

Ecological requirements of some ant species of the genus *Formica* (Hymenoptera, Formicidae) in spruce forests

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ABSTRACT: Five types of stand stages (clearings-samplings, plantations, thinnings, thickets, and mature forests) of spruce forests were examined at the foothills of the Jizerské hory Mts. in summer 2005 and 2006. The presence of ants was surveyed by catching them into pitfall traps and observing on baits. Higher numbers of *Formica fusca* ants were found in clearings-samplings and in plantations. Their activity was higher at the soil and air temperature of 20–30°C. The peak of activity was observed in July. Most specimens were trapped at lighter habitats and in the sites with more than 50% herbaceous and gramineous vegetation cover. *F. pratensis* was trapped in plantations and thickets. It was active at the soil temperatures 12–21°C and air temperatures 16–25°C. It occurred both in dark and light areas. *F. sanguinea* most commonly occurred in thinnings. This species was the most active at the soil temperature 20–30°C. Its activity depending on air temperature grew almost linearly. It occurred both in dark and in light stand stages with at least 60% vegetation cover. *F. truncorum* was observed only in thinnings. The activity of *F. truncorum* was the highest at the air and soil temperatures 15–25°C. The peak of activity was recorded in July. It was observed only in stands with the quantity of incident radiation 1,030 lx and with 20–80% of undergrowth cover.

Keywords: *Formica*; ecological requirements; spruce forests

The ants of the genus *Formica* are a significant component of forest ecosystems. They influence soil qualities and the presence of some plant species and they also have a strong influence on surrounding zoocoenosis (see VÉLE, HOLUŠA 2007). The occurrence of ants is dependent on the quantity of light (NIEMELÄ et al. 1996; PUNTTILA et al. 1996; SUOMINNE et al. 1999), the structure and quantity of vegetation and the quantity of food supplies relating to it (ELMES, WARDLAW 1982; SAVOLAINEN,

VEPSÄLÄINEN 1989; GALLÉ 1991; MORRISON 1998; RETANA, CERDÁ 2000; MARKÓ, CZECHOWSKI 2004; SORVARI, HAKKARAINEN 2005). Air and soil temperatures are important for the activity of workers (PORTER, TSCHINKEL 1987; SAVOLAINEN, VEPSÄLÄINEN 1989).

The presented paper deals with four universally widespread Central European ant species of the genus *Formica*: *Formica fusca* Linnaeus, 1758, *Formica pratensis* Retzius, 1783, *Formica sanguinea*

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Latreille, 1798, and *Formica truncorum* Fabricius, 1804 (CZECHOWSKI et al. 2002).

The aim of the paper is to scientifically describe the occurrence and activity of individual ant species depending on stand age, intensity of light incident upon the soil surface, quantity of undergrowth, and air and soil temperatures in spruce forests.

METHODS

The studies were done in Norway spruce (*Picea abies* [L.] Karst.) forests near Jablonec nad Nisou (Czech Republic) at an altitude of 620–760 m. The study area is in a slightly warm climatic zone with the mean annual temperature and precipitation of 7°C and 1,000 mm, respectively. As a result of this climate, podzols are dominant soil types. The original beech woods were replaced by spruce monocultures so that now the spruce is a predominant species in this rugged upland (CULEK 1996).

In 2005 and 2006 ant communities were sampled in closed spruce forests in the age classes 0–2 (clearings-samplings), 3–5 (plantations), 8–12 (thinnings), 26–41 (thickets) and 85–105 (mature forests) years in five independent chronosequences (25 sites in total). At each site, there were pitfall traps and baits. Six traps were exposed at each site for 2 weeks in June, July and August in both years.

The numbers of the particular species of ants were surveyed by means of pitfall traps, which is the most convenient method for these purposes (VÉLE et al. submitted). The activity of workers depending on air and soil temperature was observed by means of

baits. The baits were placed 30 cm from the pitfall traps and were checked at the same times as the pitfall traps but only twice each month. They were observed five times a day from 08.00 a.m. to 5.00 p.m. Each bait contained 2 cm³ of canned tuna fish meat (including oil) and 1 cm³ of honey, with both types of bait-food placed at the opposite sides of a 15 cm-diameter paper plate. The quantities of the baits were precisely measured and supplied throughout the day. The ants were identified using the taxonomic key of CZECHOWSKI et al. (2002).

Air and soil temperatures were measured with a Comet R0122 datalogger. An air temperature sensor was located 20 cm above the soil surface; a sensor measuring the soil temperature was placed circa 1 cm under the soil surface. The light incident upon the soil surface was measured once a year during a single cloudy day, which guaranteed the uniform brightness of solar radiation. The quantity of the incident light was measured at 10 different places on each surface. The average quantity of the light incident upon the soil surface was calculated from the acquired data.

