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ORIGINAL ARTICLE

Distribution of Finnish mound-building *Formica* ants (Hymenoptera: Formicidae) based on using a citizen science approach

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Abstract. The distance from southern Italy to Denmark is about the same as the length of Finland from south to north. A study of the biogeography of insects, such as ants, would take a lot of effort and funding to sample the whole area. Here, a citizen science approach is used to obtain distribution records for mound-building *Formica* ants in Finland. This resulted in samples from 2,434 ant nests, of which 2,363 were for nests of the target species group. The data obtained helps define the northern limits of the species in Finland and resulted in three new records for *F. suecica* Adlerz, 1902, which is a red-listed species in Finland. In addition, as a by-catch, a new imported species dispersed in a peculiar way was recorded in Finland: *Lasius emarginatus* (Olivier, 1792). Volunteer citizens are potential research assistants in the science of entomology.

INTRODUCTION

The mound-building *Formica* ants are important key species in their environment. They are effective predators and also have a role in nutrient recycling (e.g., reviews in Robinson et al., 2016 and Frouz et al., 2016). In addition, their nests are coinhabited by a multitude of other arthropods, such as beetles, spiders and oribatid mites (e.g., Päivinen et al., 2002; Härkönen & Sorvari, 2014; Elo et al., 2016; Robinson et al., 2016).

Mound-building *Formica* ants make nest mounds or cover their nests with organic material, mainly needles, small twigs and leaves of shrubs. The distributions of these ants in Finland were studied earlier by Baroni Urbani & Collingwood (1977) and Collingwood (1979) using geographical and administrative units. More recently, Punttila & Kilpeläinen (2009) report the distribution of these species based on data collected during the tenth Finnish National Forest Inventory (NFI10, National Resources Institute Finland). However, the species distributions in four Finish large-scale ecoregions; in addition, the NFI10 data exclude northern Finnish Lapland (approximately 1/5 of Finland), thus, leaving one of the most interesting geographic areas unstudied. The NFI10 sampling targeted forest and forested mire plots, thus leaving other environments unstudied, therefore missing the main habitats for some mound-building species, e.g., the meadow-dwelling *Formica pressilabris* Nylander, 1846.

In order to obtain distribution data from all over Finland and from all kinds of terrestrial habitats, a citizen science project "The big wood ant survey – citizens making science" was carried out in two summer seasons, July to October in 2018 and May to October in 2019.

MATERIAL AND METHODS

Citizens were informed about the project and an instructional website by contacting various media outlets including national TV news, radio broadcasts and newspapers. The information about sampling, reporting and methods of sending samples was given on the project's website (no longer functioning).

The targeted species were the red-black species of *Formica* sp. that build organic mounds. Organic mounds are relatively easy to find and species in this group are relatively aggressive so it is easy to get them to enter a sampling jar. The recommended method was to collect 5–20 ants from the top of the nest mound by allowing the ants to enter a collection jar and then freeze the ants. After a couple of days of freezing, put the ants in a small vial or box, e.g., a matchbox with paper towelling to prevent the brittle dry samples being damaged during mailing. Cotton wool is not as good since the ants become entangled in it. The sample was then sent to the author together with a report form that contained information about location, such as coordinates or another positioning system (e.g., street address). Participating citizens sent the samples at their own expense and get a report with species information in exchange.

Each sample was marked with a sample code and the report form marked with the same code before storing the forms in files. The ants were put in 1.5 ml screw cap tubes with 50% ethanol. The dry specimens were allowed to soften in 50% ethanol until identified two months later. Meanwhile, the sample information was stored electronically on an MS Excel file. The ants were iden-

