stumps on clearcuts in managed forest in western Poland. Entomol Fenn 20:121–128