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Distribution and Conservation Status of the European Red Wood Ant Species *Formica pratensis* Retzius, 1783 (Hymenoptera, Formicidae) in (European) Turkey

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ABSTRACT

The European Red Wood ant species *Formica pratensis* Retzius, 1783 (Hymenoptera: Formicidae) is a mound building ant species distributed in a number of European countries and is listed in IUCN Red List of Threatened species with near-threatened status. The distributional range of the species in Turkey covers only the Thrace Region. In the present study, we performed a three-stepped (inventory, monitoring and conservation) study to determine the current distribution of the species in the region and to propose a national red list status for the species. During the inventory and monitoring studies, a total of 340 localities were inspected in the region thoroughly for the presence of the colonies and a total of 89 colonies in 48 localities were recorded of which 20 died during the study period. The extent of occurrence (EOO) and area of occupancy (AOO) of the species were measured. According to the evaluation of the distributional data, *F. pratensis* was assessed as Vulnerable (VU) in Thrace Region in Turkey following the criteria B1b (i, ii, iii, iv) due to the small AOO and EOO. The possible threats acting on the species were also discussed.

Key words: Formica pratensis, European Red Wood ant, species conservation, monitoring, IUCN red list.

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INTRODUCTION

Biological diversity, or biodiversity, refers to the variety of all forms of life on earth and is usually considered at three different levels: genetic diversity, species diversity and ecosystem diversity (Vellend & Geber, 2005; Gugerli et al, 2008). Species diversity within a geographical area can be measured in terms of species richness, species abundance and taxonomic or phylogenetic diversity (Gotelli & Chao, 2013). Ants constitute a diverse group of invertebrates and about 15.363 described species and subspecies account for less than 1% of all described insect species (Bolton, 2018). However, they are considered keystone species in the ecosystem and therefore have been a subject of a number of biodiversity and conservation studies (Alonso, 2000; Robinson, 2001; Hughes, 2006; Mabelis 2007; Seppä, 2008; Bution, Tango, & Caetano, 2010; Dekoninck, Hendrickx, Grootaert, & Maelfait, 2010). They are also valuable indicators for measuring environmental change and ecosystem functioning (Andersen & Majer, 2004; Underwood & Fisher, 2006). According to Davic (2003), species can be put in different categories as “keystone species”, “key species”, “intraguild competitors/ predators” and “ecosystem engineers”. Red wood ants, which fall into several of these categories, prey on a wide range of insects including destructive ones, provide habitats for many organisms in their nests and are important food sources for birds. Therefore red wood ants are the target organisms of conservation actions in Europe (Mabelis, 2007).

The current ant fauna of Turkey includes 367 taxa (Kiran & Karaman, 2012; Kiran, Lapeva-Gjonova, & Aksoy, 2017; Karaman, Kiran, Aksoy, & Çamlıtepe, 2017; Csősz, Salata, & Borowiec, 2018; Steiner et al, 2018) and the genus *Formica* L. is represented by 17 species, one of which is *Formica pratensis* Retzius 1783, commonly known as European red wood ants or the black-backed meadow ants. *Formica pratensis* is distributed only in European part of Turkey (Çamlıtepe, 1987; Aktaç, 1987; Aras, 1989; Aktaç, Aras, & Camlitepe, 1994; Lapeva-Gjonova & Kiran, 2012; Karaman & Kiran, 2018; Wagner, Karaman, Aksoy, & Kiran, 2018) while the closely related species, the southern wood ant *F. rufa* L. 1761 is distributed exclusively in the Anatolian part of the country (Schulz & Sanetra, 2002; Kıran & Aktaç, 2006; Kıran, Aksoy, & Camlitepe, 2009). *Formica pratensis* is a mound building ant with a distributional range covering a number of countries, i.e. Albania; Andorra; Austria; Belarus; Belgium; Bosnia and Hercegovina; Britain; Bulgaria; Channel Is.; Croatia; Czech Rep.; Denmark; Estonia; Finland; France: mainland; Georgia; Germany; Greece; mainland; Hungary; Italy: mainland; Latvia; Lithuania; Luxembourg; Macedonia; Moldova; Montenegro; Netherlands; Norway; Poland; Portugal; Romania; Russia; Serbia; Slovakia; Slovenia; Spain: mainland; Sweden; Switzerland; Turkey; Ukraine (Borowiec, 2014). Although the species is widespread in Europe it is declining across the whole of its range due to fragmentation of suitable habitats, general lack of appropriate habitat management, deforestation, urbanization and intensive agricultural activities (Gyllenstrand & Seppä 2003; Domisch, Finér, & Jurgensen, 2005; Dekoninck et al, 2010). *Formica pratensis,* along with *F. aquilonia* Yarrow, 1955, *F. lugubris* Zetterstedt, 1838, *F. polyctena* Foerster, 1850 and *F. rufa* is included in the 1983 IUCN Invertebrate Red Data Book (Wells, Pyle, & Collins, 1983) and one of the 149 ant species listed in the 2008 Red