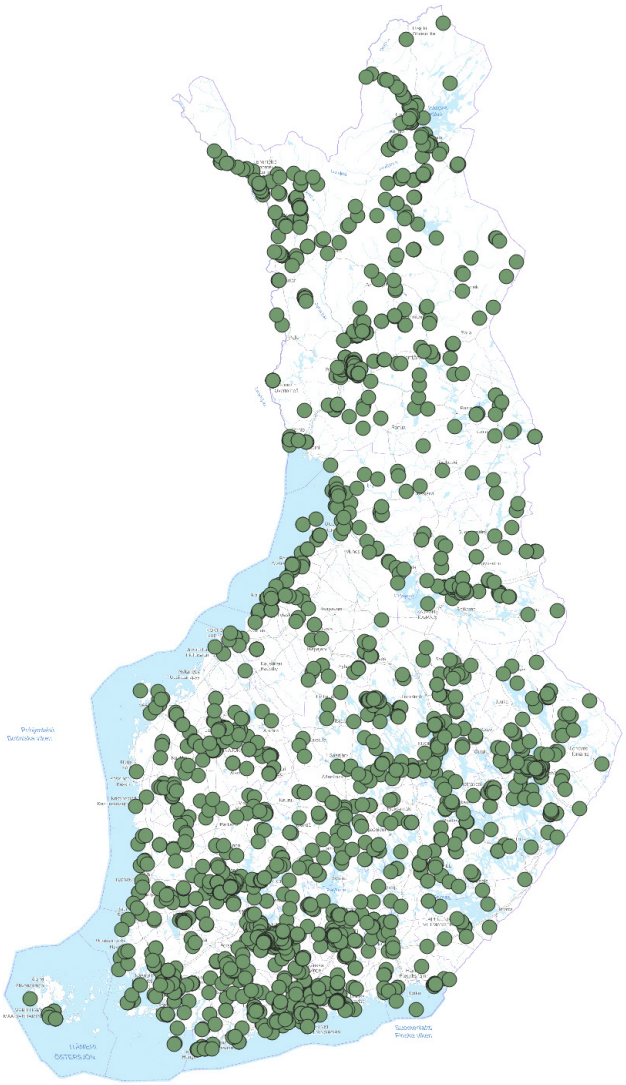

Fig. 1. Map showing the locations of the samples received from the citizen science project 2018–2019.

tified to species-level using a Wild M5A stereomicroscope and the identification keys of Czechowski et al. (2012) and Seifert (2018). After identification, 50% ethanol was replaced with 90% ethanol. All specimens and original forms are deposited in the author's private collection.

The coordinate system used by the collectors varied, being mostly variants of WGS84 and KKJ (an outdated Finnish coordinate system). All coordinates were transformed into EUREF-based ETRS-TM35FIN coordinates using the retkikartta.fi web map platform (National Land Survey of Finland). The maps showing the locations where the samples were collected were prepared using QGIS 3.14 software.

RESULTS

The project received samples from 2,434 nests and a total 30,674 specimens of ants (for a map showing the locations of all the samples see Fig. 1). Of the samples, 2,363 were of the target species group, organic mound-building *Formica* ants of the subgenera *Formica* s. str., *Coptoformica*, *Raptiformica* and *F. uralensis* (Table 1). One sample of *Formica polyctena* Förster, 1850 did not contain any information on the location, whereas all others could be

Table 1. Species, subgenera and numbers of samples from nests (N) received during the survey. *Formica uralensis* is a unique ant within the genus with no known close relatives.

Species	Subgenus	N
Formica aquilonia Yarrow, 1955	s. str.	1212
F. polyctena Förster, 1850	s. str.	299
F. lugubris Zetterstedt, 1838	s. str.	277
F. rufa Linnaeus, 1761	s. str.	240
F. pratensis Retzius, 1783	s. str.	59
F. truncorum Fabricius, 1804	s. str.	42
F. uralensis Ruzsky, 1895		10
F. exsecta Nylander, 1846	Coptoformica	196
F. pressilabris Nylander, 1846	Coptoformica	7
F. forsslundi Lohmander, 1949	Coptoformica	2
F. suecica Adlerz, 1902	Coptoformica	3
F. sanguinea Latreille, 1798	Raptiformica	14

located in at least a 10 × 10 km square, usually well within 100 × 100 m. All but two samples could be identified to species, with the two being most likely hybrids between *F. aquilonia* Yarrow, 1955 and *F. polyctena* (Czechowski, 1996; Sorvari, 2006; Kulmuni et al., 2010).

