Environ Monit Assess (2016) 188: 436
DOI 10.1007/s10661-016-5398-9

Distribution and physical traits of red wood ant mounds in a managed Rhodope mountains forest

Angelos Tsikas · Paraskevi Karanikola · Aristotelis C. Papageorgiou

Received: 2 December 2015 / Accepted: 27 May 2016 / Published online: 27 June 2016

Abstract Red wood ants (RWA) are of great ecological importance for the forest ecosystem. Forestry practices, like clear-cutting, and trampling load, due to tourism, logging, and grazing stock, can greatly affect their colonies, disturbing their microhabitat. RWA in Greek forests have not been investigated so far. We herein report on the distribution and morphological traits of *Formica lugubris* mounds studied in Elatia forest (Rhodope mountains, Northern Greece), an all-aged managed mixed forest where selective logging practices are performed. Nearby vegetation, slope, canopy cover, shrub density, and distance from the nearest neighboring trees were also recorded. Mound density was shown to be much higher in this Greek forest compared to RWA mounds in other European-managed forests. Furthermore, we recorded a continuous nest establishment, despite forest management disturbances and trampling load. Our study suggests that single-tree selective forestry practices are essential for creating ideal microhabitats for the RWA and, therefore, for maintaining RWA populations.

A. Tsikas (✉) · P. Karanikola
Department of Forestry and Management of the Environment and Natural Resources, Laboratory of Forest Protection, Democritus University of Thrace, School of Agricultural and Forestry Sciences, Pantazidou 193, 68 200 Orestiada, Greece
e-mail: atsikas@fmenr.duth.gr

A. C. Papageorgiou
Department of Forestry and Management of the Environment and Natural Resources, Laboratory of Forest Genetics, Democritus University of Thrace, School of Agricultural and Forestry Sciences, Pantazidou 193, 68 200 Orestiada, Greece

Keywords Red wood ants · *Formica lugubris* · Ant mounds · Rhodope mountains · Forest management · Mound traits

Introduction

Ants are important components of ecosystems, constituting a great part of the animal biomass and acting as ecosystem engineers (Folgarait 1998). Majer (1981) proposed ants as indicators of impacts of human disturbances on natural ecosystems. Therefore, ants became an integral part of monitoring agricultural practices (Perfecto and Vandermeer 2002), grazing by livestock (Whitford et al. 1999; Bestelmeyer and Wiens 2001), and soil erosion (Whitford et al. 1999).

Red wood ants (*Formica rufa* group), a sub-generic group within the genus *Formica*, is considered as a keystone taxon in temperate and boreal forest ecosystems due to their high abundance, high dominance, and ecological importance in forest ecosystems (Finnegan 1976; Laine and Niemala 1980; Pokarzhevskij 1981; Whittaker 1991; Frouz et al. 1997). Their mounds are reported as "hot spots" for C emissions due to the respiration activity of the ants as well as of other invertebrates such as myrmecophilous species and the microbial activities (Frouz 2000; Risch et al. 2005; Paivinen et al. 2002). RWA influence tree growth by feeding on leaf defoliators and/or protecting sap-sucking leaf aphids (Laakso and Setälä 2000). In addition, they directly affect the forest ground, canopy, and/or trunk food webs by preying on a wide range of fauna, or indirectly,

by competing with other predators, and by tending aphids (Skinner 1980; Skinner and Whittaker 1981; Von Sorensen and Schmidt 1987; Laakso 1999; Schultz and McGlynn 2000; Alonso 2000; Laakso and Setälä 2000; Graham et al. 2009).

Six species of the *F. rufa* group are considered as species of Lower Risk/Near Threatened (NT) in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2013). These species are *F. aquilonia* Yarrow, *F. polyctena* Förster, *F. rufa* L., *F. lugubris* Zetterstedt, *F. pratensis* Retzius, and *F. uralensis* Ruzsky. Key threats for these species are nest destruction by woodpeckers (Elton 1932), "wet springs" (Perrett and Stradling 1997), bracken invasion of disturbed woodlands by (Satchell and Collingwood 1955) coppice neglect (Barrett and Felton 1965), insecticide use near mounds (Wells et al. 1983), pupae collection as fish or bird food (Gauld et al. 1990), lack of forest management (Hughes 2006), fires (Nelmes 1938), grazing stock disturbance (Hughes 1975), trampling load disturbance (Martin 2010), and vandalism (Chater and Spencer 1989). On the other hand, forest management is essential for the conservation of the RWA: ride and wood edge maintenance along with the retention of honeydew-producing trees, like sycamore, oak, and Scots pine, is indispensable for favoring RWA (Fowles 1994). Albeit essential for RWA conservation, forest management may increase trampling load, overshading, forest recreation, and direct destruction of nests. Tourism can also disturb the RWA, due to heavy trampling load resulting in decreased ant paths and loss of food territory (Martin 2010).