The undergrowth was characterized by the cover of five 20% degrees. The acquired data were processed in Microsoft Office Excel. The presence of species in individual stand stages and the activity compare among three months were compared by means of one-way ANOVA and Tukey's tests in Statistica 6.0 (StatSoft 2006). General linear models (quadratic degree, Poisson distribution) were set up in Canoco for Windows 4.0 (TER BRAAK, ŠMILAUER 1998) to delineate the dependence of individual species on

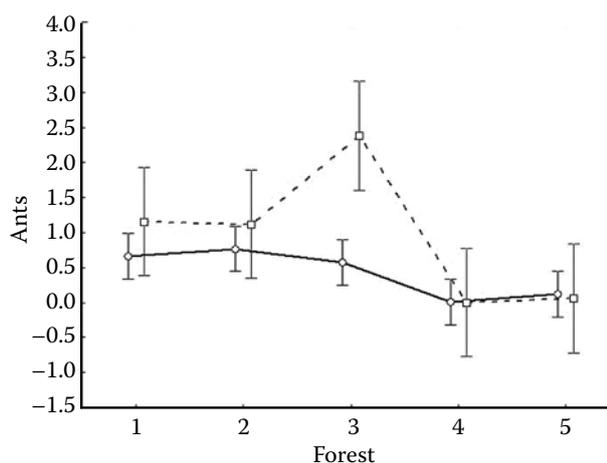


Fig. 1. Average number of *F. fusca* (solid line) and *F. sanguinea* (dash line) specimens trapped per one pitfall trap in individual stand stages [1 ... 0–2 years (clearings-samplings), 2 ... 3–5 years (plantations), 3 ... 8–12 years (thinnings), 4 ... 26–41 years (thickets), 5 ... 85–105 years (mature forests)]

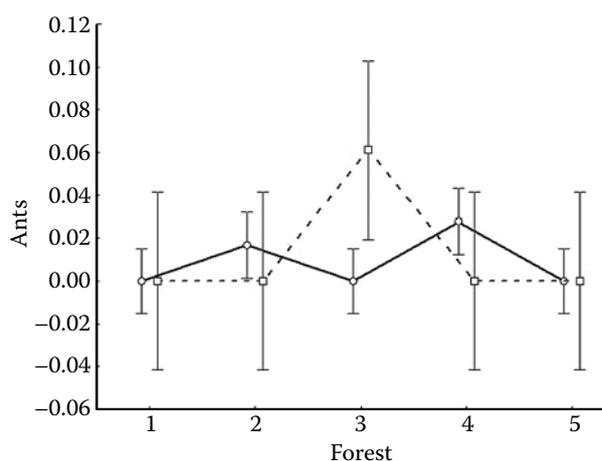


Fig. 2. Average number of *F. pratensis* (solid line) and *F. truncorum* (dash line) specimens trapped per one pitfall trap in individual stand stages [1 ... 0–2 years (clearings-samplings), 2 ... 3–5 years (plantations), 3 ... 8–12 years (thinnings), 4 ... 26–41 years (thickets), 5 ... 85–105 years (mature forests)]

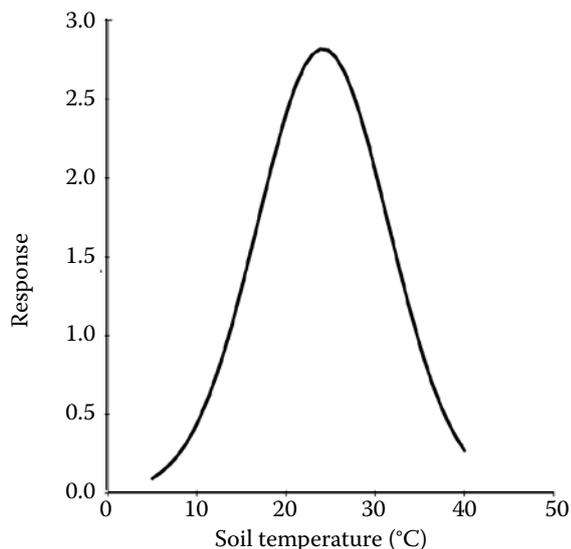


Fig. 3. GLM of the activity of the *F. fusca* ants depending on soil temperature ($F = 66.43, p < 0.001$)