Approximately one thousand people (ca. 0.018% of the Finnish population) participated in this project, mainly private citizens, but a large proportion of samples were collected by groups such as day care centre groups, school groups, scouts, etc. Biology teachers especially welcomed this project, and some even gave credit units for a biology course to those students who participated in the survey. As a bonus, many of the samples were accompanied by a story or other information and photographs. Reciprocally, the participants received a document that contained a summary of the results and information about the species.

The participants in the survey each sent approximately 2.4 colony samples, mostly one-to-two samples per participant, but it was not uncommon to receive e.g., 20 samples from a single participant. The record was an impressive 279 samples from different colonies from one enthusiastic bird ringer.

Formica s. str. (Fig. 2)

The distribution of this subgenus is clearly divided into those nesting all over Finland, *F. aquilonia*, *F. lugubris* and *F. truncorum*, and those that have a southern distribution, *F. rufa* and *F. pratensis*. While there are a few records from northern Finland, *Formica polyctena* generally seems to be mostly southern in its distribution. While Punttila and Kilpeläinen (2009) report a northern distribution for *F. polyctena*, but its exact northern range cannot be estimated based on the information provided. The northernmost record for *F. polyctena* in Finland, however, is included in the present citizen science data. The northern range of *F. rufa* and *F. pratensis* is a bit more northern based on the present data than that reported in previous studies (Baroni Urbani & Collingwood, 1977; Collingwood, 1979; Punttila & Kilpeläinen, 2009).

Coptoformica (Fig. 3)

Formica exsecta is clearly the most common and most widely distributed species of this subgenus. It is highly var-

Fig. 2. Maps showing the locations of the records for *Formica* s. str. species based on citizen scientist samples 2018–2019. The lines on the maps of the records for the *F. polyctena*, *F. rufa* and *F. pratensis* indicate their approximate known northern borders (Baroni Urbani & Collingwood, 1977; Collingwood 1979). The other species are reported all over Finland.

iable in pilosity and colouration; generally, there is a hairy normal morph and a less hairy and more reddish 'Rubens' morph (Seifert, 2018). Seifert (2000) describes a new separate species, *F. fennica* Seifert, 2000, a meadow-dwelling species, which is almost identical to the mire-dwelling 'Rubens' morph (Ødegaard, 2013; Seifert, 2018). This 'triplet' forms a taxonomic problem, especially because a recent genetic study does not support the Finnish population of *F. fennica* being a separate entity from *F. exsecta* (Hakala et al., 2018). While in the current citizen science data the majority of the samples of *F. exsecta* were of the normal morph, several samples were of a reduced pilosity typical of 'Rubens' and possibly *F. fennica*. Here, they are treated collectively as *F. exsecta*.

Fig. 3. Maps showing the locations of the records for *Coptoformica* species, *F. sanguinea* and *F. uralensis* based on citizen scientist samples 2018–2019. The lines on the maps for *F. pressilabris*, *F. suecica* and *F. forsslundi* indicate their approximate known northern border (Baroni Urbani & Collingwood, 1977; Collingwood 1979). The other species are reported all over Finland.

Formica suecica is a red-listed species in Finland (Paukkunen et al., 2019). The survey resulted in three new records for this species, all from Lapland and one of which was well north of its known range. *Formica pressilabris* and *F. forsslundi* are habitat specialists, the former of meadows and the latter of almost open mire habitats. The distribution of *F. pressilabris* revealed by this study fits its known range, but that of *F. forsslundi* is well north of its known range.

Formica sanguinea and *F. uralensis* (Fig. 3)

Formica sanguinea is mentioned as common throughout Finland (Collingwood, 1979). However, the survey result-

Table 2. Species and numbers of samples from nests (N) of non-target species of ants received during the survey.

