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Ecology, colony structure, and conservation biology of *Formica* (*Coptoformica*) *foreli* BONDROIT, 1918 in Bavaria, Germany (Hymenoptera: Formicidae)

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Abstract

The first record of *Formica foreli* BONDROIT, 1918 in Bavaria, of 2005, is described. It is the 20th location published of this species in Germany. The unpublished data bank of B. Seifert (pers. comm. 2007) contains 87 entries from about 60 localities in Germany, 37 records made after 1999. The first Bavarian locality is north of Regensburg in the Franconian Jura on limestone. The habitat is an abandoned calcareous grassland with surrounding shrubs and pines, some nests (21) were also found on an adjoining abandoned field. In 2006, 94 nests were counted on 1325 m^2, the majority of them (73) on the calcareous grassland. Nests on the calcareous grassland were smaller and closer to each other than those on the abandoned field. Two hypotheses to explain this difference are discussed: (1) A possibly larger food supply on the abandoned field allows larger nests to be formed that are further apart from each other. This is based on data on *F. pressilabris* NYLANDER, 1846. (2) A possibly enemy-free (ant-free) space in the abandoned field allows spreading and forming of large nests. The observed nest- and colony-structure in Bavaria is compared to that of other German localities and some general features are summarized.

Key words: Ants, *Coptoformica*, *Formica foreli*, conservation, colony structure, calcareous grassland.

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Introduction

The subgenus *Coptoformica* contains about 13 taxa, seven of them living in Europe. *Formica bruni* KUTTER, 1967, *F. exsecta* NYLANDER, 1846, *F. foreli* BONDROIT, 1918, *F. forsslundi* LOHMANDER, 1949, and *F. pressilabris* NYLANDER, 1846 occur in Germany (SEIFERT 2001). All of them are threatened by extinction, except *F. exsecta* which is only threatened (SEIFERT 1998). The decline of *Coptoformica* records from the period of 1890 - 1960 compared to the period after 1960 is estimated at about 43 % (WESENIGK-STURM 2002a). However, in the last few years the number of *Coptoformica* records not only in Germany slightly increased, which may be attributed to the increased entomological interest in this subgenus (e.g., WESENIGK-STURM 2002b, GLASER & MÜLLER 2003, SCHULTZ & BUSCH 2003, BLISS & PIEL 2004, DEWES 2004).

Formica foreli is one of the most endangered species of the group (SEIFERT 2000) with only few scattered records all over Europe (CZECHOWSKI & al. 2002, SCHULTZ & SEIFERT 2007a). It was considered previously as a morph of *F. pressilabris* (SEIFERT 1996). New data analysis convinced the cited author to regard it as a good species (SEIFERT 2000). Several new localities were discovered in different parts of Germany in recent years (SCHULTZ & SEIFERT 2007b). This includes the one presented as the only one in Bavaria leaving only three federal states without record (SCHULTZ & SEIFERT 2007b).

This paper describes the first record of *F. foreli* in Bavaria. We describe the Bavarian locality, nests, and colony structure. Several new records were described in Germany in the new millennium; we compare the biological and ecological data with our record.

Distribution of the study species

Formica foreli represents a Submediterranean species with northern range expansion and subsequent splitting into isolated populations after regional populations became extinct (SEIFERT 2000). It is a rare species, sporadically found in Western and Eastern Europe. The general range of the species covers northern Spain, northern Italy, Germany, Poland, Switzerland, Austria, the western Alps, southern Moravia, western Slovakia, Anatolia, and the Caucasus; the northern edge of distribution is Denmark and southern Sweden (SEIFERT 2000). Specimens from 92 locations were examined and a map of the west Palaearctic distribution of the species was published very recently (SCHULTZ & SEIFERT 2007a). In Switzerland, the decline of the species is very noticeable (AGOSTI 1989 cited by GLASER 1999). In Austria, the species was thought to be extinct (GLASER 1999) until one locality was found in 2001 (GLASER & MÜLLER 2003), and from Poland only two records exist (CZECHOWSKI & al. 2002), the species identity of which has not yet been checked by discriminant analysis (B. Seifert, pers. comm. 2007). In Germany, there seems to be a concentration of localities in the federal states of Mecklenburg-Vorpommern and Brandenburg. Six sites and in places larger populations are published for each of both states

(WESENIGK-STURM 2002a, BÖNSEL & BUSCH 2003, SCHULTZ & BUSCH 2003, BLISS & KATZERKE 2004). Two further local records are from both Saxony and Schleswig-Holstein each, and one record from Thüringen (SEIFERT 2000). In 2003, the first record of *F. foreli* succeeded in Saarland (DEWES 2004), and one year later in Saxony-Anhalt (BLISS & PIEL 2004). Here we describe the first record in Bavaria. SCHULTZ & SEIFERT (2007b) name only three federal states without locality. The published localities sum up to 20 records in Germany, the unpublished data bank of B. Seifert (pers. comm. 2007) contains 87 entries from about 60 localities, 37 records later than 1999.

