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Research Article

Seasonal dynamics and height of some wasp species (Hymenoptera), a study using beer traps

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Abstract
In this paper, we present the results of our study on the seasonal dynamics and altitudinal distribution of Vespidae in forest ecosystems of central European Russia. To conduct this study, we utilized beer traps. Our findings include the recording of 32 species from 4 families of Hymenoptera. The most numerous family was Vespidae. The dominant species from this order were *Vespula vulgaris*, *Vespa crabro*, *Dolichovespula media*, and *Vespula germanica*. The occurrence of these species was quite high, including species from the Crabronidae, Chrysididae, and Pompilidae families. These species are known to frequently visit flowers of various plants and feed on nectar and pollen. In five different biotopes, the highest number of Vespidae was found in oak forests, while the lowest number was observed in pine forests. *Vespula vulgaris* was the dominant species in birch and oak forests, while *Vespa crabro* was more prevalent in pine and linden forests. The seasonal dynamics of the number showed a large peak in early July, likely due to a significant increase in air temperature during the day and night. This peak may have been caused by a large number of new-generation workers leaving the nests at this time. Additionally, the number of Vespidae in traps located in the undergrowth was slightly higher than those in traps in the canopy.
Keywords: insects, dynamics, number, Vespidae, Hymenoptera

Introduction

In recent years, scientists have become increasingly concerned about various environmental changes. One of the most pressing issues is the loss of biodiversity (Gray et al., 2016; Ruchin & Grishutkin, 2018; Urbanavichus & Urbanavichene, 2022; Pham et al., 2023; Kirillova & Kirillov, 2023; Trujillo-Arias et al., 2023). However, it is not just the overall biodiversity that is decreasing. Climate change is also causing shifts in the distribution of species and species communities, leading to changes in population sizes, the appearance of new species in certain areas, and the invasion of harmful species (Sinervo et al., 2010; Ruchin & Khapugin, 2019; Ananyev et al., 2023; Atutova, 2023; Drago &Vrcibradic, 2023; Ivanov & Kurbatova, 2023; Kataev et al., 2023). Climate plays a crucial role in determining the characteristics of communities and ecosystems, as well as the biology and ecology of individual species. Temperature, in particular, is a key factor that affects the distribution and number of species due to physiological limitations. Changes in temperature often drive shifts in the seasonal dynamics of species (Arroyo-Correa et al., 2020; Chowdhury et al., 2021; Ruchin et al., 2021a; Ruchin, 2023).

Hymenoptera is a large order of insects, with over 153,000 described species. However, some estimates suggest that this number could reach up to 1,000,000 (Sharkey, 2007; Aguiar et al., 2013). This high level of species diversity results in a wide range of biological variations within individual taxa of this order. For example, families from the suborder Symphyta are primarily phytophagous, and can sometimes cause significant damage to forestry and agriculture (Liston et al., 2014; Lengesova et al., 2020; Tooker & Giron, 2020). On the other hand, parasitoid families play a crucial role in regulating the number of many invertebrates (Várkonyi et al., 2002; Sharkey, 2007). Additionally, Apidae is a highly important group of pollinators for plants in all geographical zones (Bawa, 1990; Ollerton et al., 2011; Ruchin & Artaev, 2016). However, many Hymenoptera species are rare and require widespread protection due to the loss of their habitats caused by factors such as agricultural intensification, the use of pesticides and fertilizers, urban development, landscape transformation, increased frequency of fires, and climate change (Konovalova, 2010; Ruchin & Kurmaeva, 2010; Monceau et al., 2015; Prosi et al., 2016; Ruchin & Egorov, 2017; Ruchin et al., 2019; MacLean et al., 2021; Popkova et al., 2021).

Researchers prefer to study social species of Vespidae due to their common occurrence and ecological and economic significance. These wasps play a crucial role in controlling pests by prey-ing on phytophages, such as butterfly larvae. Additionally, they contribute to pollination by feed-ing on flower nectar. Vespidae construct their nests using a combination of plant fibers and salivary secretions, with varying sizes. While most nests are annual, some species in warm climates build large perennial nests. However, some Vespidae species are considered pests as they can build nests in residential areas and bite humans (Spradbery 1971; Kimsey & Carpenter 2012; Jacques et al., 2015; Herrera et al., 2020; Szczepko et al., 2020). Vespidae are distributed world-wide, with the majority of species found in tropical regions. There are approximately 4,700 known species of Vespidae, divided into six subfamilies (Archer, 2014). In Russia, there are 197 species from four subfamilies: Masarinae, Eumeninae, Polistinae, and Vespinae (Antropov & Fateryga 2017). Despite the relatively small number of species, many aspects of their biology remain poorly understood. Various methods can be used to study population dynamics, horizontal and vertical distribution, population size, and other aspects of their life cycle (Islam et al., 2015; Dvořák et al., 2020; Ruchin et al., 2021b). This paper presents the results of a study on the seasonal dynamics and altitudinal distribution of Vespidae in central Russia. The objectives of the study were to: 1) assess the effectiveness of beer traps for monitoring Hymenoptera; 2) examine the seasonal dynamics of Vespidae using beer traps; 3) determine the number of Vespidae species in different forest biotopes; and 4) investigate the distribution of Vespidae at different heights in European Russian forests.

Materials and methods

Study area

The studies were conducted in the Penza, Ulyanovsk, Nizhny Novgorod regions and the Republic of Mordovia from April to October 2019 and 2021. These regions are located at the junction of the Volga Upland and the Oka-Don lowland (East European Plain) (see Fig. 1).