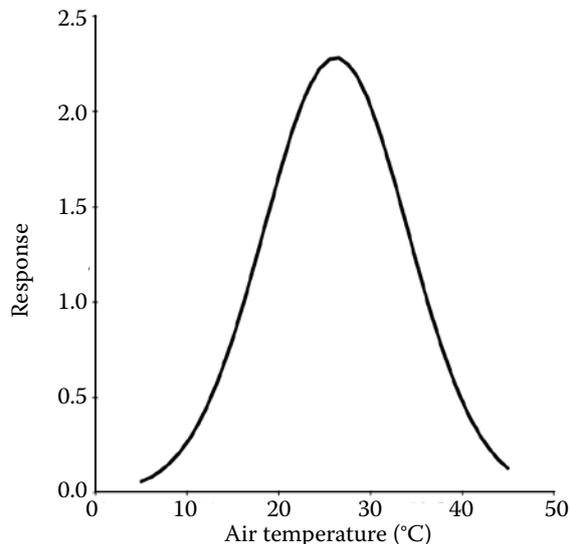


Fig. 4. GLM of the activity of the *F. fusca* ants depending on air temperature ($F = 66.43, p < 0.001$)

environmental factors. Scatter charts were created in R 2.6.2. when the GLMs were not significant.

RESULTS

Only four species of the genus *Formica* were recorded. *F. fusca* was trapped in the number of 383 specimens into pitfall traps and was observed 5,396 times on baits, *F. sanguinea* 849 specimens and 3,070×, *F. truncorum* 8 specimens and 280 observations, *F. pratensis* 8 specimens and 28×.

F. fusca ($F = 4.23, p = 0.042$) was found to be more numerous in clearings-samplings than in thickets

($p < 0.001$), it occurred more often in plantations than in thinnings ($p = 0.01$) and mature forests ($p = 0.04$) (Fig. 1). *F. fusca* was the most active at the air and soil temperature within the range of 20–30°C. The temperatures lower than 10°C and higher than 40°C subdue its activity (Figs. 3 and 4). The activity was significantly different among months ($F = 10.48, p < 0.001$). It was higher in July and September than in August ($p < 0.001$). Most specimens were trapped at lighter habitats with the quantity of incident radiation 3,000–8,000 lx (Fig. 5) and in the sites with more than 50% herbaceous and gramineous vegetation cover (Fig. 6).

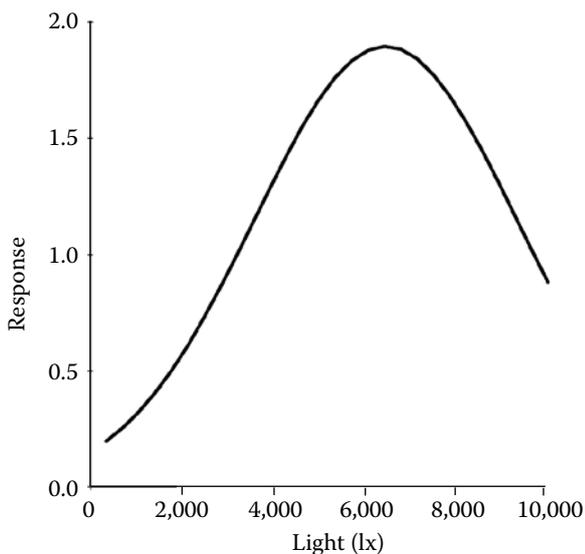


Fig. 5. GLM of the occurrence of the *F. fusca* ants depending on the quantity of light incident upon the soil surface ($F = 8.71, p < 0.001$)

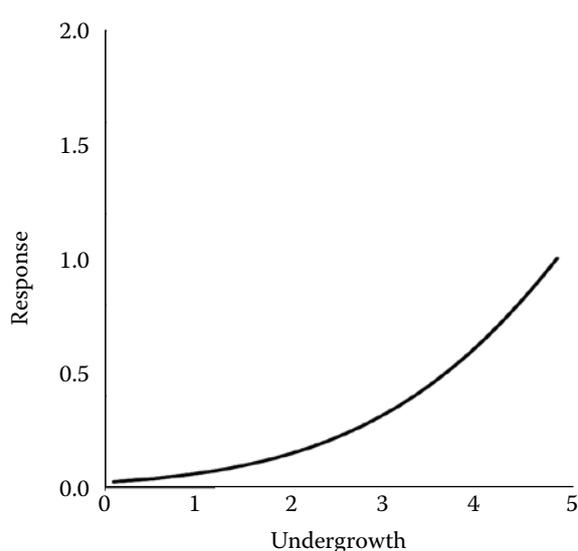


Fig. 6. GLM of the occurrence of the *F. fusca* ants depending on the quantity of undergrowth ($F = 4.92, p = 0.008$)