List (IUCN, 2008). The near-threatened status of *F. pratensis* in the IUCN Red List of Threatened species is based on old records, hence, the need of an update about the status of the species is noted in the list. *Formica pratensis* is considered to be extinct in Britain because no record has been given since 1988 (Nicholson, 1997). It is vulnerable in Belgium (Dekoninck, Vankerkhoven, & Maelfait, 2003; Dekoninck, Maelfait, Vankerkhoven, & Grootaert, 2005) and is protected with legislations in Netherlands, Germany and Hungary (Tartally, 2009). Kiss & Kóbori (2010) reported that the number of *F. pratensis* colonies in Hoia, Romania was 50 in 2004 but decreased to 8 in 2010. Benedek & Kobori (2014) reported presence of more than 100 *F. pratensis* nests in a limited area in Fânaţele Clujului Nature Reserve, Romania and highlighted that a dramatic decline in the number of colonies occurred from autumn 2004 to spring 2005. While Lapeva-Gjonova, Antonova, Radchenko, & Atasanova (2010) presents the distribution of *F. pratensis* in Bulgaria, they stated that the distribution is poorly known, so an update on its protection status is necessary in Bulgaria. The species is also known to occur in the neighboring country Greece. The records given by Legakis (2011) are based on former records given in Agosti & Collingwood (1987) but Bračko, Kiran, Karaman, Salata, & Borowiec, (2016) recorded the species from Greece Thrace 2016, and recently Borowiec & Salata (2018) from Thessaly region of Greece.

The earliest records of *F. pratensis* in Turkey were given by Forel (1906) and Donisthorpe (1950) at an altitude above 1900 meters from Bursa-Uludağ and Bitlis Nazik Lake, respectively. Since *F. pratensis* is distributed at lower altitudes with an average of 900 meters, it is clear that this collected material belongs to another *Formica* species. Moreover, *F. pratensis* has not yet been recorded so far in faunal studies of Anatolian part of Turkey (Aktaç, 1976, 1987; Kıran & Aktaç, 2006; Kıran et al, 2009; Kıran & Karaman, 2012).

Although ant fauna in Turkey is represented with a comparatively high number of taxa (Kıran & Karaman, 2012), studies on the fauna generally focused on sampling-identification-record based species lists and no long-term study was performed on a particular species. The evaluation of former and current available records of *F. pratensis* in Turkish Thrace led us to start a national conservation study for the species considering the rarity of its colonies in the region and the dramatic loss of all formerly recorded colonies. The rarity, in particular, increases the importance of *F. pratensis* for the preservation of species diversity and ecological processes which in turn raises the need of an effective and recognizable conservation status. Prior to our study, *F. pratensis* in Turkish Thrace was represented with 18 colonies which were recorded during field studies dating back to late 80s in only 8 localities in Arpaç, Avarız, Bakışlar, Doğanköy and Ortakçı villages in Edirne and Yeniceköy, Koruköy and Kula villages in Kırklareli provinces. However, ongoing monitoring studies have given us an impression that all colonies died in the past either due to natural or anthropogenic reasons, one of which, and most probably the leading one, is the increasingly continuing industrial activities in the region.