The Privolzhskaya Upland (PU) is located along the middle and lower reaches of the Volga River, spanning from Nizhny Novgorod to Volgograd. The region covers almost 1000 km from north to south and 300-350 km from west to east. To the south, the PU narrows greatly and in the Volgograd region, it does not exceed 60 km. The Volga Upland is a high plateau, dissected by numerous river valleys, gullies, and ravines. It has a stepped relief and a clearly defined asymmetric structure. The climate of the region is temperate continental and is characterized by an increase in aridity from the northwest to the southeast. Within the Volga Upland, zonal plant complexes change from north to south: pine-broad-leaved and broad-leaved forests, northern steppes, mixed grass-turf-and-slag steppes, and dry steppes (Vasjukov, 2012). The Oka-Don Plain is located to the west of the Volga Upland. The border between the Oka-Don plain and the Volga Upland is not clear and is not shown in the modern relief. The vegetation cover of the Oka-Don plain is mainly represented by forest communities: pine forests, mixed forests (with the addition of *Pinus sylvestris* and broad-leaved species such as *Betula* sp. and *Quercus robur*), oak trees, black sandstones, and secondary communities – birch and aspen, formed after logging. They are characterized by a clear association with different elements of the terrain and soil cover. The modern vegetation cover of the studied territory has been significantly altered by economic activities such as logging, fires, plowing, and grazing (Artemova & Leonova, 2011).

Design of studies

A total of 369 beer traps were installed. The traps were made from a five-liter plastic container with a window cut out on one side, placed at a distance of 10 cm from the bottom (Ruchin et al., 2020). Beer or wine was used as bait, with sugar, jam, and honey added in each specific case for fermentation.

1) Experiments on the study of seasonal dynamics

To study the seasonal dynamics of Hymenoptera, traps were placed in five different biotopes. Each biotope was distinguished by the predominance of a particular tree species. In each biotope, two traps were installed under the forest canopy at a distance of five meters from each other. The traps were hung on tree trunks at a height of seven to eight meters. Fermented beer with added sugar was used as bait. The sampling period ranged from six to 17 days and all counts were carried out by A. Ruchin. The descriptions of the studied biotopes are given below. Each biotope was distinguished by the predominance of a particular tree species.

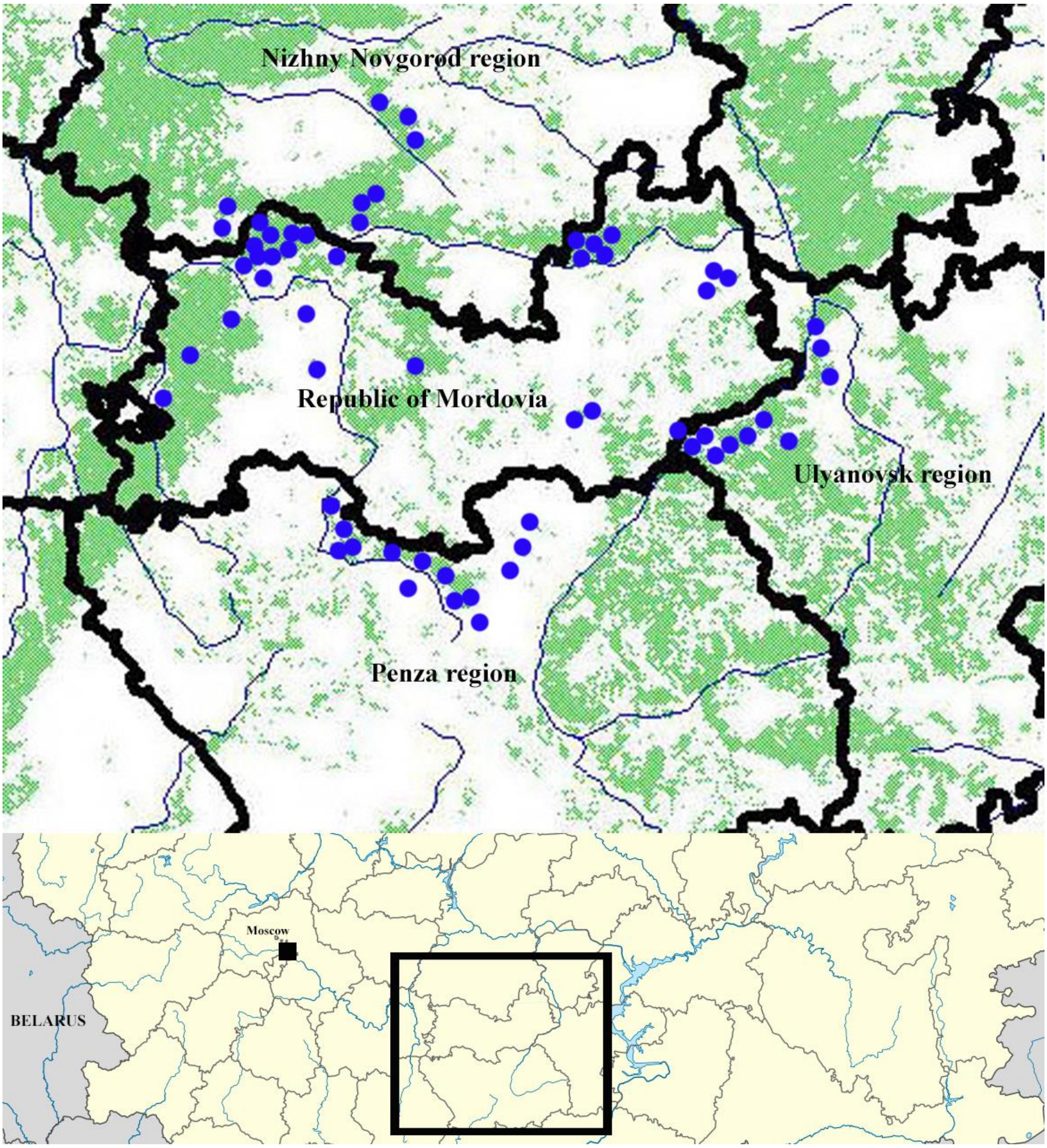

Figure 1. Schematic map of the research area location. The blue dots show the places where the material was collected.