Methods and localities

The first record of *F. foreli* in Bavaria is a by-product of an intensive study on the conservation of *Maculinea rebeli* (Lycaenidae, Lepidoptera) (DOLEK & al. 2004, 2005, 2006). Some of the baits used to attract *Myrmica* host ants of this butterfly were visited by *F. foreli* workers in one locality in 2005. To identify the taxa we sent a few workers to F.M. Steiner, B.C. Schlick-Steiner (both Vienna) and B. Seifert (Görlitz). In 2006 we collected more data on nest distribution and searched for further localities.

The locality of *F. foreli* is near Kallmünz, north of Regensburg in the eastern part of the Franconian Jura at 360 m a.s.l. It is a small patch of abandoned calcareous grassland as often found in these surroundings.

Statistical treatment of the data follows standard procedures. We used Statistica 6.1 for the analysis. The variables (nest diameter and nest distance) were log10 transformed to achieve normal distribution and homogeneity of variances. This procedure enabled us to use parametric tests. For t-test, t is the test statistic, which is compared to table values (depending on sample sizes) and thus produces p values.

Results

Our record of *F. foreli* from 2005 is the first known for Bavaria. We discovered the species on abandoned calcareous grassland being slightly southeastern exposed. The nest area is surrounded by shrubs and pine trees. *Gentiana cruciata* and *Maculinea rebeli* occurred at the same site.

The nests were built in high grass, but nevertheless they were well-exposed to the sun. The surrounding shrubs and trees did not shade the nests. All nests were constructed with finely cut grass blades as it is characteristic for *Coptoformica* ants (SEIFERT 2000). The occupied area was about 1325 m^2 in size. 94 nests were found, on the abandoned calcareous grassland (73) and in an adjacent abandoned arable field (21).

Medium nest mound diameter (± standard deviation) was 23.8 ± 8.8 cm, the smallest mound reached only a diameter of 8 cm, the biggest one 48 cm. Some nests were very close to each other, with a minimum distance of 40 cm; in 24 instances the distance was less than 1 m. Nests (parts above ground) of the calcareous grassland were significantly smaller (t-test: t (92) = -3.864, n = 94, $p < 0.001$) and closer to each other (t-test: t (91) = -4.388, n = 93, $p < 0.001$) than nests of the abandoned arable field. Over all, those nests with close neighbours were smaller than those nests with larger distances between them (correlation: r = 0.241, n = 93, p = 0.020). No further colonies were found in the five days of research, despite considerable effort.

Discussion

Biology and ecology of *Formica foreli*

A general comparison of the published habitat descriptions shows that there are some common features (WESENIGK-STURM 2002a, BÖNSEL & BUSCH 2003, GLASER & MÜLLER 2003, SCHULTZ & BUSCH 2003, BLISS & PIEL 2004, DEWES 2004). All habitats are open, dry or medium dry grasslands, many of them having been abandoned – abandoned arable fields, former military training areas, fallow pastures and meadows that have been given up. The geology is not of importance (SEIFERT 2000), the biggest known population in Mecklenburg-Vorpommern occurs on sand, our record from Bavaria on limestone. According to WESENIGK-STURM (2002a), species rich grassland is preferred but there is no relationship to a certain plant association.

As in Bavaria, at almost all localities shrubs and trees are described as part of the habitat (shrub encroachment) or at least bordering it (forest edge). As aphids are important food sources for the ants, neighbouring plants should be used for foraging. WESENIGK-STURM (2004) describes workers foraging on many tree and shrub species as there are *Betula pendula*, *Pinus sylvestris*, *Quercus robur*, *Populus tremula*, *Prunus domestica*, *Malus* sp., *Pyrgus* sp., *Tilia cordata*, *Sambucus nigra*, *Crataegus* sp., and *Sarothamnus scoparius*. Moreover, aphids (including root sucking Pemphigini) were found on some herbaceous plants as well, e.g., on *Hieracium pilosella*, *Urtica dioica*, *Tanacetum vulgare*, *Elytrigia repens*, *Achillea millefolium*, *Euphorbia cyparissias*, and *Rumex acetosella*.