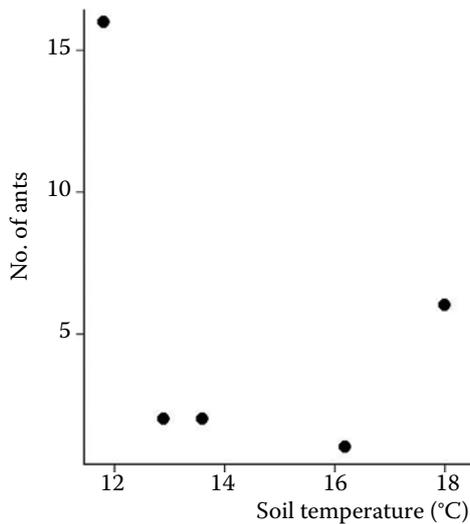


Fig. 7. The activity of the *F. pratensis* ants depending on soil temperature

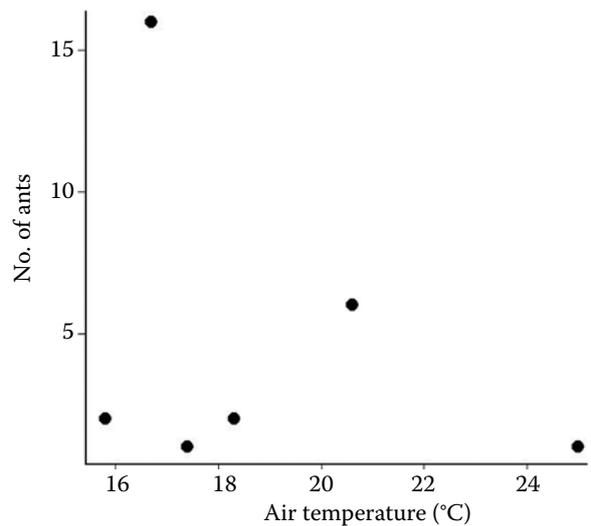


Fig. 8. The activity of the *F. pratensis* ants depending on air temperature

F. pratensis was trapped in plantations and in thickets (Fig. 2) but due to the low number of examined specimens it was not possible to prove any significant differences ($F = 2.69, p = 0.303$). *F. pratensis* was observed to be active at the soil temperatures 13–21°C (Fig. 7) and air temperatures 16–25°C, the air temperatures did not mostly exceed 21°C (Fig. 8). The activity of workers did not differ among months ($F = 0.37, p = 0.69$). It occurred both in dark and in light areas (Fig. 9) independently of the undergrowth density (Fig. 10).

F. sanguinea occurred differently in forest stages ($F = 6.11, p = 0.001$); most commonly it occurred in thinnings where it was significantly more nume-

rous than in thickets ($p < 0.001$) and mature forests ($p < 0.001$) (Fig. 1). This species was the most active at the soil temperature 20–30°C (Fig. 11); its activity depending on air temperature grew almost linearly (Fig. 12). The activity of workers did not depend on the month of observation ($F = 4.04, p = 0.18$). It occurred both in dark and in light stand stages, more numerous by the radiation 1,800–6,000 lx (Fig. 13). It is completely evident that it prefers stands with at least 60% vegetation cover (Fig. 14).

F. truncorum was observed only in thinnings (Fig. 2) but due to the low number of trapped specimens the differences among individual types of stand stages are not significant ($F = 1.66, p = 0.156$). The activity

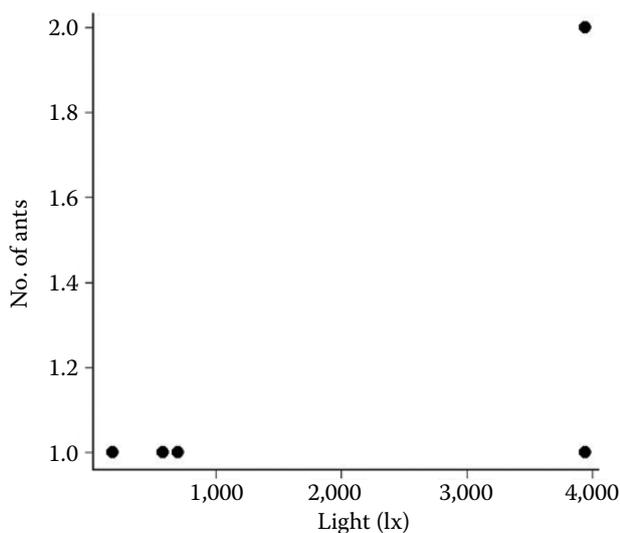


Fig. 9. The activity of the *F. pratensis* ants depending on the quantity of light incident upon the soil surface