1) The forest area is predominantly composed of *Pinus sylvestris* (pine forest).

This biotope is characterized by a pine (*Pinus sylvestris*) forest with 100% participation in the forest stand. The second layer is well pronounced, consisting of linden (*Tilia cordata*) with a projective cover of 70-80%. The shrub layer includes *Euonymus verrucosus* Scop., *Acer platanoides* L., *Sorbus aucuparia* L., and saplings of *Tilia cordata*. The herb layer is dominated by *Carex pi*losa Scop. with a projective cover of 70%. Other species present include *Glechoma hederacea* L., *Rubus saxatilis* L., *Lathyrus vernus* (L.) Bernh., *Asarum europaeum* L., *Dryopteris filix-mas* (L.) Schott, *Vicia sylvatica* L., *Convallaria majalis* L., *Aegopodium podagraria* L., *Mercurialis perennis* L., and *Pteridium aquilinum* (L.) Kuhn.

2) The forest area is predominantly composed of *Tilia cordata* (linden forest).

The first layer of forest community is formed by *Tilia cordata* Mill. (70%), *Betula pendula* Roth (20%), and *Populus tremula* L. (10%). The second layer is less pronounced and consists mainly of *Tilia cordata*. The shrub layer is sparse and includes *Acer platanoides*, *Corylus avellana* L., and *Euonymus verrucosus* Scop. The herb layer is represented by *Dryopteris filix-mas*, *Glechoma hederacea* L., *Viola mirabilis* L., *Monotropa hypopitys* L., *Asarum europaeum* L., *Stellaria holostea* L., *Asarum europaeum* L., *Carex pilosa* Scop., *Pulmonaria obscura* Dumort., *Galium odoratum* (L.) Scop., *Lathyrus vernus* (L.) Bernh., and *Convallaria majalis* L.

3)The forest area is predominantly composed of *Populus tremula* (aspen forest).

The habitat is a deciduous forest, with the first layer consisting of *Populus tremula* L. (60%), *Tilia cordata* (30%), and *Betula pendula* (10%). The second layer is represented by *Tilia cordata* and *Betula pendula*. The shrub layer has a projective cover of 40-50%, including species such as *Acer platanoides* L., *Corylus avellana* L., and *Euonymus verrucosus*. The herb layer is made up of species such as *Dryopteris filix-mas*, *Aegopodium podagraria* L., *Mercurialis perennis* L., *Asarum europaeum* L., *Lathyrus vernus* (L.) Bernh., *Glechoma hederacea* L., *Carex pilosa* Scop., *Rubus saxatilis* L., *Stachys sylv*atica L., and *Pulmonaria obscura* Dumort.

4) The forest area is predominantly composed of *Betula pendula* (birch forest).

The first layer of the forest community is mainly made up of *Betula pendula* (90%) and *Tilia cordata* (10%). The second layer includes *Tilia cordata* (25%) with some *Betula pendula*. The shrub layer has a total projective cover of 40-50%, consisting of *Acer platanoides*, *Prunus padus* L., *Euonymus verrucosus*, *Lonicera xylosteum* L., *Sorbus aucuparia* L., *Frangula alnus* Mill., saplings of *Picea abies* (L.) H.Karst., and *Tilia cordata*. The herb layer is composed of *Dryopteris filix-mas*, *Asarum europaeum* L., *Oxalis acetosella* L., *Lathyrus vernus* (L.) Bernh., *Pulmonaria obscura* Dumort., *Carex digitata* L., *C. pilosa* Scop., *Glechoma hederacea* L., *Aegopodium podagraria* L., *Mercurialis perennis* L., *Equisetum sylvaticum* L., *Geum urbanum* L., *Polygonatum multiflorum* (L.) All., and *Stellaria holostea* L.

5) The forest area is predominantly composed of *Quercus robur* (oak forest).

The habitat is a floodplain forest consisting of 90% *Quercus robur* and 10% *Ulmus glabra* Huds. The second layer is made up of *Quercus robur*, *Tilia cordata*, *Betula pendula*, and *Ulmus glabra*. The shrub layer has a projective cover of approximately 50-55%, including species such as *Prunus padus* L., *Acer platanoides* L., *Corylus avellana* L., *Viburnum opulus* L., *Rubus idaeus* L., and saplings of *Ulmus glabra*, *Tilia cordata*, and *Malus sylvestris* (L.) Mill. The herb layer is represented by species such as *Mercurialis perennis* L., *Scrophularia nodosa* L., *Fallopia convolvulus* (L.) Á.Löve, *Geum urbanum* L., *Urtica dioica* L., *Mentha arvensis* L., *Glechoma hederacea* L., *Impatiens noli-tangere* L., *Festuca gigantea* (L.) Vill., *Convallaria majalis* L., *Carex pilosa* Scop., *Stel-*

laria media (L.) Vill., *Arctium lappa* L., *Alliaria petiolata* (M.Bieb.) Cavara & Grande, *Stellaria holostea* L., and *Campanula trachelium* L.