Another common feature of the inhabited sites is southern exposure. According to BLISS & KATZERKE (2004) an increase in nest number in two years was stronger on more xerothermous sites. This shows the increased heat requirement of *F. foreli* which is described as xerothermophilous (SEIFERT 2000). Like all other *Coptoformica* species *F. foreli* cannot increase nest temperatures by metabolic heat production independently of environmental temperatures; *Coptoformica* therefore shows a clear dependence on direct insolation (SEIFERT 2000).

The tendency towards polygyny and polycaly is common. The largest polycalic colonies in Brandenburg comprised 100 nests / 2500 m^2 and 78 nests / 1200 m^2 (SEIFERT 2000). Another colony in Mecklenburg-Vorpommern consisted of 57 nests / 400 m^2 (SCHULTZ & BUSCH 2003). According to SEIFERT (2007), in small areas densities of 8 nests / 100 m^2 are typical. Therefore, the Bavarian colony seems to be rather typical (94 nests / 1325 m^2).

The size of the individual nests in the Bavarian colony was comparatively small. Nests larger than 50 cm did not occur. However, such large nests represent 20.8 % of a colony with 48 nests in Saxony-Anhalt (BLISS & PIEL 2004), even larger nests with a diameter of 70 - 160 cm were described by BÖNSEL & BUSCH (2003). In general, size and type of the nests seem to be dependent on vegetation structure, management, and soil conditions. Under certain circumstances nests may entirely lack any vegetable cover and only simple entrances in the soil surface may be visible (SEIFERT 2000).

In the Bavarian locality, we found different nest sizes and distances between nests in the two habitat types. The ecology of *F. pressilabris* was used to set up a hypothesis to explain the difference between the two types. This closely

related species is very similar to *F. foreli* in its habitat requirements. In habitats with good food supply, nests are larger with a greater number of workers, nests are less numerous, and occur in greater distances (CZECHOWSKI 1975). In contrast, in habitats with poor food supply, workers tend to maximize the exploitation of the territory. Therefore, in such habitats, more and smaller nests are constructed, with fewer workers inhabiting them. Additionally, there is a higher exchange of ants between nests, if nest density is high. They may also migrate to nests with better food supply. Thus, *F. pressilabris* is able to adjust social structure to environmental conditions. If this is true for *F. foreli* as well, the differences in nest size and density in the Bavarian locality may reflect differences in food supply in the two habitat types. This would mean that on the abandoned field the food resources are better than on the calcareous grassland with shrubs and pines.

A second hypothesis can be based on the possibly enemy-free (ant-free) space in the abandoned field. *Formica foreli* may migrate into this space quickly and form large colonies, by chance being earlier than other ant species in colonising this space. Anecdotal evidence is contradictory as *F. foreli* seems to spread its area at the cost of *Lasius* sp., which is distributed in other parts of the field. Anyhow, as there are no exact quantitative data on the ant fauna of this field, this hypothesis can by no means be excluded.

SEIFERT (2007) summarizes that abandoned fields and abandoned military training areas in East Germany (Mecklenburg-Vorpommern, Brandenburg, Saxony) led to an increase of *F. foreli* on these formerly disturbed sites. He also warns that further succession to higher vegetation, shrubs, and trees will bring a new decline to the colonies soon. This relationship and the different hypotheses on creation of different colony structures certainly need further attention.

Conservation of *Formica foreli*

In general, *F. foreli* is threatened by habitat destruction, due to intensive use of mineral fertilizers and liquid manure, high atmospheric nitrogen input, decline of sheep pasturing and traditional mowing, intensified pastures, and afforestation programs (SEIFERT 2000).

