



## Distribution and habitat requirements of red wood ants in Switzerland: Implications for conservation



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### ABSTRACT

Mound-building red wood ants (*Formica rufa* group) fulfill keystone roles in forest ecosystems, and several species are on the red list of the International Union for Conservation of Nature. Nonetheless, detailed information on their distribution and habitat requirements is lacking, yet needed to evaluate population changes and develop conservation strategies.

To assess their status in Switzerland, we studied red wood ant mounds in a nationwide, systematic survey of forests (Swiss National Forest Inventory). We identified key predictors of mound occurrence and mound size related to forest structure, forest composition, climate, and topography.

Red wood ants were found to be relatively rare across Switzerland (1.4 mounds per ha of forest), especially at lower elevations (0.16 mounds per ha). *Formica lugubris* and *F. paralugubris* were common only in mountainous areas. Few *F. rufa* and *F. polyctena* mounds were found countrywide, the latter mostly at lower elevations. *Formica aquilonia* was restricted to the Engadine region of the Alps. Wood ants mainly depended on slope aspect, climate, forest structure, and conifer abundance, but did not depend on forest fragment size, distance to forest edges, or woody vegetation diversity.

Our baseline data will enable population changes of red wood ants to be quantified, to reassess their conservation and protection status. For now, based on their observed rarity, conservation measures for red wood ants seem advisable in Switzerland. Our data suggest that red wood ants are not restricted to large, continuous, or diverse forests. Conservation strategies could thus focus on optimizing the structure of coniferous forests.

### 1. Introduction

Mound-building red wood ants (*Formica rufa* group) are legally protected in several European countries (Sorvari, 2016). In addition, five of the six European red wood ant species are globally listed as “lower risk/near threatened” by the International Union for Conservation of Nature (IUCN, 2016). The protection of red wood ant species, which in some countries has a long history (e.g., Gfeller, 1975), relates to the long-standing recognition of their importance as keystone species, ecosystem engineers, and biocontrol agents against forest pests (Domisch et al., 2016; Frouz et al., 2016; Gößwald, 1990; Robinson et al., 2016).

The impact of red wood ants extends over several trophic levels and ecosystem processes (Domisch et al., 2016; Frouz et al., 2016; Johansson and Gibb, 2016; Robinson et al., 2016). These ants engage in a mutualism with aphids and other phloem-feeding insects, which provide the ants with nutritious honeydew in return for protection (Domisch et al., 2016; Morales, 2000; Stadler and Dixon, 2005). Wood ants also prey on invertebrates (Domisch et al., 2009; Gößwald, 1989; Punttila et al., 2004; Robinson et al., 2016) often suppressing insect pests of forest trees (Gößwald, 1990; Karhu and Neuvonen, 1998; Maňák et al., 2013; Punttila et al., 2004). As predators, wood ants compete with other invertebrate predators (Hawes et al., 2013;

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Reznikova and Dorosheva, 2004), including other ants (Gibb, 2011; Savolainen and Vepsäläinen, 1988), and insectivorous birds (Aho et al., 1999). On the other hand, wood ants are a food source for birds and mammals (Rolstad et al., 2000; Swenson et al., 1999). Their mounds harbor a suite of myrmecophilous species (Paivinen et al., 2002; Parmentier et al., 2015) and are hotspots of nutrient accumulation and CO<sub>2</sub> production (Finér et al., 2013; Frouz and Jílková, 2008; Risch et al., 2005), while the ants deplete nutrients from the surroundings and increase the pH of the mound and the soil surrounding the mound (Jílková et al., 2011; Jílková et al., 2012). Wood ants disperse plant seeds (Gorb and Gorb, 1995; Pfeiffer et al., 2010) and can cause vegetation changes with wide-ranging effects on the soil food web (Wardle et al., 2011).

Given this wealth of information about red wood ants' ecological importance and the resulting conservation interest, knowledge of their distribution and abundance is surprisingly limited (Risch et al., 2016). Even though five European red wood ant species are on the IUCN red list, they were added twenty years ago, and the general criteria for inclusion on the red list have since been updated (IUCN, 2016). The conservation status of most other species in the subgenus *Formica sensu stricto* has not yet been assessed (Sorvari, 2016). There is thus a clear need to evaluate the current situation of the different red wood ant species and, if necessary, to develop conservation strategies accordingly. However, both these objectives are currently difficult to achieve for two reasons.

First, our knowledge of red wood ant distribution is fragmented, stemming mostly from studies conducted in areas where ants were known to occur or from various small-scale surveys often based on opportunistic rather than systematic sampling (e.g., Freitag and Cherix, 2009; Freitag et al., 2016a, but see Glaser, 2008; Punttila and Kilpeläinen, 2009). Such studies report declines (Cherix et al., 2012; Dekoninck et al., 2010; Mäki-Petäys and Breen, 2007; Mäki-Petäys et al., 2005), but also increases (Freitag, 2008) in some local red wood ant populations. Therefore, good baseline information is unavailable to quantify population changes over time, which form a main component of the currently used IUCN criteria (IUCN, 2012).