Despite the ecological importance of the RWA and conservation concerns for certain species and their habitat, the status of the RWA Greek populations has not been investigated so far. *Formica lugubris* Zetterstedt, one of the species of the *F. rufa* group classified as Lower Risk/Near Threatened in the IUCN's Red List of Threatened Species (IUCN 2013), is only considered to be widespread from central Italy to northern Norway and in the British Isles (Breen 1977; Collingwood 1979). However, more recent studies highlight the presence of *F. lugubris* also in Greece (Legakis 1983; Borrowiec and Salata 2013), Bulgaria (Lapeva-Gjonova et al. 2010), and the rest of the Balkan Peninsula (Agosti and Collingwood 1987a). Since RWA species are morphologically very similar and able to hybridize (Seifert 1991; Czechowski 1996), the taxonomy has always been difficult and controversial concerning correct species identification (Yarrow 1955; Seifert 1991).

The aim of the present study was to report on the presence of *F. lugubris* in Elatia forest and to assess the size and physical traits of its mounds. Elatia forest in Drama (Rhodope mountains) is a mixed forest where *F. lugubris* species has been recorded. Opposed to most even-aged boreal forests where *F. lugubris* is abundant, Elatia is an all-aged managed forest where selective logging practices are performed; these practices have far less impact on forest processes than clear-cutting but can change microclimate and therefore affect RWA (Ray et al. 2005). We also assessed the main flora species found nearby *F. lugubris* mounds and attempted to discuss our findings relative to forest management practices applied in this habitat. Considering that ecological studies of *F. lugubris* in Mediterranean forests are lacking, our study presents the first report on RWA mounds traits in an all-aged Mediterranean forest.

Materials and methods

Study area

We studied RWA mounds in a 7-ha area in Elatia forest, Northern Greece (41° 29′ N, 24° 18′ E), an all-aged managed forest dominated by Norway spruce (*Picea abies* L.), Scots pine (*Pinus sylvestris* L.), and copper beech (*Fagus sylvatica* L.). By the 1960s, the stand was put under the management of the Forest Service (Oikonomakis and Ganatsas 2012). Selective logging silvicultural practices are performed every 10 years, last practiced in 2010. The altitude is 1510–1535 m above sea level. The understory vegetation was dominated by shrubs, mainly by common bilberry (*Vaccinium myrtillus* L.) and European raspberry (*Rubus idaeus* L.), and the bottom layer by wild strawberry (*Fragaria vesca* L.).The site type is classified as Vaccinio-Piceion (Cajander 1949). The geological formation consists mainly of granite, gneiss, and limestone (Zagas 1990) For more detailed description of the study area, see Tsiaoussi (1996).

Field study

All RWA mounds were inspected during July–August 2012. Parameters recorded with regard to the mound physical traits were top height and base diameters (northsouth, eastwest, minimum, and maximum). These were mapped with a Global Positioning System. We also

recorded the slope, the nearest neighboring tree distance from the mounds and their breast height diameter, canopy cover species assemblage, shrub density in a 5-m radius, and ground vegetation species in a 1-m radius. Abandoned and/or destructed mounds were not included in our analyses.

Ant species

Ant species were collected with direct sampling. Individuals were kept in ethanol and later on identified in the lab by using identification keys by Agosti and Collingwood (1987b).