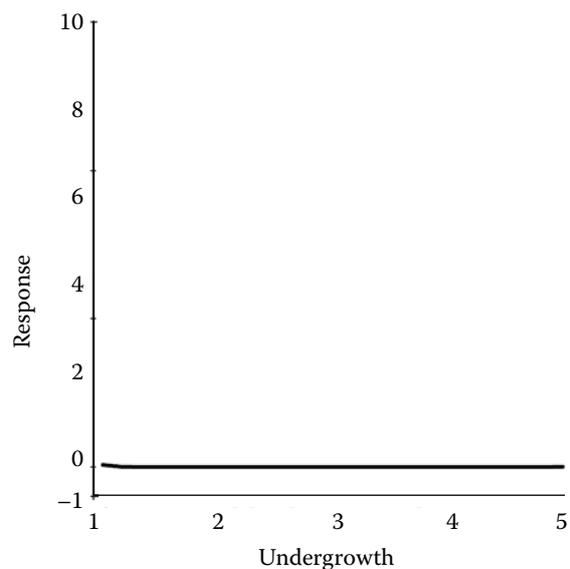


Fig. 10. GLM of the occurrence of the *F. pratensis* ants depending on the quantity of undergrowth ($F = 6.17, p = 0.002$)

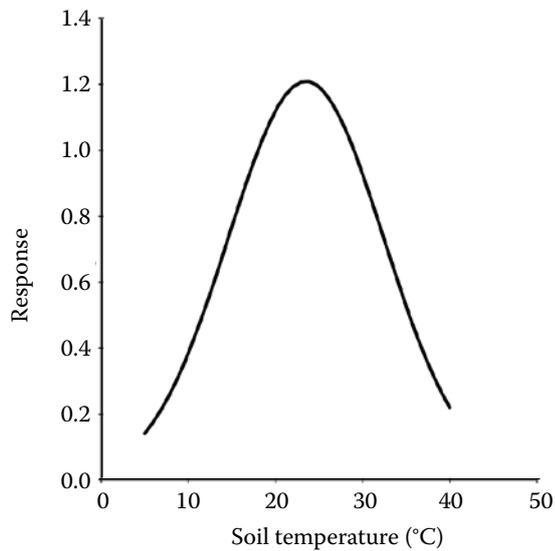


Fig. 11. GLM of the occurrence of the *F. sanguinea* ants depending on soil temperature ($F = 9.89, p < 0.001$)

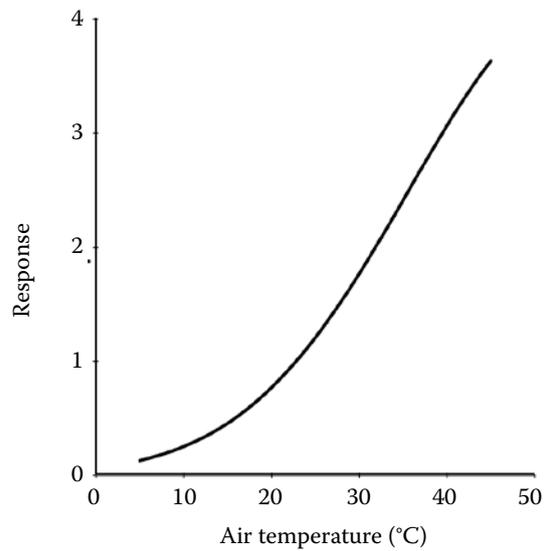


Fig. 12. GLM of the occurrence of the *F. sanguinea* ants depending on air temperature ($F = 33.02, p < 0.001$)

of *F. truncorum* was the highest at the air and soil temperatures 15–25°C (Fig. 15 and 16). The activity of workers differed among months ($F = 9.38, p < 0.001$). It was higher in July than in August ($p = 0.001$) and September ($p = 0.007$). It was observed only in stands with the quantity of incoming radiation 1,030 lx and most often in stands with 40–60% of undergrowth cover (Fig. 17).

DISCUSSION

All four species of ants inhabit a wider spectrum of biotopes including conifer forests, and thus also

spruce forests. The occurrence of individual species in different stand stages mostly corresponds with the general requirements mentioned by other authors (see below).

It is evident that the environmental factors measured by us depend on the age of a forest and on the quantity of solar radiation penetrating into individual stand stages.

F. fusca is a typical eurytopic and pioneering species that inhabits various habitats (PUNTTILA et al. 1991; CZECHOWSKI et al. 2002). It occurs both in dry and in wetland sites. It inhabits sunny habitats, meadows, light and dense forests, wetlands, and

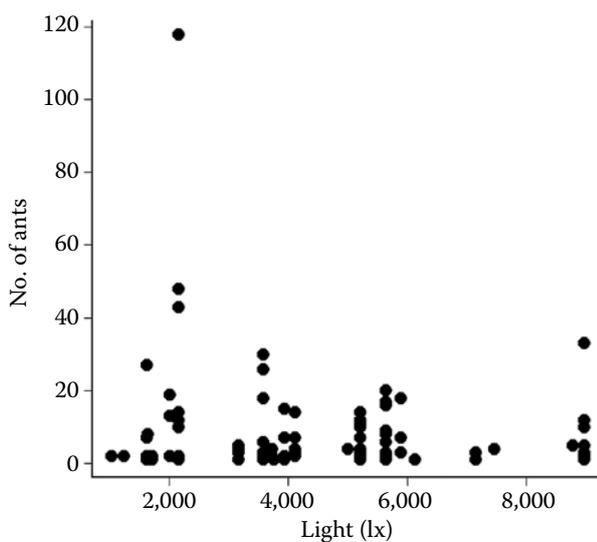


Fig. 13. The activity of the *F. sanguinea* ants depending on the quantity of light incident upon the soil surface

