Lesn. Cas. For. J. 62 (2016) 223–228 DE GRUYTER OPEN DOI: 10.1515/forj-2016-0026

Lesnícky časopis - Forestry Journal
http://www.nlcsk.sk/fj/

ORIGINAL PAPER

Foraging strategy and food preference of *Formica polyctena* ants in different habitats and possibilities for their use in forest protection

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Abstract

Food availability is an important factor influencing the lives of ant colonies. Wood ants consume protein-rich and sugary foods. Protein-rich food is comprised primarily of insects, a considerable proportion of which the ants acquire by direct predation. They therefore play an important function in biological protection of forests. The objective of our study was to determine if workers activity is dependent on habitat type, size of the nest, bait size and food type (sugar, protein). We selected 23 nests in a spruce forest and placed food baits of various sizes and types near each nest. The results obtained show that the number of individuals on the baits was substantially higher in clearings than within mature forest. The number of worker ants recorded on the baits was slightly higher for larger nests. Bait size and type had no influence on the number of workers present. Because wood ants do not focus solely on food of a certain size or quality, they can effectively decrease the abundance of forest pests.

Key words: clear-cut; food bait; forest pest control; *Formica* wood ants; mound; nest size

Editor: Tomáš Hlásny

1. Introduction

Foraging strategy is an important characteristic for ants which influences the life of the entire colony (Hölldobler & Wilson 1990). Insufficiency of food or its low quality is negatively reflected in the body size of adult ants and in the colony's survival (Sommeijer & Veen 1990; Sorvari & Hakkarainen 2009). Therefore, ants employ various strategies and adaptations in order to increase the efficiency of food acquisition (Dornhaus & Powell 2009; Novgorodova 2015), and ants' food intake accordingly is greater than that of other, similarly sized invertebrates (Petal 1978). Ants acquire food by predating on animals and collecting honeydew, which can comprise up to 80% of wood ants' food (Domisch et al. 2009). To reach a stable food source, they follow marked paths which may remain the same for years (Gordon et al. 1992; Buhl et al. 2009).

Wood ants' predation pressure on other invertebrates is an important factor in relation to forest protection (Niemelä & Laine 1986; Olofsson 1992; Mahdi & Whittaker 1993; Punttila et al. 2004). When they occur in high densities, wood ants can change the taxonomical composition of other animal communities and their behaviours (e.g. Reznikova & Dorosheа 2004). Although wood ants forage for food as much as 100 m distant from their nests, their significant impact is limited to a distance of ca 20 m (Koehler 1976; Punttila et al. 2004; Sorvari 2009). One nest of average size acquires food from a territory of 0.27 ha. During a season, more than 6 million animals are gathered (Horstmann 1972). The occurrence of wood ants is therefore actively supported (Čapek 1985) and ants are used in forest pest management (Starý et al. 1987; Švestka et al. 1998). Wood ants demonstrably reduce the population densities of Symphyta larvae (Codella & Raffa 1993). They predate on adult larvae of the lesser spruce sawfly – *Pristiphora abietina* (Christ, 1791) fallen from trees (Beier-Petersen 1956; Schwerdtfeger 1957, 1960, 1970, 1971; Kolubajiv 1958; Ruppertsho-Fen 1958; Beyer 1967; Codella & Raffa 1993) and of the moths (Wiśniewski 1956, 1978 in Čapek 1985): *Bupalus piniarius* (Linnaeus, 1758), *Panolis flammea* (Denis & Schiffermüller, 1775), and *Dendrolimus pini* (Linnaeus, 1758). An impact of ant predation has often been observed as the existence of "green islands" of undefoliated trees around nests during periods of high herbivore insect abundance (Wainhouse 2008).

There is currently not sufficient information on wood ants' food preferences in relation to their function in forest protection. We studied the wood ant *Formica polyctena* Förster, 1850, which is a common forest ant species (Bezděčka & Bezděčková 2011). Given its reproductive potential, strong concentration of individuals, aggressiveness, and ability to divide swarms, it is the most important species for forest pest management (Starý et al. 1987). *Formica polyctena* inhabits primarily coniferous and mixed forests and is found less commonly also in broadleaf forests. The species builds its nests most frequently in sunny places (clearings and forest edges). According to its food strategy it is classified as a scavenger and non-selective predator (Czechowski et al. 2002; Bezděčka & Bezděčková 2011). Within our study we were interested in whether: (i) worker ants' predation activity is greater in clearings or within forests, (ii) this activity differs depending on the size of the nests from which the workers come, (iii) the ants prefer smaller or larger prey, and (iv) they prefer sugary or protein-rich foods.