Mathematical calculations

Above-ground volume of ant mounds was calculated using the formula of an ellipsoid ($V = \frac{4}{3}\pi abc$), while the base area of each mound was calculated using the formula of an ellipse ($A = \pi ab$). Mound dispersion was calculated using the index of dispersion ($D = \frac{\sigma^2}{\mu}$). Mound physical traits (height, basal area, and volume) were analyzed with factor analysis (principal components method). The component with the largest eigenvalue (cumulative = 93.08 %) was again analyzed with factor analysis with the environmental factors (slope, brightness, shrub density, distance from the nearest tree, and its breast height diameter) (SPSS 17.0). The nest density was calculated and analyzed with QGIS 2.2.0.

Results and discussion

In the study area, we found 46 active mounds of the species *F. lugubris* with an average of 6.53 mounds/ha, following a random spatial pattern (Fig. 1), number far higher than European forests. Mound density of RWAs can be high (up to 18 mounds/ha) in certain forest types, like temperate and boreal forests (Raignier 1948; Ceballos, and Ronchetti, 1965; Gris and Cherix 1977; Cherix and Bourne 1980). Sudd et al. (1977) recorded a mean density of 1.61 mounds/ha in Northern England, with a maximum in a forest compartment which contained gills and scrubs of 5.6 mounds/ha. However, most recent studies showed much lower densities. The mean density we calculated was much bigger than the respective in forests in the Republic of Ireland, France, Germany, and Poland (0.005–0.320 mounds/ha) (Breen 1979; Klimetzek 1981; Szczepanski and Podkowka 1983; Travan 1990; Nageleisen 1999). Even compared to the boreal forests of Finland, where *F. lugubris* is abundant, the average density of mounds in several studies was found to be much lower (3 mounds/ha) (Rosengren et al. 1979; Domisch et al. 2005; Kilpelainen et al. 2005). Travan (1998) found densities between 0.32 and 17.78 mounds/ha of all the RWA species in the Bavarian Alps, 15 % of which were *F. lugubris*.

Nests were found to be 0.74 m in height and 0.5 m^3 in volume (Table 1). Domisch et al. (2005) found an average of 0.47 m in height and 0.68 m^3 in volume in 5-year old Scots pine stands and 0.77 m in height and 1.23 m^3 in volume in mature Norway spruce stands. But since

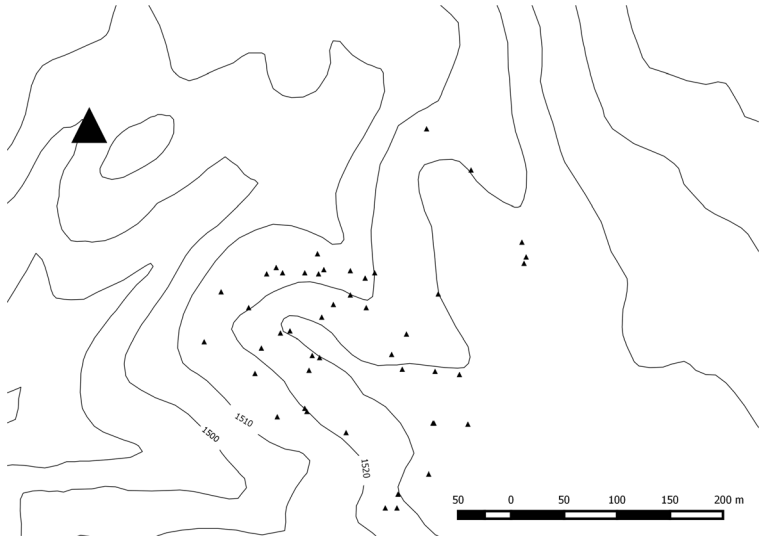

Fig 1 *F. lugubris* mounds in the study area (QGIS 2.2.0)

Table 1 Physical traits of *F. lugubris* mounds found in Elatia forest (Rhodope mountains)

Mean diameters (m)				Mean physical traits		
NS	EW	Min	Max	Height (m)	Basal area (m^2)	Volume (m^3)
0.87 (0.35)	0.90 (0.27)	0.72 (0.27)	1.16 (0.63)	0.74 (0.31)	0.76 (0.62)	0.50 (0.41)

Standard deviations are in parentheses

NS north to south base diameter, *EW* east to west base diameter, *Min* minimum base diameter, *Max* maximum base diameter

such measurements have been made in even-aged stands and found significant differences depending on the age of the stand, we cannot infer anything for an all-aged forest, like Elatia forest.

