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STRUCTURAL AND FUNCTIONAL ORGANIZATION OF ANT COMMUNITIES IN SECONDARY MEADOW ECOSYSTEMS

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Introduction. Due to a significant biomass and diverse ecological niches, ants (Formicidae, Hymenoptera) are crucial in establishing the structure and functioning of the co-adaptive species complexes, i.e. myrmecocomplexes, to which they belong. The majority of ant species, which build their nests with visible anthills, create humpy micro-relief changing the habitats of numerous plant and animal species. The number of active ant families and the number of their nests indicate the functional power of every species in an ant community. According to the dynamics of nest numbers, it is possible to analyze the changes in the ecosystem as a whole.

Materials and methods. The research territory is located in the SE suburb of Lviv on the edge of Davydiv and Holohory ridges. It includes two former agricultural sites: fallow arable land and fallow grazing land. The material was collected by the method of ant exclusion with its following conservation, laboratory analysis and determination. Anthill mapping was conducted on 200 sq. m sites.

Results and discussion. The results suggest that the more structured a habitat is, the higher ant species diversity is observed: seven species were found in the fallow grazing land (*Formica pratensis* – dominant, *F. cunicularia* – subdominant, *Tetramorium caespitum*, *Lasius niger*, *L. flavus, Myrmica rubra*, *Solenopsis fugax* – all are influents). It is typical of the three influent species (*L. flavus, T. caespitum, M. rubra*) to distribute within the territory of a dominant's foraging area. However, the influent ant species avoid contacting each other. The less structured habitat (fallow arable land) is presented by only two of the most adaptive species, which are in high numbers (*L. niger* – 95 % of the site nests, and *L. flavus* – only 5 % of them).

Conclusions. Thus, each ant community is a system of „dominant–subdominant–influent" species, which is under permanent transformation due to anthropogenic habitat changes; only well-adapted species can stay in the community under the influence of the mentioned changes. The research on the spatial distribution of ant nests testifies to the prospects and need for the mapping method used to establish the type and level of previous anthropogenic impact on the ecosystem (grazing, ploughing, grass burning, etc.).

Keywords: Formicidae, myrmecocomplex, anthills mapping, spatial distribution, former agro-ecosystems, anthropogenic impact

INTRODUCTION

Ants (Formicidae, Hymenoptera) are highly organized social insects. They are an inherent component of the majority of terrestrial habitats. Due to a significant biomass and diverse activity (predation, pollination, environmental role), Formicidae plays a crucial part in establishing the community structure and function to which they belong. Ants create a co-adaptive species complex – myrmecocomplex – with a particular anthill spatial structure.

The majority of ant species that build their nests with a visible substrate elevation (anthill) belong to the functional group of „ecosystem engineers" (Lavelle *et al.*, 1997; Jones, Lawton, & Shachak, 1997; Del Toro, Ribbons, & Pelini, 2012; King, 2021). Their environmental activity creates humpy micro-relief changing the habitats of numerous animals and plants (Jones, Lawton, & Shachak, 1996). Additionally, the biomass of ants in some habitats may reach 15–20 % of all animals in a particular ecosystem (Schultz, 2000). Most ants are non-specialized predators and necrophages, while some grow fungi or rear insects in their nests.

Ant nest types, their changes depending on the habitat, size and age are the features of a species' ecological plasticity. The number of active families and the number of their nests combined with the system of foraging routes indicate the functional power of any species in an ant community (Schatz, Lachaud, 2008). Investigating ant nest dynamics is one of the main ecological research questions within this taxonomic group of animals. The number of ant nests is a vital species feature in a particular ant community. According to the dynamics of nest numbers, it is possible to analyze the changes in the ecosystem as a whole (Hnativ, & Snitynskyi, 2017). Ant nest complexes of different species and their spatial distribution display each ant species function in a co-adaptive complex within the ant community by the principle "dominant–subdominant–influent" (Stukaliuk, 2012). The nests of different ages and sizes are located depending on the hierarchical species status. Every ant species' nest density depends on its distribution strategy and intra-specific relations. Nest mapping is an approach that allows showing the structure of a specific spatial system of anthills in myrmecocomplex due to foraging expansion.

Based on the abovementioned, our goal was to investigate the structural and functional organization of ant communities in secondary ecosystems on the example of former agricultural lands.

MATERIALS AND METHODS

Our research territory is located in the SE suburb of Lviv (49.739454 24.170885) on the edge of Davydiv and Holohory ridges (Herenchuk, 1972). According to the geobotanical zoning of Ukraine, it belongs to Holohory-Voroniaky district, which is included in the European broadleaf forest region (Barbarych, 1977). The research territory comprises two sites: a) fallow arable land and b) fallow grazing land (neither of them has been used for the last ten years) (**Fig. 1**).