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2. Material and methods

The study was conducted in a coniferous forest in the Kamenný vrch nature reserve near the Czech village of Horní Řasnice (50°58'30.02"N, 15°13'09.34"E) at an altitude of 440 m a.s.l. The forest is dominated by Norway spruce (*Picea abies*). The research was conducted on 25 August 2015, at a time when the ant population is highest and activity of workers is also high (Domisch et al. 2009; Rosengren & Sundström 1987, 1991). Study of ants activity was done between 13 – 15 hour CET. In this time air temperature was approximately 22 °C at the nearest meteorological station in Frýdlant. Twenty-three nests were selected at random. We choose nests with ca. 70 m distance at 1700 m long path intersecting whole locality. Choosed distance is higher than average radius of wood ants territory (Horstmann 1974, Whittaker 1991). Seven nests were located in a clearings, 16 nests in forest. At a distance of 3 m from each nest we placed large and small baits consisting of sugary (honey) and protein-rich (tuna fish) foods. The baits were placed on paper plates. The large bait contained 1 cm^3 of each type of food, whereas the small bait had only 0.3 cm^3 of each. Baits with the same food were placed on opposite sides of the nest. The distance was selected so it would be apparent to which nest the ants recorded on the baits belonged and at the same time so that the numbers of ants would not be affected by excessive distance from the nest. The numbers of ants on baits should not be dependent on distance up to 20 m from the nest (Lenoir 2002). The number of workers on each bait was observed 15 min after its placement. For each nest, we recorded its location (grown forest or clearing) and dimensions. Nest volume was calculated from the measured dimensions based on the formula $V = 0.5\ \pi\ l\ s\ h$. This formula expresses the mean volume of a cone and three axis ellipsoid (Frouz & Finer 2007).

We used a generalized linear model for statistical evaluation. Because animal abundance is usually not well approximated by normal distribution, the Poisson generalized model is frequently used for this purpose (Pekár & Brabec 2009). Although one of the assumptions of the Poisson model is that the distribution's mean is equal to its variance, the data on the number of worker ants in various biotopes and in various types of baits did not fulfil this assumption. Resolving this situation required a correction for overdispersion using the quasiPoisson model (Pekár & Brabec 2009). The regression model was created according to the procedure stated in Crawley (2007) and Pekár & Brabec (2009) in the environment of the R statistical software (R Core Team 2013). Because the data was not normally distributed, the Poisson model was used to predict mean values and the 95% confidence interval around the mean. Bivariate normality assumption was not fulfilled in the relationship between number of workers and nest size, for that reason the Spearman's rank correlation method was used (Quinn & Keough 2002).

3. Results

The mean (± SD) number of workers on sugary baits in clearings was 152 ± 107, whereas on the same type of baits in mature forests there were 70 ± 88 workers. We recorded a mean of 222 ± 148 workers on meat baits placed in clearings versus 72 ± 85 workers within the forest (see Table 1). The mean number of workers on large baits in clearings was 157 ± 110, in mature forests there were 63 ± 73 workers. We also recorded a mean of 217 ± 148 workers on small baits placed in clearings and 79 ± 97 workers within the forest (see Table 2). The number of observed individuals was substantially higher in clearings than within the forest and the difference between these two biotopes was statistically significant ($p < 0.001$; Table 3). The number of worker ants present was slightly higher for larger nests (Spearman's $r = 0.23$), although the influence of this parameter only bordered upon the level of significance ($p = 0.065$; Table 3). The interaction of these two factors, however, was significant ($p < 0.01$; Table 3). The presence of workers in clearings was high but in this case the nest size was small. In clearings, numbers of workers on baits decreased with increasing size of the recorded nest. In the case of forest biotopes, just the opposite situation occurred. The number of worker ants present increased in proportion with increasing nest size (Fig. 3). Bait size, type of food, size:food interaction, and even the third-degree biotope:type:food interaction all had no significant influence on the number of workers present (Table 3).

Table 1. Number of workers in the compared locations according to food type used. Simple mean and standard deviation (sd) are stated. Due to the non-Gaussian distribution of the data, the mean predicted by the Poisson model is also stated along with the sd and 95% confidence interval.