Physical traits, like size and shape, of RWA mounds are largely dependent upon environmental factors, but in general, older mounds have larger domes (Fowles 1994). Morley (1953) suggests that nests over 1 m in height may be between 40 and 100 years old. Since we did not find any correlation among the physical characteristics, brightness, slope, distance from the nearest overstory tree and its breast height diameter, and density of shrubs and understory trees (Table 2), we conclude (due to the large variation of the physical trait measurements) that there was a variability in the age of the nests, which means that there is still nest establishment as well as older mounds, despite the management disturbances and the trampling load caused by visitors and the residents of Forest Village of Elatia (loggers and officials of the Forest Service and the students do their internships in the area during the summer months). Further research is needed about other environmental factors that can affect the physical characteristics of the mounds that were not taken into account, such as the availability of nest material and exposure to wind and rain.

For most mounds (78.26 %), there was at least one tree in distance of 2 m from the center of the mound (mean 1.77 m with mean BHD 0.39 m), mostly of Norway spruce (91.67 %) and occasionally of Scots pine (5.55 %). Also, all mounds had some form of ground vegetation within 1.5 m radius; a total of 20 different plant species, a species of the genus *Campanula*, a species of the genus *Lathyrus*, and certain grasses that could not be identified, a total of 15 different families (Table 3). In 77 % of the mounds, the ground vegetation included *Vaccinium myrtillus*, and other common species were *Rubus idaeus* (68 %) and *Fragaria vesca* (46 %).

Since we have a variance of the age of the nest, we conclude that we have continuous nest establishment and a low rate of nest abandonment. That means that trampling load due to tourism activities do not seem to disturb the RWA nest establishment and population. Also, silviculture practices, like single-tree selection, do not affect negatively the mounds, but, contrary, they create sunny hotspots, considered as the ideal microhabitat for the RWA. Maybe the all-aged forests managed with single-tree selection silviculture practices create the ideal habitat for RWA, and that is the reason why they are abundant, since the number of mounds per hectare in even-aged stands was found much lower (Breen 1979;

Table 2 Correlation matrix of the quantitative variable used in factor analysis

	Slope	Brightness	Shrub density	Nearest tree	Physical characteristics	BHD
Slope	1					
Brightness	−0.005	1				
Shrub density	0.062	0.214	1			
Nearest tree	−0.059	−0.377	−0.112	1		
Physical characteristics	−0.036	0.144	−0.035	−0.166	1	
BHD	0.01	0.311	0.142	−0.431	0.161	1

Physical characteristics: variable related to the factors height, basal area, and volume with factor analysis (cumulative = 93.08 %)

BHD diameter at 1.3 m height

Table 3 The flora species found within 1.5 m radius from the center of the mounds

Asteracea	Pinaceae
Cirsium apeticulatum	*Picea abies*
Mycelis muralis	*Pinus sylvestris*
Campanulaceae	Poaceae
Campanula sp.	*Dactylis glomerata*
Dennstaedtiaceae	*Festuca arundinacea*
Pteridium aquilinium	*Poa trivialis*
Ericaceae	Other grasses
Vaccinium myrtillus	Rosaceae
Euphorbiaceae	*Fragaria vesca*
Euphorbia amygdaloides	*Rubus idaeus*
Fabaceae	Rubiaceae
Lathyrus sp.	*Galium verum*
Trifolium repens	Salicaceae
Fagaceae	*Populus tremula*
Fagus sylvatica	*Salix caprea*
Lamiaceae	Urticaceae
Prunella vulgaris	*Urtica dioica*
Onagraceae	
Epilobium angustifolium	

Rosengren et al. 1979; Klimetzek 1981; Szczepanski and Podkowka 1983; Travan 1990; Nageleisen 1999; Domisch et al. 2005), so maintaining the all-aged forest management could be essential in order to keep the number of mounds high. But further monitoring of the mounds is needed for the reaction of the ants after the logging of nearby trees, especially for the aphid-rich trees, like Scots pine (Fowles 1994) and the photophilic trees, because they create sunny gasps in the forest. The Scots pine *P. sylvestris*, which is co-dominant in Elatia along with the Norwegian spruce *P. abies*, is aphid-rich and photophylic too, so maintaining its populations with variable retention practices could be important for maintaining RWA populations. Felling trees are important for RWA too, so thinning and coppicing trees are the best methods to mimic naturally occurring, small-scale disturbances. But large and unsustainable clear fells can be devastating for the RWA, especially the small and vulnerable populations (Hughes 2006). Although Sudd et al. (1977) proposed rides and clearings at intervals of about 40 m to establish wood ants at a high even density.