The process of identifying and listing threatened species is inevitably a dynamic and iterative process needing revisions, additions and updates to the list which will

help researchers to determine which species may warrant listing, delisting or status change. In the present study we evaluated the former and most recent distributional data of *F. pratensis* in Thrace region of Turkey and proposed a national red list status for the species. A distribution map for the species was constructed and the possible threats that the species faces in the region were also discussed in a framework of a conservation action plan.

MATERIAL AND METHODS

Study area

The study area, Turkish Thrace, is most probably the south-easternmost border of distributional range of *F. pratensis* in Europe. It covers an area of 23.485 km^2 and provides suitable habitats and habitat patches for the species particularly in the northern and southern woodland parts separated from each other with a wide anthropogenic steppe area in the central part of the region. *Bromus* sp. (cheatgrass) and *Festuca* sp. (fescue) pastures and scattered *Paliurus spina-christii* Mill. (Jaruselam thorn) patches can also be observed in the steppic area. The highest elevation of the region is 1031 m asl. in Mahya Tepe in the north and 924 m asl. in Ganos Mountain in the south (Dönmez, 1990).

The northern mountainous region is covered by dry and humid forest areas. *Fagus orientalis* Lipsky. (beech), *Ilex colchica* Pojark. (Black Sea holly) and *Rhododendron ponticum* L. (rhododendron) are typical vegetation members of the humid forests. The beech forests include *Acer campestre* L. (field maple), *Cornus mas* L. (cornelian cherry), *Corylus avellana* L. (common hazel), *Mespilus germanica* L. (Medlar) and *Prunus spinosa* L. (blackthorn) and *Sorbus torminalis* (L.) Crantz (wild service tree). *Quercus cerris* L. (Turkey oak), *Q. frainetto* Ten. (Hungarian oak), *Q. infectoria* Olivier (Aleppo oak), *Q. petraea* (Matt.) Liebl. (sessile oak), *Q. pubescens* Willd. (downy oak) and *Q. robur* L. (common oak) are members of the deciduous dry forests. *Acer campestre*, *Fraxinus ornus* L. (Manna ash), *Sorbus* sp., *Pyrus elaeagnifolia* Pall. (silver sail), *Tilia platyphyllos* Scop. (large-leaved lime), *T. tomentosa* Moench (silver linden) are other trees seen occasionally in oak forests. The southern mountainous region is characterized with *Pinus brutia* Ten. (red pine) and maquis vegetation. Scrubby/heathland type areas are also common in both north and southern parts.

Data collection

The field studies were performed from 2012 to 2015 in a total of 340 localities throughout Thrace Region. The localities were selected in a manner that ensured a homogenous sampling of the region. The main field studies were performed from May to October of each year in three simultaneous steps as i) inventory and habitat characterization, ii) monitoring and iii) conservation of *F. pratensis* colonies. The first step included determination of the distributional range of the species in the region. Habitats providing suitable conditions for colonization of *F. pratensis* were visited and visually inspected thoroughly for the presence of colonies. The localities where the species had formerly been recorded were also visited. Colonies were determined

either by their visual identifications in vegetation poor environments or by following the inbound journals of foraging individuals in vegetation dense environments, who eventually helped us to pinpoint the colonies. The locations of some of the colonies were reported to us by local residents. The coordinates and habitat details/types of all determined colonies were recorded. Social structures (polydomy - monodymy) of the colonies were also recorded by determining presence of inter-nest traffic between sympatric colonies. The monitoring of recorded colonies was performed whenever possible during the study. The conservation step was achieved by enclosing the colonies vulnerable to disturbance with a wire net when they were first found in the field. A short description and biological importance of the species with its visuals were printed on UV resistant Plexiglas plates and fixed on visible parts of the nests. The local people in all localities, irrespective of presence or absence of *F. pratensis*, were given short briefings on the species on site with the live material or using photographs, videos, slides and leaflets. All possible factors that may have caused disturbance on and/or extinction of the colonies were evaluated and listed.