Location	Bait type	Mean simple	sd	Mean prediced	sd	2.50%	97.50%
forest	honey	70	88	64	27	45	103
	meat	72	85	78	33	46	106
clearing	honey	152	107	168	42	83	206
	meat	222	148	206	51	146	300

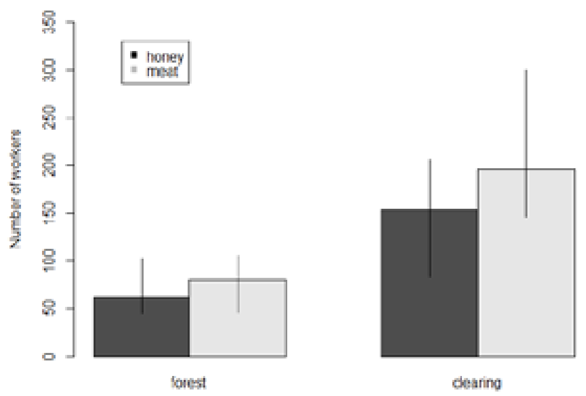

Fig. 1. Bar graph showing mean number of workers within forest and in clearings according to bait type used (honey and meat). Vertical lines correspond to the 95% confidence interval for the mean value.

Table 2. Number of workers in the compared locations according to bait size used. Simple mean and standard deviation (sd) are stated. Due to the non-Gaussian distribution of the data, the mean predicted by the Poisson model is also stated along with the sd and 95% confidence interval.

Location	Bait size	Mean simple	sd	Mean prediced	sd	2.50%	97.50%
forest	large	63	73	61	25	40	95
	small	79	97	81	33	52	114
clearing	large	157	110	162	37	101	233
	small	217	148	212	48	128	274

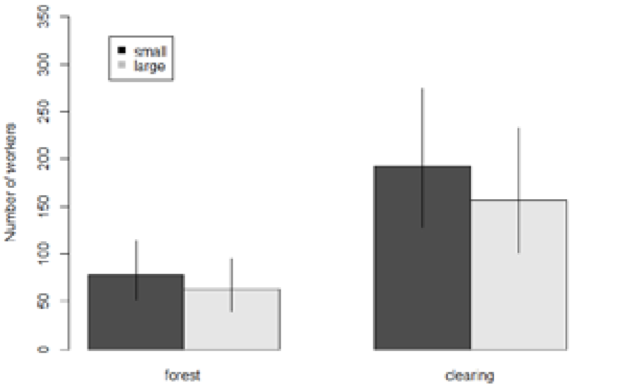

Fig. 2. Bar graph showing mean number of workers within forest and in clearings according to bait size used (small and large). Vertical lines correspond to the 95% confidence interval for the mean value.

Table 3. Results of the regression analysis after correcting for over dispersion.

	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL		87	9965.6		
nest size	314.54	86	9651.1	3.5018	0.065005 .
locations	1812.19	85	7838.9	20.1751	2.38E-05 ***
bait type	165.95	84	7673	1.8475	0.177944
bait size	91.14	83	7581.8	1.0147	0.316853
nest size: locations	753.7	82	6828.1	8.391	0.004876 **

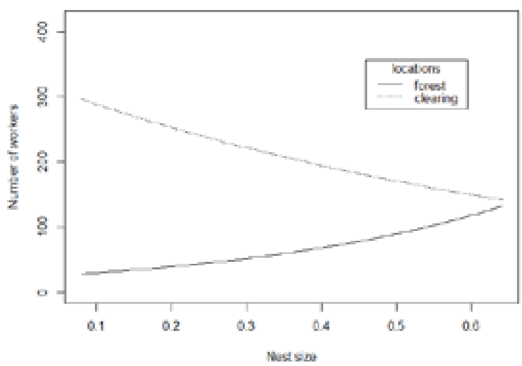

Fig. 3. Recorded numbers of workers depending on nest size. Lines represent the trend predicted using the quasi-Poisson model: log (workers) = nest size+locations+nest size: locations.