Fig. 1. Research territory sites in the vicinity of Davydiv village (Lviv province): a) the fallow arable land, b) the fallow grazing land

The material was collected using the method of ant exclusion (Radchenko, 2016). The preliminary ant species determination in the field was done by means of magnifying glass with a LED lamp (10×). The material was conserved in 70% alcohol. We used standard methods for the laboratory analysis and determination of the collected material (Gilarov, 1975; Dunger, & Fiedler, 1989; Lavelle, & Spain, 2001). Anthill mapping was done on two 200 sq. m sites with a 2.5×2.5 m raster step.

RESULTS AND DISCUSSION

Unlike our previous faunistic investigations of soil invertebrates (Tsaryk, & Yavornytskyi, 2020), the synecological research of ants aims to study the spatial distribution of nests and species abundance depending on the area covered by nests, ant species hierarchy, and chorological features of ant complexes etc.

The focal ant species belong to the horizontal herpetobiontic and soil-litter chorological ant complexes. There are five of them: vertical herpetobiontic, horizontal herpetobiontic, poly-layer, soil-litter, and dendrobiontic (Putyatina, 2007). According to the goal of our research, particularly the investigation of the structural and functional organization of ant communities in secondary ecosystems in the example of former agricultural lands, we analyzed the obtained data based on the results of ant species nest mapping. Our results indicate that the more structured a habitat is, the higher the ant species diversity is observed (**Fig. 2–3**). The less structured habitat is inhabited by only the most adaptive species, which are in high numbers there (**Fig. 6–7**). Similar results, which reflect the same tendency, were obtained in various non-forested European habitats of moderate climate, inhabited by different ant species (Dauber, Bengtsson, & Lenoir, 2006; King, 2006; Wills, & Landis, 2018). In particular, *Lasius flavus*, which is presented in our research as well, is one of the most important ant species in European grasslands, producing vegetated long-lasting anthills (Waloff, & Blackith, 1962; King, 2021). The anthills make a distinctive contribution to grassland heterogeneity.

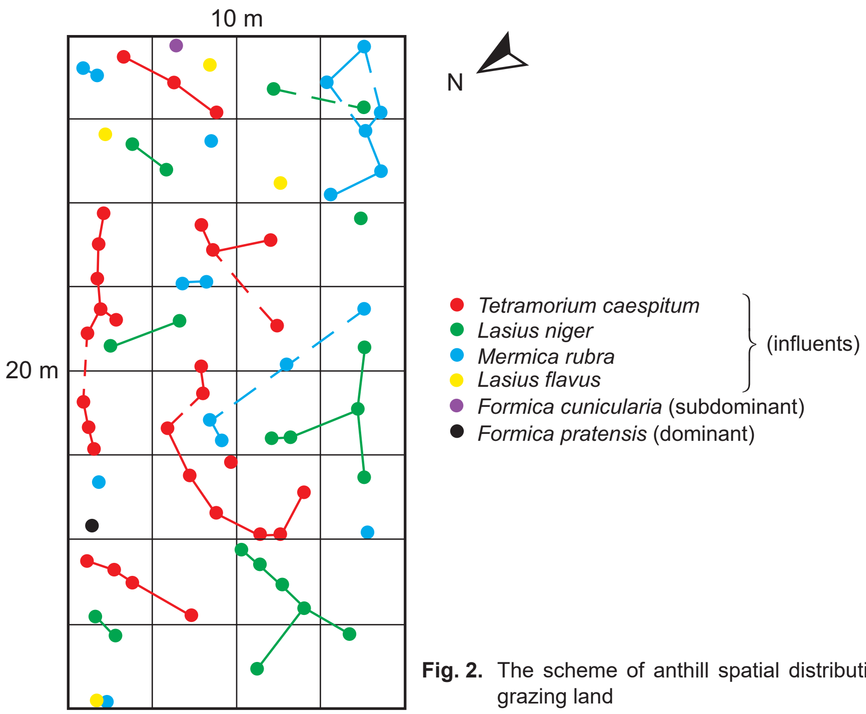

Fig. 2. The scheme of anthill spatial distribution on the fallow grazing land

Fig. 3. Humpy micro-relief of the fallow grazing land

Fig. 4. *Formica pratensis* Retzius, 1783 – dominant species on the fallow grazing land (Photo: https://www.antwiki.org/)

Fig. 5. *Formica cunicularia* Latreille*,* 1798 – subdominant species on the fallow grazing land (Photo: https://www.antwiki.org/)