2) Experiments on the study of the altitude distribution of Vespidae

In these experiments, we used the installation of traps at two heights. The traps were located on the edges of the forest or on the edges of clearings within the forest. One trap was placed in the undergrowth at a height of 1.5 m from the ground level (below). The second trap was hung in the forest canopy at an altitude of 7-8 m (above). At the same time, pairs of such traps (below–above) were located on the same tree. A total of 90 repetitions were conducted, with varying numbers of repetitions for each species (ranging from 6 to 29). The data from all repetitions were then averaged.

The occurrence of a species (or taxonomic group) was calculated as the ratio of the number of samples where it was present to the total number of samples, expressed as a percentage. The expo-sure time, or the period between hanging the trap and collecting samples for analysis, was measured in days.

Results and discussion

In total, 7768 individuals from 32 species and 4 families were captured using beer bait in our study (see Table 1). Among the social Hymenoptera, the Vespidae family was the most abundant. The dominant species within this order were *Vespula vulgaris* (54.8% of all captured specimens), *Vespa crabro* (26.6%), *Dolichovespula media* (8.3%), and *Vespula germanica* (7.6%), making up a total of 97.3% of the captured individuals. The remaining species were present in much lower numbers, with some being represented by only a single individual. However, their occurrence was still notable (see Table 1). Previous studies have also reported high numbers of Vespidae in beer traps (Dvořák & Landolt, 2006; Dvořák, 2007; Sorvari, 2013).

Table 1. List of species and their corresponding number of captured individuals

Species	Total number specimens	Occurrence, %
Chrysididae		
Chrysis fulgida Linnaeus, 1761	9	1,36
Chrysis ignita (Linnaeus, 1758)	3	0,81
Chrysis iris Christ, 1791	3	0,81
Pseudomalus auratus (Linnaeus, 1758)	2	0,27
Pseudomalus pusillus (Fabricius, 1804)	1	0,27
Crabronidae		
Crossocerus cetratus (Shuckard, 1837)	1	0,27
Crossocerus subulatus (Dahlbom, 1845)	1	0,27
Ectemnius cephalotes (Olivier, 1792)	16	2,71
Diodontus medius Dahlbom, 1844	3	0,54
Mellinus arvensis (Linnaeus, 1758)	25	2,44

Pemphredon inornata Say, 1824	1	0,27
Pemphredon lugubris (Fabricius, 1793)	5	1,36
Psenulus pallipes (Panzer, 1798)	6	1,08
Pompilidae		
Auplopus albifrons (Dalman, 1823)	1	0,27
Deuteragenia bifasciata (Geoffroy, 1785)	1	0,27
Deuteragenia vechti (Day, 1979)	1	0,27
Priocnemis perturbator (Harris, 1780)	1	0,27
Vespidae		
Ancistrocerus nigricornis (Curtis, 1826)	3	0,54
Ancistrocerus parietum (Linnaeus, 1758)	1	0,27
Ancistrocerus trifasciatus (Müller, 1776)	4	0,81
Discoelius zonalis (Panzer, 1801)	13	2,44
Dolichovespula media (Retzius, 1783)	644	40,7
Dolichovespula saxonica (Fabricius, 1793)	46	6,78
Polistes dominula (Christ, 1791)	1	0,27
Polistes nimpha (Christ, 1791)	21	2,44
Symmorphus bifasciatus (Linnaeus, 1761)	5	0,81
Symmorphus crassicornis (Panzer, 1798)	1	0,27
Symmorphus murarius (Linnaeus, 1758)	11	1,08
Vespa crabro Linnaeus, 1758	2064	60,4
Vespula germanica (Fabricius, 1793)	587	22,5
Vespula rufa (Linnaeus, 1758)	28	5,96
Vespula vulgaris (Linnaeus, 1758)	4259	62,9
Total	**7768**	

Vespula vulgaris is the most commonly found species in beer traps, with the highest number of specimens (Table 1). This is an oligoeurythermic species that is rare in the southern parts of Europe. This species dominates open habitats (Dvořák & Landolt, 2006; Dvořák 2007). Nests are built mainly in underground cavities (abandoned burrows of mammals) or in the cavities of walls and under various structures. A juvenile nest did not have an entrance tube. The prey is various Diptera. The family development cycle is long – from May to October (Free, 1970; Harris & Oliver, 1993; Edwards & Telfer, 2002).

Vespa crabro is the second largest and most frequent species in this study. It is very common throughout Europe, with the exception of the UK. Nests are typically constructed in sheltered areas such as tree hollows or attics, although we have also observed nests in abandoned rodent burrows. The prey of this species includes a range of insects, from large Diptera to bees and male bumble-bees. The family development cycle of Vespa crabro is relatively long, lasting from May to October (Nixon, 1982; Edwards & Telfer, 2002; Nadolski, 2013).

Dolichovespula media is the third largest and most frequent species. Nests are made openly hanging in the middle or upper tiers on the branches of trees and shrubs, or under the eaves of buildings. The main prey consists of various Diptera. The family development cycle is short – from the end of May to August (Dvořák et al., 2008; Ruchin & Antropov 2019). Dvořák (2007) noted that *D. media* is often found in beer traps, although many authors had previously pointed out its rarity in Europe. He suggested that this species is particularly drawn to beer traps. Our own research confirms this finding. The number of *D. media* found depends on the bait used. For example, in our previous study (Ruchin & Antropov, 2019), we noted that the closely related species *D. saxonica* was more commonly found, while *D. media* was rarer. This conclusion was based on observations made during training camps using a net. However, our current study yielded different results, with *D. media* being found more frequently and in larger numbers than *D. saxonica*.