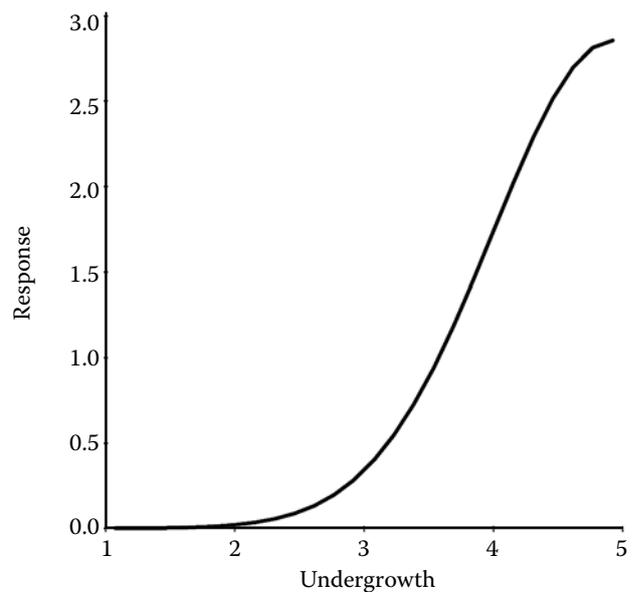


Fig. 14. GLM of the occurrence of the *F. sanguinea* ants depending on the quantity of undergrowth ($F = 4.06, p = 0.018$)

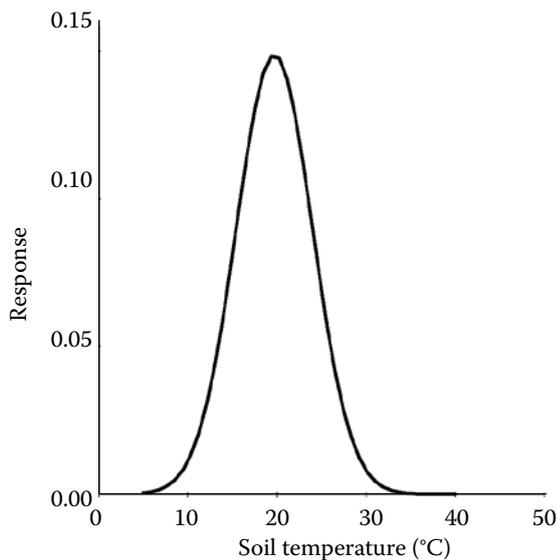


Fig. 15. GLM of the occurrence of the *F. truncorum* ants depending on soil temperature ($F = 5.68, p = 0.003$)

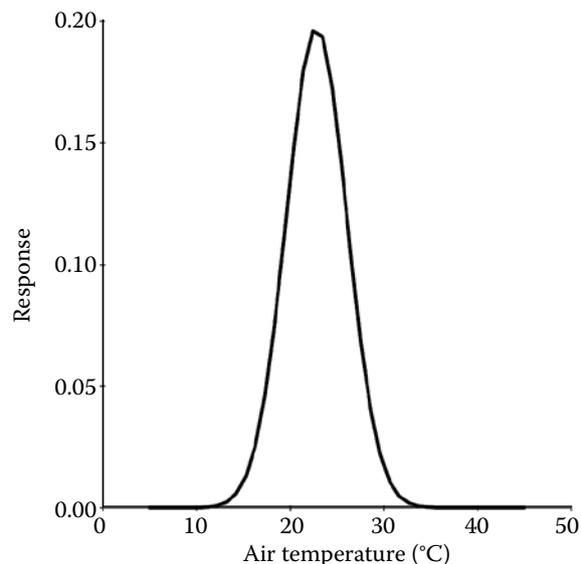


Fig. 16. GLM of the occurrence of the *F. truncorum* ants depending on air temperature ($F = 13.97, p < 0.001$)

rocks and artificial biotopes (VYSOKÝ, ŠUTERA 2001; CZECHOWSKI et al. 2002; HOLEC, FROUZ 2005; GROC et al. 2007). Yet it is evident that its numbers differ depending on the type of biotope. In reclaimed areas it was most often found in stands with autonomically growing bushes and trees and least often in non-reclaimed areas with initial successional stages. It was more abundant in open spaces than in forests (HOLEC, FROUZ 2005). DAUBER and WOLTERS (2004) discovered differences not only among biotopes but also differences depending on the location in a given biotope.