Data analysis

The obtained GIS data of *F. pratensis* was mapped and analyzed using QGIS 2.0.1. The total study area was divided into 5x5 km^2 UTM grid cells and the evaluation was based on the number of colonies per grid cell and on the total number of grid cells with colony records. The extent of occurrence (EOO) and area of occupancy (AOO) of *F. pratensis* in the study region were measured with the help of Google Earth and GE Path using the convex hull method for EOO and 2x2 km^2 grid method for AOO. Area of occupancy is defined as the area within the total range (and hence within EOO) that is currently occupied by the species and excludes unsuitable and unoccupied habitat (IUCN, 2017). Based on the distribution pattern of *F. pratensis* and its habitat choice in the region, the species was assigned one of the categories given in Table 1 (see Dekoninck et al, 2003 for details), all which agree with the criteria and categories developed by the IUCN (IUCN, 2001; see also Binot, Bless, Boye, Gruttke, & Pretscher, 1998; Maelfait, Baert, Janssen, & Alderweireldt, 1998).

RESULTS

Inventory and monitoring studies in the study region revealed presence of 89 colonies in 48 localities scattered in 47 UTM grids (5x5 km^2, Fig. 1). However, 20 of these colonies died at one stage of the study period (see Fig. 2 for the localities of the lost colonies). A total of 70 colonies were enclosed with wire nets and 45% of the dead colonies were those enclosed with a net. Vast majority of the colonies (74%) were determined in the northern woodland parts and some (26%) in areas to the south of the northern distribution range with typical steppe characteristics. No colony was determined in the southern parts of the region. Most of the localities were represented with only one colony and some with multiple sympatric colonies ranging from 2 to 9 in number. The planimetric distance between sympatric colonies ranged from 22 meters to more or less 1000 meters.

Table 1. IUCN categories. Stenotopic species (ST): a species found in only one habitat type, Almost stenotopic species (AST): species present in only two or three habitat types; Moderate stenotopic (MST): species present in four or five different habitat types, with no discernable preference for any one, Eurytopic species (EU): species found in six or more habitat types.

IUCN category	Assignment requisites
Critical (CR)	Species with few recent observations, that became very rare due to a drastic reduction of their preferred habitat or living in highly threatened habitats, which are stenotopic and were found in less than five UTM 5x5 km^2 and less than 10 records.
Endangered (EN)	Species that became rare because of the extensive deterioration and destruction of their habitat, which are at least moderately stenotopic (ST, AST or MST), which were found in 5-10 UTM 5x5 km^2 and for which we have less than 15 records.
Vulnerable (VU)	Species which became quite uncommon or with a restricted distribution in Thrace Region, which are at least moderately stenotopic (ST, AST or MST) and which were found in 10 to 40 UTM 5x5 km^2
Indeterminate (IN)	Species assumed to be threatened, but for which there is not enough information to decide which of the preceding categories is appropriate.
Not Threatened (NT)	Common and widespread, eurytopic (EU) species that are not currently threatened.

The area of occupancy (AOO) and the extent of occurrence (EOO) were measured as 280 km^2 and 6380 km^2, respectively (Fig. 2). Based on the different habitat types where the colonies were recorded, two separate habitat preference were evident as woodland (mostly open forest areas with sun exposure) and scrubby-heathland making *F. pratensis* in the region an AST species in terms of habitat preference (see Table 1). The evaluation of distribution of the species and the different types of habitats preferred led us to assess *F. pratensis* as Vulnerable (VU) in Thrace Region following the criteria B1b (i, ii, iii, iv) due to the small AOO and EOO.