Vespula germanica (Fabricius, 1793) is also a common species attracted to beer traps. Nests are usually built in underground cavities (abandoned mammalian burrows) or under buildings. The main prey consists of various Aranei, Diptera, Coleoptera, and Hymenoptera (Free, 1970; Sackmann et al., 2000). The family development cycle is long – from May to October (Edwards & Telfer, 2002).

Dolichovespula saxonica (Fabricius, 1793) is less commonly found in beer traps compared to *D. media*. Nests are typically built in open areas, hanging from tree branches or shrubs, or in shelters such as outbuildings or attics. The main prey consists of various Diptera (Ruchin & Antropov 2019). The family development cycle is short – from May to August.

Vespula rufa is found in isolated instances in beer traps. It builds round-shaped nests in cavities under tree roots or in abandoned underground burrows of mammals. The main prey consists of various Diptera. The family development cycle is short – from May to the end of August (Archer, 2007).

Furthermore, the Vespidae species mentioned above not only hunt for invertebrates as a source of protein, but also actively consume nectar, honeydew, and fruit juice (Spradbery, 1973; Edwards 1980). It is well known that they use both visual and olfactory signals for this purpose, with the sense of smell being the more important sensory mode (Hendrichs et al., 1994; Moreyra et al., 2006). In addition, several studies have demonstrated that the presence of yeast in the composition of dried fruits and fruit powder compositions leads to a multiple increase in the attractiveness of bait for Vespidae (Babcock et al., 2017; Meriggi et al., 2020). Apparently, such components of the bait as sugar and yeast developing in it are very attractive for certain species of Vespidae.

Wasps of the genus Polistes (specifically *Polistes nimpha* and *Polistes dominula*) were rarely caught. Species of the subfamily Eumeninae (*Ancistrocerus*, *Discoelius*, and *Symmorphus*) were found in traps very rarely. These are species that prey on imagos and larvae of various other insects (Coleoptera, Lepidoptera, and Hymenoptera) (Blüthgen 1961; Chilcutt & Cowan, 1992; Budriene, 2003). Highly likely, representatives of these genera were accidental in beer traps. On the other hand, for many adult solitary wasps of Eumeninae, the main source of carbohydrates is the nectar of flowers (Fateryga, 2010, 2020). Therefore, it is possible that these wasps are also attracted by fermenting mixtures that contain sugar.

The species *Mellinus arvensis* (Linnaeus, 1758) and *Ectemnius cephalotes* (Olivier, 1792) were the most numerous among the Crabronidae. The prey of *M. arvensis* includes Diptera from the families Anthomyiidae, Calliphoridae, Muscidae, Sacrophagidae, Syrphidae, Tabanidae, Tachinidae, and others (Boreham 1951; Ruchin & Antropov 2019). The prey of *E. cephalotes* is also various flies from the families Calliphoridae, Muscidae, Syrphidae, and Tabanidae (Richards, 1980; Giovanni et al., 2017). Our observations have shown that many of these Diptera families are quite common in beer traps (Dvořák et al. 2020; Mcgowan et al., 2021), indicating that Crabronidae are attracted to the traps while hunting their prey.

It is interesting to examine how species from the Chrysididae and Pompilidae families are attracted to beer traps. Representatives of the family Chrysididae quite often fly to the flowers of various plants and feed on nectar and pollen (Linsenmaier 1997; Paukkunen et al., 2015). Some Pompilidae also fly to flowers and can feed on nectar (Makino & Okabe, 2019; Johansson et al., 2020). However, they were clearly accidental in our traps. It is possible that this is due to the height at which most of the traps were located - 7-8 m. At this altitude, Pompilidae are rare because their prey, spiders, live on the ground (Kurczewski, 1981; Makino & Okabe, 2019).

Thus, four species (*Vespula vulgaris, Vespa crabro, Dolichovespula media, Vespula germanica*) are the most commonly attracted social wasp species in the European part of Russia and the Volga region. While other species may also be present, they are less frequent and in smaller numbers. Similar findings have been reported in other regions of Central and Western Europe (Dvořák 2007, Dvořák et al. 2008, 2010; Demichelis et al., 2014). These four species can be found almost anywhere, without any specific association with a particular country.

The seasonal dynamics of insect number is characterized by extreme diversity, with each species having its own unique seasonal cycle (Tauber & Tauber, 1981; Ruchin 2021; Ruchin et al., 2021b). In our experiments, we captured a total of 2041 specimens from six species of Vespidae in various habitats. The majority (50.4%) of these specimens were captured in oak forests, while the lowest number of Vespidae was observed of pine forests (6.8%). Among the captured specimens, *Vespula vulgaris* was the most abundant species, representing 58.2% of the total (see Fig. 2).