4. Discussion

The number of workers recorded on baits was higher in clearings and near large nests (Figs. 1 and 2). This can be explained by the generally higher number of workers foraging for food. The higher number of workers in clearings may indicate a greater interest in food or its insufficiency within the nest's territory. In clearings, food sources are reduced as compared to mature forest (Sorvari & Hakkarainen 2007). Ants obtain more food at forest edges (Jokimäki et al. 1998). According to Sorvari & Hakkarainen (2005), selection of locations for founding new nests in clearings is influenced by their vicinity to forest edges. The reason for their more abundant occurrence in clearings, however, also could be the sufficient amount of solar radiation. In spruce forests, higher species diversity and larger ant abundance occur in forest clearings (Véle et al. 2016). Less intra- and inter-species competition can also be assumed to occur in clearings because ants are found in very low abundance there (Véle et al. 2011). Larger colonies occur in mature forests (Kilpeläinen et al. 2008) and have better capability to ensure sufficient food (Sorvari & Hakkarainen 2007). The presence of large numbers of aphids on trees in comparison to other plants is another positive circumstance (Punttila & Kilpeläinen 2009). Trees in mature forests with larger crown diameters also demonstrate higher concentrations of some sugars attractive for ants than do young trees in clearings (Johansson & Gibb 2012). Ants in a forest will therefore probably have dependable honeydew sources. Sufficiency of food is reflected in nest volume growth (Sorvari & Hakkarainen 2005), and it is known that more voluminous nests occur in mature forests (Kilpeläinen et al. 2008). This can also explain our finding that the number of workers present on baits near nests in clearings decreased with increasing nest size. Larger nests have wider territories (Maavara et al. 2008) and can forage for food on trees at clearing edges and in the full-grown forest. It is worthwhile for ants to carry precious resources or larger loads even over longer distances (Orians & Pearson 1979).

Smaller nests were found in clearings than in mature forests. The results correspond to those of Frouz & Finer (2007), Ellis et al. (2014), and Chen & Robinson (2015), who recorded larger nests in shady areas due especially to the ants' population dynamics (new nests are often established in clearings) and their need to ensure a suitable temperature within the nests. Less-populated nests are more dependent on sunlight for thermoregulation (Frouz 2000), and forests provide lower local temperature (Chen & Robinson 2015). Although trees influence local temperature parameters (Junttila et al. 2006), they also provide better food sources (Jokimäki et al. 1998). Nest size depends, too, on food availability (Sorvari & Hakkarainen 2005). According to Chen & Robinson (2015), in clearings where there are fewer trees a smaller abundance of aphids can also be expected. Considerable demand for additional food may explain the fact that the type of bait used and its size did not influence the baits' occupation by ants. That the visitation rate of the baits is independent of their size indicates that ants take advantage of both small and large food sources. Wood ants are able quickly to occupy food sources (see Rosengren & Fortelius 1987), as confirmed by the high number of workers on certain baits recorded in this study. *F. polyctena* ants gather sugar and protein food together. Their ratio depends on the quality and availability of the food (Horstmann 1972). Preference for specific bait types can change throughout the year and over the years (Rust et al. 2000) and also depending on the forest's succession stage (Véle et al. 2009). The recorded foraging on both types of baits indicates the ants' need to acquire additional food sources. Also Horstmann (1972) states that *F. polyctena* are specialized exploiters. As stated above, ants in clearings may suffer from insufficient presence of food sources (Sorvari & Hakkarainen 2007), whereas ants in mature forests likely face strong intra-specific competition. In the studied location covering an area of 30 ha, 150–200 nests have long been observed (Sýkorová et al. 2015), and thus competition can reasonably be expected to have an important influence there. The results obtained confirm that wood ants are capable of hunting prey regardless of its size, and this is advantageous from a forest protection perspective. Herbivorous insects are considered pests in cases of their increased abundance (Metcalf & Luckmann 1994). A more abundant species would be encountered more frequently by hunting ants. Given that they do not focus their predation solely on prey of a certain size, ants may effectively decrease pest abundance.

5. Conclusion

In this study of *F. polyctena* it was determined that the number of workers recorded on baits was higher in clearings and near larger nests. Their number in clearings decreased, however, with increasing nest size. Smaller nests were found in clearings than in mature forests. Neither the type of bait used (honey, meat) nor its size (1 cm^3 and 0.3 cm^3) had an influence on ant occupation. In clearings, ants probably find less food and therefore more abundantly occupy any new source. Larger nests probably already have more food available due to their larger territories, and thus new sources are less necessary for them. Wood ants are able to hunt prey regardless of its size, which confirm their importance in reducing the abundance of various forest pest invertebrates.

Acknowledgements

This contribution was prepared with support of a project of the Ministry of Agriculture through institutional support for long-term conceptual development of a research organization of the Ministry of Agriculture of the Czech Republic – Decision No. RO0116 (reference number 10462/2016-MZE-17011).

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