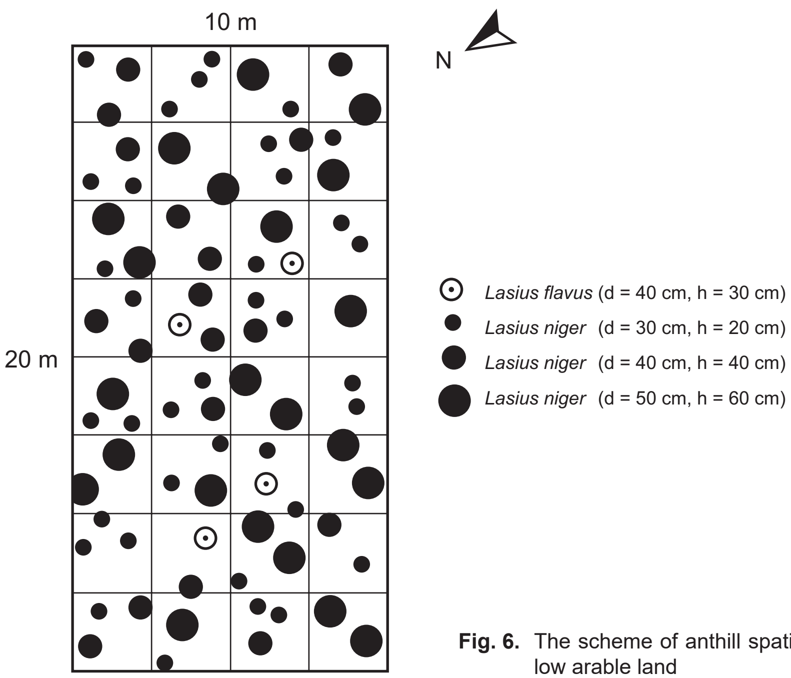

Fig. 6. The scheme of anthill spatial distribution on the fallow arable land

The species composition of the fallow grazing land research site includes seven ant species: *Formica pratensis* Retzius, 1783 – dominant with a high number of workers and a large territory, which is under active protection (**Fig. 4**). *F. cunicularia* Latreille*,* 1798 – subdominant (**Fig. 5**), *Tetramorium caespitum* (Linnaeus, 1758)*, Lasius niger* (Linnaeus, 1758)*, L. flavus* (Fabricius, 1782)*, Myrmica rubra* (Linnaeus, 1758), *Solenopsis fugax* Latreille, 1798 – influents.

Fig. 7. The view of the fallow arable land

The mechanism of spatial distribution of the influents' nests (*L. flavus, T. caespitum, M. rubra*) significantly optimizes their living conditions. It is typical of them to distribute within the territory of the dominant's foraging area. However, influent ant species avoid contacting each other, especially during foraging (**Fig. 2**). This is confirmed by the investigations conducted in an extensively grazed temperate grassland, which show differences in trophic distances of three ant species including *L. flavus* (Boots *et al.*, 2012). One of the important things to mention here is the foraging type on different successional stages of any grassland habitat, which is crucial for an ant species to survive in a myrmecocomplex. Thus, later successional stages, in contrast to the early ones, show much less variation in species composition, providing strong evidence for a rather predictable myrmecocomplex in mature grasslands in the moderate climate region. A change from the species that predominantly forage above-ground to the increasing abundance of *Lasius flavus* foraging mainly below-ground is known (Dauber, & Walters, 2005). This might be one of the important reasons for the influent ant species to optimize their living conditions and avoid foraging competition on the fallow grazing land.

On the contrary, ant nests on the fallow arable land belong to only two species: 95 % of which are *Lasius niger* and 5 % – *L. flavus*. Even distribution of their nests is possible in a relatively homogeneous habitat, which is in tight connection with their ability to create a foraging territory for the individuals of each nest (**Fig. 6–7**). Taking into account the limited species diversity on the fallow arable land in contrast to the fallow grazing land, we have to assume that the arable land, being the example of former more intensive land use, provides less living conditions for the species, so, only high-tolerance ant species can survive. In our case *L. niger* belongs to that group, which is supported by the recent research (Heuss, Grevé, Schäfer, Busch, & Feldhaar, 2019). Moreover, *L. niger* demonstrates the increasing density of its nests compared to the grazing land due to the absence of competition between the above-ground ant species.

We conducted the research on spatial distribution of *Lasius niger* nests in secondary meadow ecosystems (after their agricultural use) for the first time in our region. According to the existing scale of anthropogenic impact level (Blinova, & Dobrydina, 2019), the sites with 1–2 ant species with the total domination of *Lasius niger* (90 % nests) belong to the high-impact level ones. Middle-impact level means the presence of

3–4 ant species with a 50 % share of *Lasius niger* nests in the habitat. If there are five or more ant species with less than 50 % of *Lasius niger* nests, we can conclude about the low anthropogenic impact level on the particular habitat site.