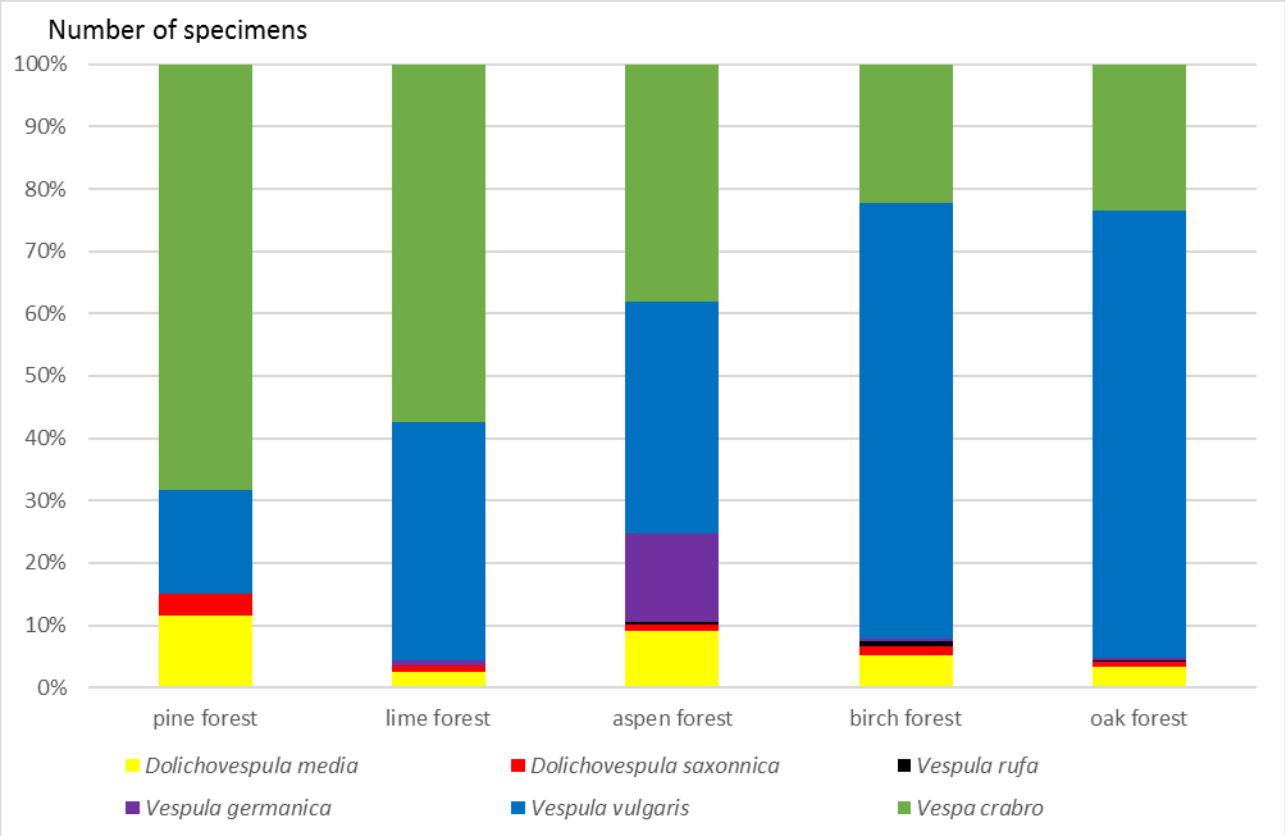

Figure 2. A ratio of six species of Vespidae were captured in beer traps from April to October 2019 in different biotopes of the Mordovia State Nature Reserve.

Vespula vulgaris was the dominant species in forests such as birch and oak, while *Vespa crabro* was dominant in pine and linden forests. In aspen forests, the number of these two species was similar. We also observed a relatively high number of *Vespula germanica* in aspen forests.

Our data represents four species of Vespidae and shows a common trend of increased number by the end of the spring-summer season (see Fig. 3–7). Additionally, we noted that *Vespa crabro* also showed an increase in number in early spring.