The threats that *F. pratensis* face in the region were evaluated and they were placed in two categories as human related and natural threats. Human related activities which were observed to have a direct effect on viability of the colonies included increasing rate of industrialization, insecticide usage, urbanization, road construction and increasing number of mining activities mostly taking place in the northern parts of the region where most of *F. pratensis* colonies were recorded. Habitat fragmentation is another human related threat factor posing on the species by dividing the distributional range of the species into several habitat patches, which eventually reduces dispersal rate of the species in the region. Natural threats were listed as deaths of colonies due to natural aging and physical destroying of colonies by boars and foxes. Locals reported that they saw boars and foxes feeding on the brood of *F. pratensis.* All colonies except one in Balaban village were determined to be monodomous meaning that they were most probably governed by one reproductive queen.

The conservation studies such as protection nets, information plates, face to face briefings, leaflets, posters etc. greatly contributed to awareness-raising activities. A number of news appeared in regional and national newspapers which also led to an apparent increase in the popularity of the species in the region. Moreover, the locations of some of the colonies were reported to us by local people who paid special attention to the species after being informed about its presence and importance in the region.

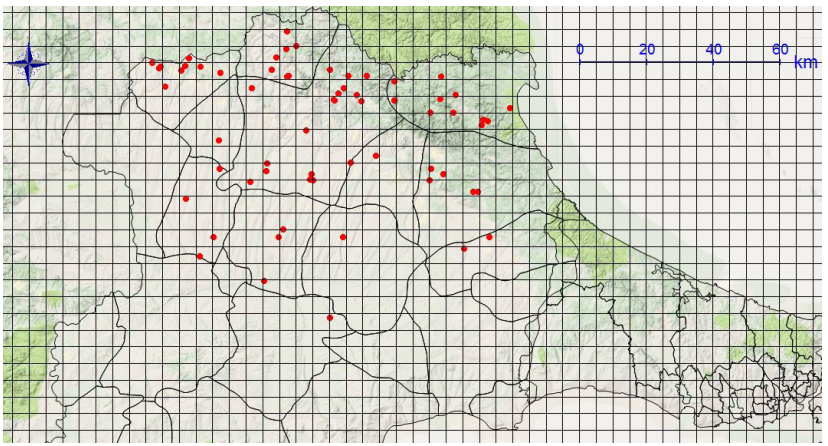

Fig. 1. The map showing distributional range of *F. pratensis* in Thrace Region. All recorded colonies were shown in the map. Localities with one or more colony deaths were shown in Fig. 2. Solid red circles denote the localities where one or more colonies were recorded during the study.

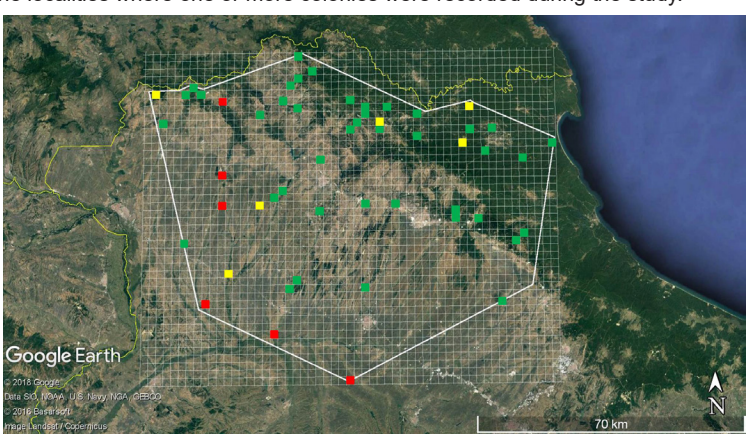

Fig. 2. The map showing EOO and AOO of *F. pratensis* in Turkish Thrace. The white polygon shows the borders of the obtained EOO and colored squares denote grids inside the EOO containing localities with a colony record (AOO). Red squares show the localities where all recorded colonies died, yellow squares show the localities where some of the colonies died and green squares show the localities where no colony loss occurred.