Also, additional briefing is needed for the tourists, herders, and lumberjacks, in order to prevent future vandalisms, grazing stock, and direct damage when carrying out forestry operations, respectfully.

Acknowledgments The first author of this study was financed by the Greek Scholarships Foundation, in the framework of the Operational Programme "Education and Life Long Learning" within the National Strategic Reference Framework (2007–2013) implemented the Action "Scholarships Programmes by the State Scholarships Foundation.

References

Agosti, D., & Collingwood, C. A. (1987a). A provisional list of the Balkan ants (Hym. Formicidae) with a key to the worker caste. I. Key to the worker caste, including the European species without the Iberian. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft, 60*, 51–62.

Agosti, D., & Collingwood, C. A. (1987b). A provisional list of the Balkan ants (Hym. Formicidae) with a key to the worker caste. II. Key to the worker caste, including the European species without the Iberian. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft, 60*, 261–293.

Alonso, L. E. (2000). Ants as indicators of diversity. In D. Agosti, J. D. Majer, L. E. Alonso, & T. R. Schultz (Eds.), *Ants: standard methods for measuring and monitoring biodiversity* (pp. 80–88). Washington, DC: Smithsonian Institution Press.

Barrett, K. E. J., & Felton, J. C. (1965). The distribution of the wood ant *Formica rufa* L. (Hym., Formicidae) in south-east England. *Entomologist, 98*, 181–191.

Bestelmeyer, B., & Wiens, J. (2001). Ant biodiversity in semiarid landscape mosaics: the consequences of grazing vs. natural heterogeneity. *Ecological Applications, 11*, 1123–1140.

Borrowiec, L., & Salata, S. (2013). Ants of Greece—additions and corrections (Hymenoptera: Formicidae). *Genus, 24*, 335–401.

Breen, J. (1977). The distribution of *Formica lugubris* Zetterstedt (Hymenoptera, Formicidae) in Ireland, with a discussion of its possible introduction. *Irish Naturalists' Journal, 19*, 123–127.

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

Cajander, A. K. (1949). Forest types and their significance. In: *Acta Forestalia Fennica* 56(5): 1–71. Helsinki: Finnish Society of Forest Research.

Ceballos, P., & Ronchetti, F. G. (1965). Le formiche del grouppo *F. rufa* sui Piranei orientali spagnoli nelle province di Nerida i Gero. *Estretto delle Memorie Societá Entomologica Italiana, 45*, 153–168.

Chater, A. O. & Spencer, R. A. (1989). The wood ant *Formica rufa* in Ceredigion, VC46. *Dyfed Invertebrate Group Newsletter, 15*, 12–17.

Cherix, D., & Bourne, J. D. (1980). A field study on a supercolony of the red wood ant *Formica lugubris* Zett. in relation to other predatory arthropods (spiders, harvestmen and ants). *Revue Suisse de Zoologie, 87*, 955–973.

Collingwood, C. A. (1979). The Formicidae (Hymenoptera) of Fenoscandia and Denmark. *Fauna Entomologica Scandinavica, 8*, 141.

Czechowski, W. (1996). Colonies of hybrids and mixed colonies, interspecific take over in wood ants (Hymenoptera, Formicidae). *Memorabilia Zoologica, 50*, 1–116.

Domisch, T., Finer, L., & Jurgensen, M. F. (2005). Red wood ant mound densities in managed boreal forests. *Annales Zoologici Fennici, 42*, 277–282.

Elton, C. (1932). Territory among wood ants (*Formica rufa* L.) at Picket Hill. *Journal of Animal Ecology, 1*, 69–76.

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

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

Fowles, A. P. (1994). A review of the ecology of the red wood ant *Formica ruffa* L. (Hymenoptera, Formicidae) and its status in Wales. *Conservation Biology in Wales, 1*, 1–22.