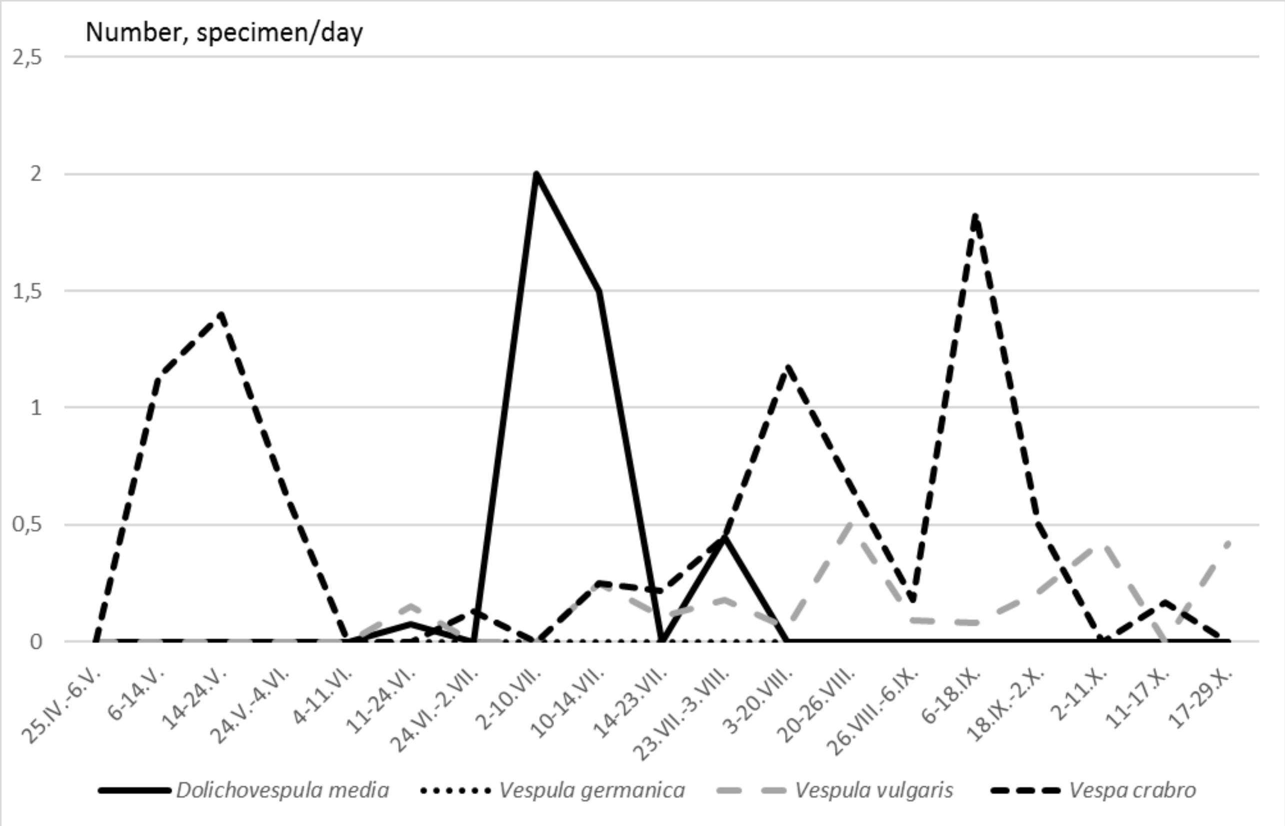

Figure 3. Seasonal dynamics of the number of Vespidae species in pine forests.

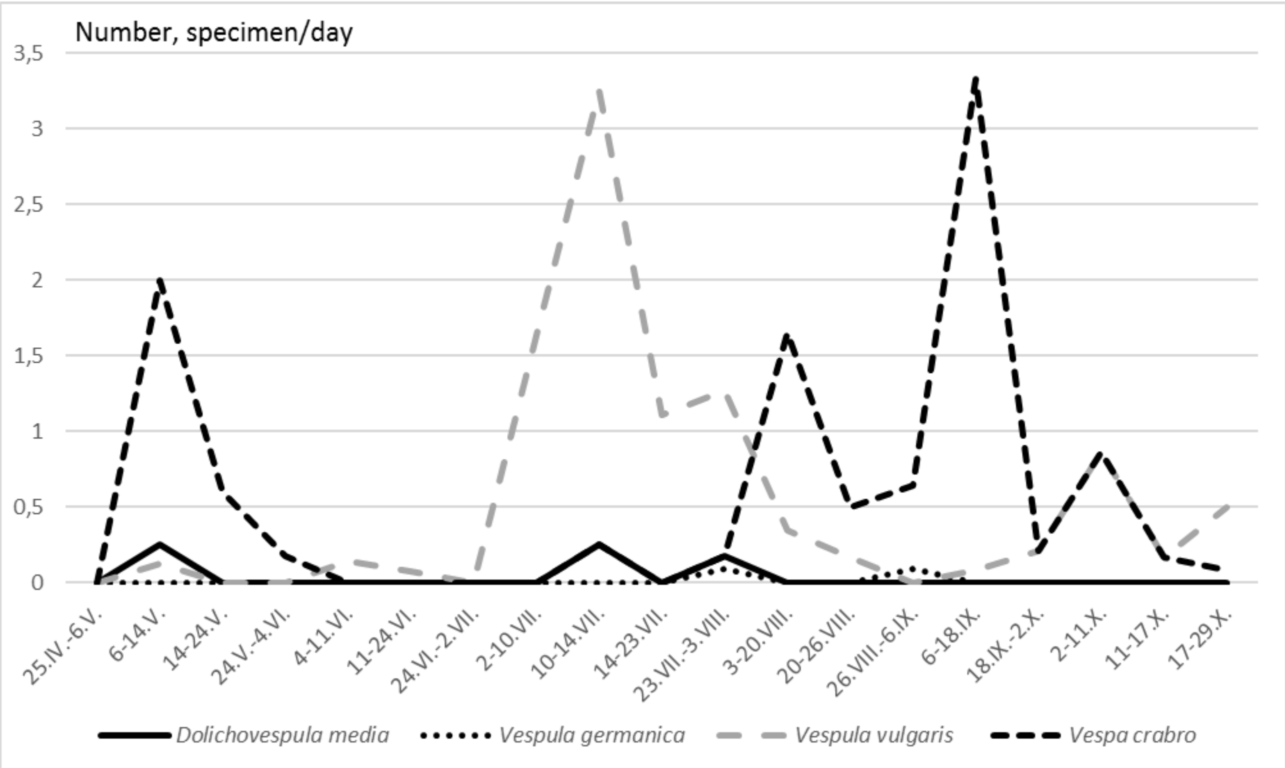

Figure 4. Seasonal dynamics of the number of Vespidae species in linden forests.