F. fusca is a species common in spruce forests (PUNTTILA et al. 1991; NIEMELÄ et al. 1996). The

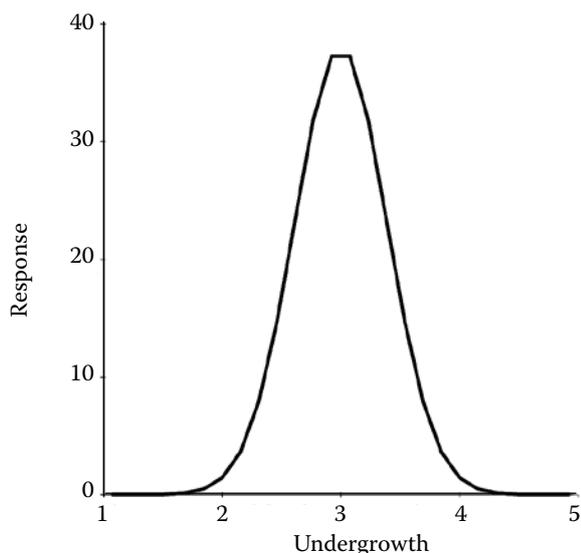


Fig. 17. GLM of the occurrence of the *F. truncorum* ants depending on the quantity of undergrowth ($F = 12.23, p < 0.001$)

occurrence of this species in individual stands (Fig. 1) entirely corresponds with information in literature. In the Carpathian Mountains it was found in the raspberry bush stage and one-year clear-cut (MARKÓ 1999). It is found particularly in young stands including clearings, most numerous in ten- up to twenty-years old stands (PUNTTILA et al. 1991; NIEMELÄ et al. 1996). It can also occur in older stands if they are phytic enough, e.g. by means of fragmentation or the presence of clearings (PUNTTILA et al. 1996).

NIEMELÄ et al. (1996) believed that *F. fusca* do not inhabit stands that are less than 10 years old and more than 20 years old very much because colonies of this species are dependent on direct solar radiation and require open spaces and unclosed tree layers. Similarly, during our research *F. fusca* was found especially in lighter sites (Fig. 5). In the areas with high density of the slaver species *F. sanguinea*, *F. fusca* can be displaced into less convenient shady localities (PUNTTILA et al. 1996).

F. pratensis is a polytopic species of dry habitats; it lives in open sites in forests, treeless plains, meadows and pasturelands (CZECHOWSKI et al. 2002). It was also found on rocks or in artificial biotopes (gardens, trenches; VYSOKÝ, ŠUTERA 2001); it was rare in wet heathlands (MAES et al. 2003). In forests it was found e.g. by HOLEC and FROUZ (2005) but it was much more numerous on meadows in the surrounding countryside. Its occurrence was validated in oak forests and caussa, not in pine forests (GROC et al. 2007). According to MABELIS and KORCZYŃSKA (2001) it prefers dry localities in open stands.

It is very rare in spruce forests, it is found only in young stands (up to 10 years) and on the edges of older stands (PUNTTILA et al. 1991; NIEMELÄ et al. 1996). It was also found in older stands but very rarely (Fig. 2).

Although we found out that its occurrence is independent of the undergrowth cover (Fig. 10), MABELIS and KORCZYŃSKA (2001) stated that *F. pratensis* avoids dense undergrowth and high gramineous vegetation, because it seeks food in trees and bushes in particular. At extreme temperatures it decreases its activity (HARTNER 2004). We also registered its higher activity at temperatures lower than 24°C (Fig. 8).

Although *F. sanguinea* is considered a forest species inhabiting especially clearings and forest edges, as a matter of fact it inhabits more of dry habitats (CZECHOWSKI et al. 2002). It prefers sunny areas; therefore it was found also on meadows, detritus, quarries, rocks, displacements of stones on meadows, and old dumping grounds (VYSOKÝ, ŠUTERA 2001; CZECHOWSKI et al. 2002) but also in anthropogenic sites. In some areas it was found in open areas and not in forests (GROC et al. 2007), in other places more specimens were trapped in forests than in open spaces (HOLEC, FROUZ 2005). In isolated cases it is said to inhabit wet heathlands (MAES et al. 2003).

In spruce forests it is one of the most numerous represented species (PUNTTILA et al. 1991; NIEMELÄ et al. 1996). It is already found in clearings (PUNTTILA et al. 1991, 1996; MARKÓ 1999), mostly, however, in young forests (2–0 years) (PUNTTILA et al. 1991, 1996; NIEMELÄ et al. 1996) and also in mature forests (NIEMELÄ et al. 1996). Nonetheless, its occurrence in mature forests probably depends on forest canopy because colonies of this species are dependent on direct solar radiation and require open spaces and unclosed tree layers (NIEMELÄ et al. 1996; PUNTTILA et al. 1996). Information in literature referring to the age of forest and light demands corresponds with our findings (Figs. 1, 13). *F. sanguinea* is able to form very strong colonies only until the canopy closes (PUNTTILA, HAILA 1996). Another factor that makes this species dominate in young forests is interspecific relationships. The strongly aggressive *F. sanguinea* displaces territorial wood ants into older forests (PUNTTILA et al. 1996).