Frouz, J. (2000). The affect of nest moisture on daily temperature regime in the nest of *Formica polyctena* wood ants. *Insectes Sociaux, 47*, 229–235.

Frouz, J., Santruckova, H., & Kalcik, J. (1997). The effect of wood ants (*Formica polyctena* Foerst.) on the transformation of phosphorus in a spruce plantation. *Pedobiologia, 41*, 437–447.

Gauld, I. D., Collins, N. M., & Fitton, M. G. (1990). *The biological significance and conservation of Hymenoptera in Europe*, *Nature & Environment 44*. Strasbourg: Council of Europe.

Graham, J., Krzysir, A., Kovacic, D., Duda, J., Freeman, C., Emlen, J., et al. (2009). Species richness, equitability, and abundance of ants in disturbed landscapes. *Ecological Indicators, 9*, 866–877.

Gris, G., & Cherix, D. (1977). Les grandes colonies de fourmis des bois du Jura (groupe *Formica rufa*). *Bulletin de la Societe Entomologique Suisse, 50*, 249–250.

Hughes, I. (1975). Changing altitude and habitat preferences of two species of wood-ant (*Formica rufa* and *F. lugubris*) in North Wales and Salop. *Transactions of the Royal Entomological Society, London, 127*, 227–239.

Hughes, J. (2006). A review of wood ants (Hymenoptera: Formicidae) in Scotland. Scottish Natural Heritage Commissioned Report No. 178 (ROAME No. F04AC319).

IUCN. (2013). IUCN red list of threatened species. Version 2013.1. <www.iucnredlist.org>. Accessed 15 May 2014.

Kilpelainen, J., Punttila, P., Sundstrom, L., Niemela, P., & Finer, L. (2005). Forest stand structure, site type and distribution of anr mounds in boreal forests in Finland in the 1950s. *Annales Zoologici Fennici, 42*, 243–258.

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

Laakso, J. (1999). Short-term effects of wood ants (*Formica aquilonia* Yarr.) on soil animal community structure. *Soil Biology and Biochemistry, 31*, 337–343.

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

Laine, K. J., & Niemala, P. (1980). The influence of ants on the survival of mountain birches during an Oporinia autumnata (Lep., Geometridae) outbreak. *Oecologia, 47*, 39–42.

Lapeva-Gjonova, A., Antonova, V., Radchenko, A. G., & Atanasova, M. (2010). Catalogue of the ants (Hymenoptera, Formicidae) of Bulgaria. *ZooKeys, 62*, 1–124.

Legakis, A. (1983). First contribution to the study of the ants (Hymenoptera, Formicidae) of the Zagori region (Epirus, Greece): an annotated list of species. *Entomologia Hellenica, 1*, 3–6.

Majer, J. (1981). Ants: bioindicators of minesite rehabilitation, land use, and land conservation. *Environmental Management, 7*, 375–383.

Martin, A. (2010). Red wood ants settlements as outside objects and management of ant-friendly tourism. Nature Conservation Beyond 2010, May 27–29, 2010, Tallinn, Estonia. Abstract.

Morley, D. W. (1953). *Ants. New naturalist monograph*. London: Collins.

Nageleisen, L. M. (1999). Etude de la densite et du role bioindicateur des fourmis rousses dans les forets du nord-est. *Revue Forestiere Francaise, 51*, 487–495.

Nelmes, E. (1938). A survey of the distribution of the wood ant (*Formica rufa*) in England, Wales and Scotland. *Journal of Animal Ecology, 7*, 74–104.

Oikonomakis, N., & Ganatsas, P. (2012). Land cover changes and forest succession trends in a site of Natura 2000 network (Elatia forest), in northern Greece. *Forest Ecology and Management, 285*, 153–163.

Paivinen, J., Ahlroth, P., & Kaitala, V. (2002). Ant-associated beetles of Fennoscandia and Denmark. *Entomologica Fennica, 13*, 20–40.

Perfecto, I., & Vandermeer, J. (2002). Quality of agroecological matrix in a tropical montane landscape: ants in coffee plantations in southern Mexico. *Conservation Biology, 16*, 174–182.