CONCLUSIONS

Each ant community is a system of „dominant–subdominant–influent" species, which is under permanent transformation due to anthropogenic habitat changes; only the species well adapted to the changes remained in the community.

Nests density in the ant communities of secondary meadows under the influence of agricultural activity displays a non-adaptive trend. Some species increase their nest density, the density of other ones decrease, or nests disappear. The body size reduction of workers under the decreasing of species hierarchy level in such ant communities is typical.

The research on the spatial distribution of ant nests can be used to determine the type and level of anthropogenic impact on the ecosystem (grazing, ploughing, grass burning etc.). The termination of agricultural land use leads to habitat overgrowing, and as a result, the gradual disappearance of high-level insolation ant species is seen.

Our research gives a possibility to broaden the existing myrmecocomplex classification based on the „dominant–subdominant–influent" principle and testifies to the prospects and need for the use of anthill mapping method for the evaluation of succession processes that take place on former agricultural lands.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Human Rights: This article does not contain any studies with human subjects performed by any of the authors.

Animal studies: All international, national and institutional guidelines for the care and use of laboratory animals were followed.

AUTHOR CONTRIBUTIONS

Conceptualization, [I.T.; O.R.]; methodology, [I.T.]; validation, [I.T.; O.R.]; formal analysis, [I.T.; O.R.]; investigation, [I.T.; O.R.]; resources, [I.T.]; data curation, [I.T.; O.R.]; writing – original draft preparation, [I.T.; O.R.]; writing – review and editing, [I.T.; O.R.]; visualization, [O.R.] supervision, [I.T.; O.R.].

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СТРУКТУРНО-ФУНКЦІОНАЛЬНА ОРГАНІЗАЦІЯ МІРМЕКОУГРУПОВАНЬ У ВТОРИННИХ ЛУЧНИХ ЕКОСИСТЕМАХ

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Вступ. Завдяки значній біомасі та різноманітним екологічним нішам, мурашки (Formicidae, Hymenoptera) відіграють важливу роль у формуванні структури та функціонуванні коадаптивних видових комплексів – мірмекоугруповань, – до складу яких вони входять. Більшість видів мурашок, яким притаманні гнізда з мурашниками, формують купинястий мікрорельєф, змінюючи середовище існування багатьох видів рослин і тварин. На функціональну потужність кожного виду у мірмекоугрупованні вказує число активних сімей, а відтак і гнізд мурашок. На основі зміни чисельності гнізд можна проаналізувати зміни, що відбуваються в екосистемі загалом.

Матеріали й методи. Дослідна територія розташована на південний схід від Львова на межі Давидівського та Гологірського пасем і складається з двох закинутих сільськогосподарських ділянок: ріллі та пасовища. Збір матеріалу проводили методом вилучення мурашок із гнізд з подальшою їхньою фіксацією, камеральною обробкою і визначенням. Картування мурашників відбувалося на ділянках 200 $м^2$ кожна.

Результати і їхнє обговорення. Результати вказують на те, що структурованість місць проживання мурашок призводить до більшої різноманітності їхнього видового складу – сім видів мурашок на закинутому пасовищі (*Formica pratensis* – домінант, *F. cunicularia* – субдомінант, *Tetramorium caespitum*, *Lasius niger*, *L. flavus, Myrmica rubra*, *Solenopsis fugax* – інфлюєнти). Для трьох видів інфлюєнтів (*L. flavus, T. caespitum, M. rubra*) характерне таке розселення в межах території кормової ділянки домінанта, аби не перетинатися один з одним. А закинута рілля, яка характеризується обмеженим оселищним різноманіттям, заселена лише найбільш пристосованими видами, які сягають там високої чисельності: *L. niger* – 95 % усіх гнізд на ділянці, *L. flavus* – лише 5 %.

Висновки. Кожне мірмекоугруповання представляє собою систему “домінант–субдомінант–інфлюєнт”. Антропогенна зміна середовища трансформує цю систему, залишаючи лише ті види, які адаптуються до таких змін. Дослідження територіальності розташування гнізд мурашок доводить перспективність і потребу застосувати метод їхнього картування для встановлення рівня і типів попереднього антропогенного впливу на екосистему (випас, розорювання, випалювання тощо).

***Ключові слова*:** Formicidae, угруповання мурашок, картування мурашників, просторовий розподіл, закинуті агроекосистеми, антропогенний вплив

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