DISCUSSION

A vulnerable species is one which has been categorized by the IUCN as likely to become endangered unless the circumstances that are threatening its survival and reproduction improve (IUCN, 2001). As revealed by current distributional data, *F. pratensis* has a vulnerable status in Turkish Thrace pointing out the importance of planning and implementation of active and urgent conservation strategies for the species in the region. A successful conservation study should be based on a thorough knowledge of the factors that cause the vulnerability of the species.

Formica pratensis has a very restricted area of occupancy (AOO) (280 km^2) in Turkish Thrace within the relatively large extent of occurrence (EOO). In other words, the substantially larger EOO than AOO means that occurrences spread over a large area (Fig. 2). The difference between the two areas of occupancies and the loss of all earlier records of the colonies has indicated a clear tendency of declination of the species in the region. As reported in IUCN (2017), a species with a smaller AOO is likely to have a higher risk of extinction not only because of its smaller population sizes but also because of the threats to its restricted habitat are likely to reduce its habitat more rapidly to an area that cannot support a viable population.

When the present distributional data of *F. pratensis* in Turkish Thrace is considered, the study area seems to potentially support two separate meta-populations, one in the northern woodland parts and the second in the northern parts of the central steppic area. The rarity of the species and the low number of suitable habitats in the latter shows that the central steppe area is the weak point of the dispersal corridor and can explain the non-existence of the species in the southern parts of the region. Moreover, the number of colonies died during the study is higher outside the northern woodland parts showing how the species is vulnerable to extinction here. As far as we know, Turkish Thrace is the southeasternmost border of the range of the species in Europe. As one moves from the core to the periphery of a species' geographical range, populations occupy less favorable habitats and exhibit lower and more variable densities (Channel & Lomolino, 2000). Keeping in mind this conclusion, one may expect a wide range of or a relatively better distribution in the neighboring Bulgaria and Greece, but this is not the case. The mountainous southwestern parts of Bulgaria is located to the north of Turkish Thrace and a few *F. pratensis* colonies were reported in this region (Lapeva-Gjanova et al, 2010) but the picture is clearer for the western parts of the country where more colonies were recorded. In Greece, although the species was reported from only 3 localities in neighboring Greek Thrace, it is with a more northern distribution and is rarely found in other parts of the country (Bračko et al, 2016). Borowiec & Salata (2012) reported distributional range of *F. pratensis* in Greece as Greek Macedonia to the west of Greek Thrace. On the other hand, Borowiec & Salata (2018) recorded the species from Thessaly region of Greece. These data shows that the species in the two neighboring countries is also rare and more detailed studies are urgent.

The evaluation of the data about the possible threats on *F. pratensis* showed that low representation of the species in the study region is an inevitable outcome of activities mainly related with human actions leading to habitat fragmentation and physical disturbances of colonies. It is also clear that the lack of public awareness about the biological and ecological importance of the species also favors disturbance and loss of the colonies. Bution et al (2010) reviewed the main risks that ants have been facing to maintain their communities and he reported that habitat fragmentation by human activities greatly influenced distributional patterns of ants which in turn led to fluctuations in ecosystem dynamics. The researchers also proposed that ants could be used as bioindicator organisms in monitoring of ecosystem dynamics and highlighted

the importance of ants in conservation studies. Ants can be very sensitive to habitat transformation and disturbance, and for this reason they have already been extensively used as indicator species (Hoffmann & Andersen, 2003). Studies related with wood ants reported that human agricultural activities, industrialization, recreation and habitat fragmentation are, alone or in combination with each other, the main threats of wood ant colonies (Robinson, 2001; Mabelis, 2007; Bernasconi, Maeder, Cherix, & Pamilo, 2005; Mäki-Petäys, Zakharov, Viljakainen, Corander, & Pamilo, 2005; Dekoninck et al, 2010). For instance, Kiss & Kobori (2010) reported that the number of *F. pratensis* mounds in Hoia forests in Romania was 50 in 2004 and decreased to 8 in 2010 due to human destructions. A similar decrease was observed in Fanatele Clujului where more than 100 mounds decreased to 15 in a relatively short time period of monitoring.