Second, the development of effective conservation measures for red wood ant species is hampered by a limited understanding of their natural habitat requirements (Robinson and Stockan, 2016). Most studies of red wood ants' habitat associations have been conducted at very local scales, limited to a few habitat characteristics, or based on presence only rather than presence/absence data (Risch et al., 2016).

Nevertheless, some general patterns can be gleaned from these earlier studies. Red wood ants seem to prefer slopes with aspects between south and west, avoiding north-facing slopes (Risch et al., 2016). In Central Europe, *F. polyctena*, *F. rufa*, and *F. pratensis* occur mainly below 1500 m, whereas *F. aquilonia*, *F. lugubris*, and *F. paralugubris* mostly live at higher elevations (Risch et al., 2016). Depending on colony strategy, certain red wood ant species are thought to perform best in the interior of large forest fragments and others at the edges of smaller, more isolated fragments (Punttila, 1996; Risch et al., 2016; Sundström et al., 2005). Mound size, a general proxy for the size and health of the colony (Freitag et al., 2016b), tends to be greater under more closed canopies (Chen and Robinson, 2014; Kilpeläinen et al., 2008), as only large nests can thermoregulate independently of sun exposure (Coenen-Staß et al., 1980; Rosengren et al., 1987). However, this limited information is not sufficient to determine which habitat properties are most important for wood ants, and thus need to be prioritized in conservation efforts.

As part of the National Forest Inventory (NFI) of Switzerland, we surveyed (presence/absence) and measured mounds of red wood ant species in a systematic grid of forest plots across the entire country. The survey started in 2009, and each year a different set of plots was surveyed. A large set of environmental variables related to forest composition and structure, climate, and topography was determined for these plots. These data provide a unique opportunity to study both the

distribution of red wood ant species and the relative importance of many habitat characteristics for red wood ants at a large spatial scale. In this study, we: i) provide a systematic assessment of the distribution of red wood ant species across Switzerland, which can serve as a baseline for future population changes; ii) identify the most important predictors of occurrence and size of red wood ant mounds from a large set of environmental variables; iii) evaluate how the resulting information about distribution and habitat preferences can be used to derive conservation strategies for red wood ants.

## 2. Material and methods

### 2.1. Study area and study species

The study area was the entire country of Switzerland (41,248 km<sup>2</sup>; 45°49'–47°48' N, 5°57'–10°30' E). The Jura Mountains cover 12% of the country and run along the northwestern border. The Alps (Prealps, Alps, and Southern Alps) cover the southeastern 65% of the country. The Swiss Plateau, covering 23% of the country, is located between the Jura and the Alps. Within Switzerland, our study was restricted to forested areas. Forests cover about one third of the country and increase in area from lower to intermediate elevations, but are lacking from the highest regions, which are above the tree line (Abegg et al., 2014).

Our study focused on the subgenus *Formica sensu stricto*, and more specifically on the red wood ants, i.e., the *F. rufa* group, which is a subgroup of this subgenus. Currently, 13 Palearctic and 19 Nearctic species are considered members of the *Formica sensu stricto* subgenus, although its taxonomy is far from stable (Stockan et al., 2016). Of these 32 species, eight have been recorded in Switzerland: *F. aquilonia* Yarrow, 1955, *F. lugubris* Zetterstedt, 1838, *F. paralugubris* Seifert, 1996, *F. rufa* Linnaeus, 1761, *F. polyctena* Förster, 1850, *F. uralensis* Ruzsky, 1895, *F. truncorum* Fabricius, 1804, and *F. pratensis* Retzius, 1783 (Kutter, 1977; Seifert, 1996). Of these eight species, *F. uralensis* and *F. truncorum* do not belong to the *F. rufa* group according to Goropashnaya et al. (2004). *F. uralensis* would even form its own subgenus, distinct from *Formica s. str.*, according to Goropashnaya et al. (2012). Thus, in this view, the red wood ants are represented by six species in Switzerland.

### 2.2. Ant mound survey

As part of the ongoing fourth National Forest Inventory (NFI), the occurrence of wood ant mounds was recorded between 2009 and 2014 in 4271 plots across the entire country (Fig. A1), in forested areas according to the NFI definition of forest (Brassel and Lischke, 2001; Keller, 2011). The NFI plots are located on the intersections of a systematic 1.4 km × 1.4 km grid mapped onto the country, and cover the entire range of forest types present in Switzerland. In each plot, ant mounds were recorded in a circle of 12.62 m radius (500 m<sup>2</sup> surface area) around the plot center. Of these plots, 267 randomly selected ones were reassessed for ant mounds during a control survey. In three of them where no ant mounds were found during the first survey, one red wood ant mound was found during this second survey (1.1% of reassessed plots). In one plot where only one red wood ant mound was found during the first survey, two additional mounds belonging to the same species were detected during the second survey (0.37% of reassessed plots). We consider this detection probability satisfactory, even though it was not 100%. Of each mound, a first diameter was measured along the line connecting plot center with mound center. A second diameter was measured through the mound center (highest point), perpendicular to the first diameter. At each of the four intersections of the diameters with the edge of the mound, mound height was measured from the ground to the highest point of the mound (mound center). The mean of these four measurements was used as the height of the mound. Around 12 ants were collected from each mound, stored in 95% ethanol, and morphologically identified based on Seifert (2007),

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