Perrett, J. & Stradling D. J. (1997). Population status and reproductive biology of the endangered British ant *Formica exsecta* in Devon. Unpublished report for English Nature.

Pokarzhevskij, A. D. (1981). The distribution and accumulation of nutrients in nests of ant *Formica polyctena* (Hymenoptera, Formicidae). *Pedobiologia, 21*, 117–124.

Raignier, A. (1948). L'économie thermique d'une colonie polycalique de la Fourmi des bois. *La Cellule, 51*, 279–367.

Ray, D., Nepstad, D., & Moutinho, P. (2005). Micrometeorogical and canopy controls of fire susceptibility in a forested Amazon landscape. *Ecological Applications, 15*, 1664–1678.

Risch, A. C., Jórgensen, M. F., Schótz, M., & Page-Dumroese, D. S. (2005). The contribution of red wood ants to soil C and N pools and to CO2 emissions in subalpine forests. *Ecology, 86*, 419–430.

Rosengren, R., Vespalainen, 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.

Satchell, J. E., & Collingwood, C. A. (1955). The wood ants of the English Lake District. *North Western Naturalist, 3*, 23–29.

Schultz, T. R., & McGlynn, T. P. (2000). The interaction of ants with other organisms. In D. Agosti, J. D. Majer, L. E. Alonso, & T. R. Schultz (Eds.), *Ants: standard methods for measuring and monitoring biodiversity* (pp. 35–44). Washington, DC: Smithsonian Institution Press.

Seifert, B. (1991). The phenotypes of the *Formica rufa* complex in East Germany. *Abhandlungen und Berichte des Naturkundemuseum Gorlitz, 65*, 1–27.

Skinner, G. J. (1980). The feeding habits of the wood-ant *Formica rufa* (Hymenoptera: Formicidae), in limestone woodland in north-west England. *Journal of Animal Ecology, 49*, 417–433.

Skinner, G. J., & Whittaker, J. B. (1981). An experimental investigation of inter-relationships between the wood-ant (*Formica rufa*) and some tree-canopy herbivores. *Journal of Animal Ecology, 50*, 313–326.

Sudd, J., Douglas, J., Gaynard, M., Murray, M., & Stockdale, J. (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 region. *Sylwan, 127*, 271–281.

Travan, J. (1990). Bestandsaufnahme der Waldameisennester im Staatswald Oberbayerns Teil. I. Flachlandforstamter. *Waldhygiene, 18*, 119–142.

Travan, J. (1998). Über den Einfluss von Standortfaktoren auf die Besiedlung des bayerischen Hochgebirges durch Waldameisen (Formica spp.) (Hymen., Formicidae). *Anzeiger für Schadlingskunde Pflanzenschutz, 71*, 105–109.

Tsiaoussi, V. (1996). *Specific management plan for the site Periochi Elatia (GR1 140003)*. Thermi: The Goulandris Natural History Museum-Greek Biotope/Wetland Centre 197 p. (In Greek).

Von Sorensen, U., & Schmidt, G. H. (1987). Vergleichende Untersuchungen zum Beuteeintrag der Waldameisen (Genus: Formica, Hymenoptera) in der Bredstedter Geest (Schleswig-Holstein). *Journal of Applied Entomology, 103*, 153–177.

Wells, S. M., Pyle, R. M., & Collins, N. M. (1983). *The IUCN Invertebrate Red Data Book*. Gland: International Union for Conservation of Nature and Natural Resources.

Whitford, W., Van Zee, J., Nash, M., Smith, W., & Herrick, J. (1999). Ants as indicators of exposure to environmental stressors in North American desert grasslands. *Environmental Monitoring and Assessment, 54*, 143–171.

Whittaker, J. B. (1991). Effects of ants on temperate woodlands. In C. R. Huxley & D. F. Cutler (Eds.), *Ant-plant interactions* (pp. 67–69). Oxford: Oxford University Press.

Yarrow, I. H. H. (1955). The British ants allied to *Formica rufa* L. (Hym., Formicidae). *Transactions of the Society for British Entomology, 12*, 1–48.

Zagas, T. (1990). Conditions for natural establishment of *Pinus sylvestris* in an area of Rhodopi mountain, northern Greece (p. 170). Ph.D. thesis. Thessaloniki: Aristotle University.