There are a number of factors which affect the habitat or niche requirements of wood ants, including food supply, microclimate, competition from other ant species, type of social organization of the colony and dispersal ability. As in the case of many other ant species, red wood ants rely on honeydew as the primary sugar source (Rosengren & Sundström, 1991). Therefore, availability of aphid bearing trees is one of the important factors in selection of nest location. They also prefer sunny hotspots to ensure temperature conditions for optimal brood development. Canopy close and clearfelling in mature and old growth stands are among the reasons of declination of wood ants in dense forests by reducing sunlight exposure and leading to loss of ants' primary food source and their orientation ability which is based on visual cues (Rosengren & Pamilo, 1978). We recorded almost all nests in open forest areas, meadows or along borders of agricultural fields all which provide optimum sunlight conditions and vegetation with enough aphid source. However, such preference clearly brings the species close to human activities which is the main cause of loss of some of the existing colonies and prevention of dispersal. It is therefore a necessity to take strict measurements for protection and facilitate dispersal and viability of the species in the region. Red wood ants (*Formica* spp.) have been the targets of conservation action in Europe mainly to preserve the essential services they provide to their ecosystem, e.g. heavy predation on a wide range of insects including destructive ones, dispersing seeds of many myrmechorous plants such as *Viola* spp., providing habitat in their nests for a multitude of organisms (e.g. over 30 beetle species), and as an important food source for birds (especially woodpeckers) and other animals (Mabelis, 2007).

The social structure of *F. pratensis* colonies in our study region can be considered as another factor that may have played role in low level of spreading of the species in the region. *Formica pratensis* can form polygyne colonies with several functional queens which allow polydomy (Seifert, 1996), but monogyny is frequent (Rosengren, Sundström, & Fortelius, 1993). We determined that all colonies in the study region were monodomous colonies except one polydomous nest determined in Balaban village with two interconnected colonies. Polydomy allows colonies to create new nests without going through the high-risk bottleneck of single-queen nest foundation (Robinson, 2014). Risk spreading is one of the ways used by polydomous systems for survival. For instance, if local conditions change, the inhabitants of a nest that becomes unsuitable can relocate to other more successful nests (McGlynn, 2012) or ants can

isolate pathogens or parasites by cutting off contact with an infected nest (Ugelvig & Cremer, 2012). Although single large monodomous nests promote homeostasis and increase chances of survival, monodomy in our case can be a potential factor that may affect dispersal of colonies negatively in the region. A colony of a species that accepts many queens, like *F. polyctena*, has a lower probability of going extinct than a colony of a species that accepts just one or only a few queens, like *F. rufa* (Mabelis, 1986). Moreover, a species which has many queens per nest can disperse by means of budding, during which workers transport several queens from the mother nest to newly built daughter nests. This is a much safer means of dispersal than trying to colonize an area by means of flying queens (Rosengren & Pamilo, 1983; Rosengren et al, 1993). The presence of multiple nests, i.e. 9 nests in Ahmetler village, in a single locality is interesting since one can ask how these sympatric colonies achieved to disperse while most others in other localities were not successful even though most were very similar in terms of their ecological conditions. Although these individual nests showed no sign of inter-nest traffic among each other proving monodomy, we do not know precisely that they are individually founded colonies.

In conclusion, the available data on distribution of *F. pratensis* in Thrace region points out the importance of protection of the species which can be achieved by conservation and sustainable management of the biotopes in which they occur. *Formica pratensis*, a keystone and vulnerable species, deserves to be a target species to be monitored and conserved. The protection of the species is a challenging task requiring involvement of not only scientists but also local people. The preparation of a national red list of invertebrates, which are paid less attention compared to vertebrates and plants in conservation studies, is urgently needed to reveal a more clear picture of the biodiversity which in turn will lead to more robust and well planned conservation studies for those species needing protection.

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