F. truncorum is bound especially to conifer and mixed forests but it occurs also in deciduous forests. It inhabits sunny places particularly in mid-forest glades, open places and open stands (BETREM 1960; CZECHOWSKI et al. 2002). Even though it principally

lives in forest biotopes, in isolated cases it occurs on shrubby meadows and rocks. It builds its nests of vegetable material leaned against tree stumps, more rarely in tree stumps and independent hills (VYSOKÝ, ŠUTERA 2001); there were many nests on the south edges of trunks of fallen trees (BETREM 1960).

It is already found in clearings and young forests (PUNTTILA et al. 1991, 1996; NIEMELÄ et al. 1996) only until the canopy is closed (PUNTTILA et al. 1996; MABELIS, KORCZYŃSKA 2001). We validated its presence only in young forests (thinnings, Fig. 2). It was not found in clearings, which could have been caused by its low numbers in observed localities.

We found out that *F. truncorum* mostly occurred in areas approximately half covered with vegetation (Fig. 17), which roughly corresponds to the thesis that the *F. truncorum* ants avoid dense undergrowth and high gramineous vegetation because they seek food particularly in trees and bushes (MABELIS, KORCZYŃSKA 2001). On that account vegetation effects are indirect because they lie mainly in changes in accessibility of food (PUNTTILA et al. 1991; NIEMELÄ et al. 1996; PERFECTO, VANDERMEER 1996; PUNTTILA, HAILA 1996; DAUBER, WOLTERS 2005).

The activity of ants strongly depends on microclimate conditions. The ant activity is affected mainly by the temperature of soil surface (present study, SKINNER 1980; MACKAY, MACKAY 1989; CHALLET 2005; AZCARATE et al. 2007), but it may also be influenced by wind (PICKLES 1935). The activity increases with raising temperature (HOLT 1955), reaches the maximum and decreases later (present study, POL, DE CASENAVE 2004; DREES et al. 2007; ZHENG et al. 2007; AZCARATE et al. 2007). The dependence of activity on solar radiation has a very similar curve like the dependence on soil or air temperature because there is a significant correlation between the amount of light and temperature (LAJZEROWICZ et al. 2004). But these relationships can be partly influenced by photoperiod (NORTH 1993) and of course by interspecific competition (FELLERS 1989). We suggest that microclimate conditions could explain differences in the activities of *F. fusca* and *F. pratensis* during the season. Another possible explanation of this difference is an oscillation of worker numbers during the season (ANDREWS 1929) as a result of available food (DESLIPPE, SAVOLAINEN 1995).

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Ekologické nároky některých druhů mravenců rodu *Formica* (Hymenoptera, Formicidae) ve smrkových lesích

ABSTRAKT: Výzkum probíhal v pěti typech porostních stadií (paseka, kultura, mlazina, tyčovina, dospělý porost) smrkových lesů na úpatí Jizerských hor v létě roku 2005 a 2006. Přítomnost mravenců byla zjišťována pomocí odchytů do zemních pastí a pozorováním na návnadách. *Formica fusca* byl nejpočetnější na pasekách a v kulturách. Jejich aktivita byla nejvyšší při 20–30 °C teploty půdy i vzduchu. Sezonní aktivita kulminovala v červenci. Nejvíce jedinců bylo odchyceno na slunnějších stanovištích a na místech s pokryvností vegetace více než 50 %. *F. pratensis* byl odchytáván pouze v kulturách a tyčovínách a byl aktivní při půdní teplotě 12–21 °C a teplotě vzduchu 16–25 °C. Vyskytuje se jak na tmavých, tak i na světlých stanovištích. *F. sanguinea* byl nejpočetnější v mlazinách. Byl nejaktivnější při teplotách půdy 20–30 °C. Aktivita roste se zvyšující se teplotou vzduchu téměř lineárně. Vyskytoval se na tmavých i světlých stanovištích s pokryvností vegetace vyšší než 60 %. *F. truncorum* byl pozorován pouze v mlazinách. Aktivita *F. truncorum* byla nejvyšší při teplotě půdy i vzduchu 15–25 °C. Aktivita byla nejvyšší v červenci. Byl pozorován v lesích, kam pronikalo záření 1 030 lx a měly pokryvnost 20–80 % vegetace.

Klíčová slova: *Formica*; ekologické nároky; smrkové lesy

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