For the Bavarian locality, we hypothesize that the abandoned calcareous grassland is the original habitat and that the ants spread subsequently into the abandoned field. Although there are many other, similar calcareous grassland patches and similar, abandoned fields in the surrounding, no further colonies were found despite an intensive search. It is not clear what makes the ants inhabit the present locality, and why they do not use any other locality in the vicinity (to present knowledge). The present distribution may, though, be due to past changes in habitat quality, which were by chance only positive in the present locality for *F. foreli*. With its social parasitic foundation of colonies and a low frequency of monogynes in Central Europe (SEIFERT 2007), there is probably only a low potential for expansion. Consequently, a (re-)colonisation over greater distances is unlikely.

The small size of the locality and our poor understanding of the habitat choice make *F. foreli* very vulnerable to any changes in the locality. We therefore informed local conservation authorities and managers immediately to avoid management changes without recognition of the ant. During a later visit to the locality in November 2006 we found that the field had been mown including the destruction of the above ground parts of the nests. Further observation of the development is planned to gain insight into how the ants cope with the situation and to alter the management if necessary.

For the calcareous grassland, conservation authorities had planned shrub removal and further management, which are necessary in these habitats in the area to avoid overgrowth. The usual and most common traditional management is sheep grazing occasionally including some goats (DOLEK & GEYER 2002). This management was postponed for the *F. foreli* site to first address the ant's needs thoroughly – it is not clear whether *F. foreli* will tolerate grazing or not. WESENIGK-STURM (2004) judges extensive pastures not to be a problem; a threatened colony was relocated to a low-intensity sheep pasture. In the first year after the relocation the number of nests decreased. However, the colony is strong enough, so it was not considered as necessary to exclude the area of the nests from the pasture. In another instance it was reported that in a high-intensity sheep pasture *F. foreli* nests had constructed their subterranean galleries within the solidified root bale of vegetation to increase the resistance against trampling (SEIFERT 2000). Nevertheless, grazing animals may mechanically destroy nests. Also, intensive pasturing may destroy food supply of the ants due to feeding and trampling on plants infested with aphids (CZECHOWSKI 1975). Likewise, shrub and tree removal may decrease food supply as *F. foreli* readily forages on trees and shrubs.

On the other hand, BÖNSEL & BUSCH (2003) noticed a negative correlation between nest density and increasing tree stock. WESENIGK-STURM (2002a) already observed the extinction of a population by succession; in Brandenburg, a decrease of 30 % in average was observed in 2007, the reasons being unclear (WESENIGK-STURM 2008). Shrub and tree encroachment is one common problem for all the inhabited grasslands being abandoned in Germany. Trees and bushes must be removed to receive the required microclimatic conditions but it must be done sporadically and in a well-balanced way to maintain their nutrition function (BÖNSEL & BUSCH 2003). In general, it will be a difficult task to maintain the population against successional changes without destroying it through massive management. For a wise management, further knowledge has to be gathered on the habitat needs of *F. foreli*; the unplanned "mowing experiment" on the field habitat may deliver first insights.

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Zusammenfassung

2005 gelang der erste Nachweis von *Formica foreli* BONDROIT, 1918 in Bayern. Es handelt sich um den 20. publizierten Standort in Deutschland, die unveröffentlichte Datenbank von B. Seifert (pers. Mitt. 2007) enthält 87 Datensätze von ungefähr 60 Standorten, davon sind 37

Nachweise jung (nach 1999). Der bayerische Standort befindet sich nördlich von Regensburg im Fränkischen Jura auf Kalk. Der Lebensraum ist ein brach gefallener Kalkmagerrasen, der von Gebüsch und Kiefern umgeben ist. Einige Nester (21) befanden sich auch auf einer benachbarten Ackerbrache. 2006 wurden 94 Nester auf 1325 m^2 gezählt, die Mehrheit (73) auf dem Kalkmagerrasen. Die Nester auf dem Kalkmagerrasen waren kleiner und enger benachbart als die auf der Ackerbrache. Zwei Hypothesen, die diesen Unterschied erklären könnten, werden diskutiert: (1) Ein eventuell größeres Nahrungsangebot auf der Ackerbrache ermöglicht die Bildung größerer Nester in größerem Abstand. Diese Hypothese basiert auf vergleichbaren Daten zu *F. pressilabris* NYLANDER, 1846. (2) Ein eventuell konkurrenzfreier (ameisenfreier) Raum auf der Ackerbrache ermöglicht die Ausbreitung und Bildung großer Nester. Die in Bayern festgestellte Nest- und Koloniestruktur wird mit den Daten von anderen deutschen Standorten verglichen und einige generelle Zusammenhänge werden herausgearbeitet.

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