Species	N
Formica fusca Linnaeus, 1758	7
Formica lemani Bondroit, 1917	9
Formica picea Nylander, 1846	2
Formica gagatoides Ruzsky, 1904	1
Formica cinerea Mayr, 1853	5
Camponotus herculeanus (Linnaeus, 1758)	5
Lasius niger (Linnaeus, 1758)	13
Lasius platythorax Seifert 1991	17
Lasius emarginatus (Olivier, 1792)	1
Lasius flavus (Fabricius, 1782)	5
Lasius fuliginosus (Latreille, 1798)	1
Myrmica rubra (Linnaeus, 1758)	7
Myrmica ruginodis Nylander, 1846	4
Myrmica rugulosa Nylander, 1849	2
Myrmica scabrinodis Nylander, 1846	1
Myrmica lobicornis (Nylander, 1846)	1

ed in only 14 records, possibly due to its inconspicuous and irregular nests that are often located in tree stumps, under stones or in rock crevices. It covers its nests with shrub leaves rather than needles and sometimes they are not covered with organic matter.

Formica uralensis (Fig. 2) typically nests mostly in pine mires but sometimes in woodlands (e.g., forest margins). The survey resulted in only ten records, but it is relatively common in mires throughout Finland (e.g., Collingwood, 1979; Punttila & Kilpeläinen, 2009).

Other ants

The survey resulted in an additional 81 records of 16 non-target species from the genera *Formica* (subgenus *Serviformica*), *Lasius*, *Camponotus* and *Myrmica* (Table 2). One sample was a queen of *Lasius emarginatus* (Olivier, 1792), which has not been previously reported in Finland. However, this is a result of a peculiar introductory event. A citizen had bought a box of peaches from a supermarket in Pori, a town in southwestern Finland, and noticed at home that one of the peaches was in a bad condition. He opened it, and the queen ant came out of the peach stone. Unfortunately, the label on the peach box was not saved and, therefore, the exact origin of this ant is unknown, but peaches sold in Finland mainly come from southern Europe and Turkey (FAO, 2020). This species' native range is Central and Southern Europe and parts of Turkey and the Caucasus (Seifert, 2018). Notably, this species has recently expanded its northern range, especially in Western Europe (Seifert, 2018).

DISCUSSION

Citizen science and/or crowdsourcing is a growing method for obtaining data. This is especially beneficial in zoogeography since researcher-based sampling of large geographical areas would be time-consuming, very laborious and costly. There are already a few successful citizen science projects on the distribution of species, e.g., *Ixodes* tics, baboon spiders and bumblebees (Laaksonen et al., 2017; Campbell & Engelbrecht, 2018; Falk et al., 2019). The citizen science approach was successful in this study of mound-building *Formica* ants, as a high number of samples was received and with a very low budget. There were no costs to the researcher for collecting the samples and the cost for storing samples in alcohol-containing screw-cap tubes and cardboard storage boxes was below 1,500 €.

The survey records complemented earlier distribution records in a way that enable more precise estimates of distributions of species in Finland. The project received three new records of the nationally red-listed Near Threatened (NT) species *F. suecica*. It is noteworthy that they all came from Lapland, which could mean that the species is more common in the north than in the south of Finland. However, the species is rare, and the current data is based on only three records. Citizen science data can thus result in new records of endangered species of ants, but also of taxa other than ants.

Of course, citizen sampling is not free of errors. In this case, meadow-dwelling species such as *F. pressilabris* and mire-dwelling species such as *F. uralensis* and *F. forsslundi* can be underrepresented since people probably tend to seek mound nests in forested environments as only ca. 2% of samples were from meadows and 5% from mires (Sorvari, unpubl. data); thus, the citizen science data did not fully resolve the same habitat bias as that in the NFI10 data (Punttila & Kilpeläinen, 2009). Another source of error may be the size of the nests with the large mounds of the *F. rufa* species group, especially *F. aquilonia* and *F. polyctena,* being more attractive to citizen scientists and thus possibly increasing results for these species at the expense of other species with less conspicuous nests, e.g., *F. forsslundi* (making small flat nests in mires) and *F. sanguinea* (making irregular shrub leaf-made nests or nests without any organic material cover).

Regardless of the potential biases, the data contained valuable information on species' distributions and provides over 30,000 individual specimens for further study. In addition, the survey can be repeated in the future to detect any northward shift in range of the southern species by comparing the results with existing data.

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