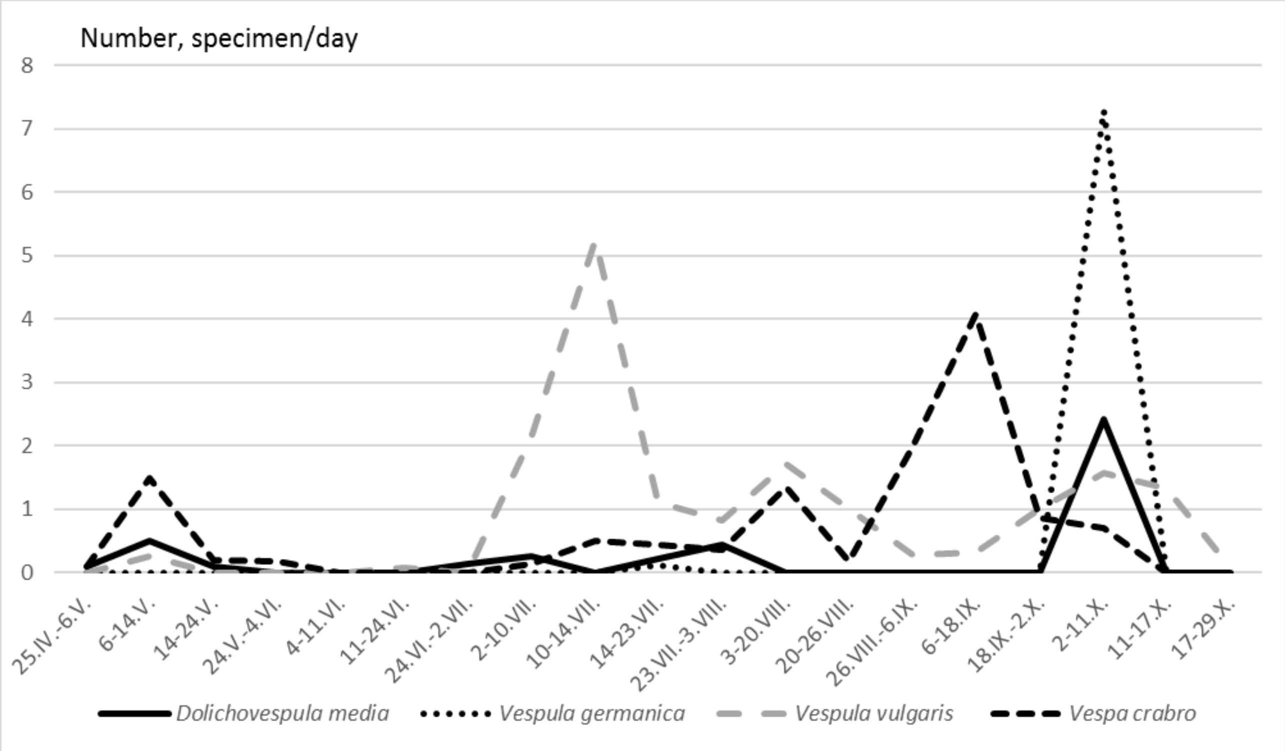

Figure 5. Seasonal dynamics of the number of Vespidae species in aspen forests.

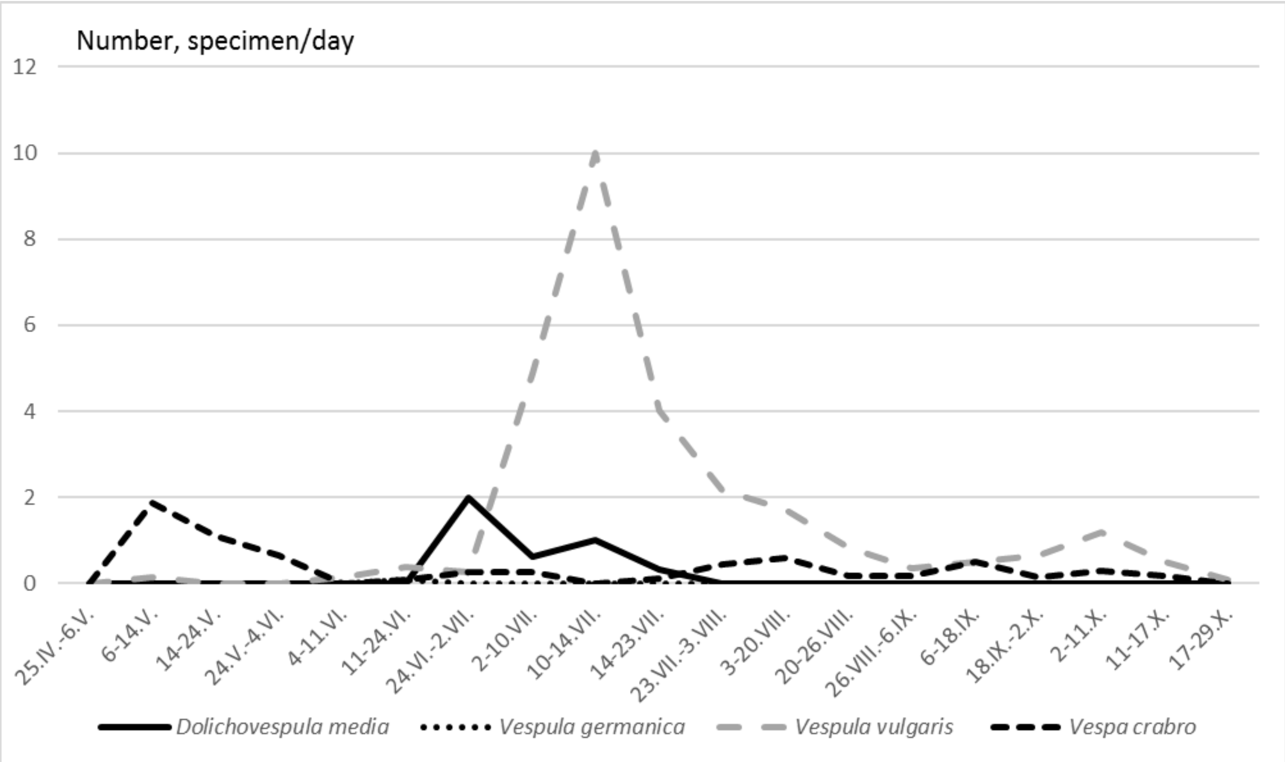

Figure 6. Seasonal dynamics of the number of Vespidae species in birch forests.

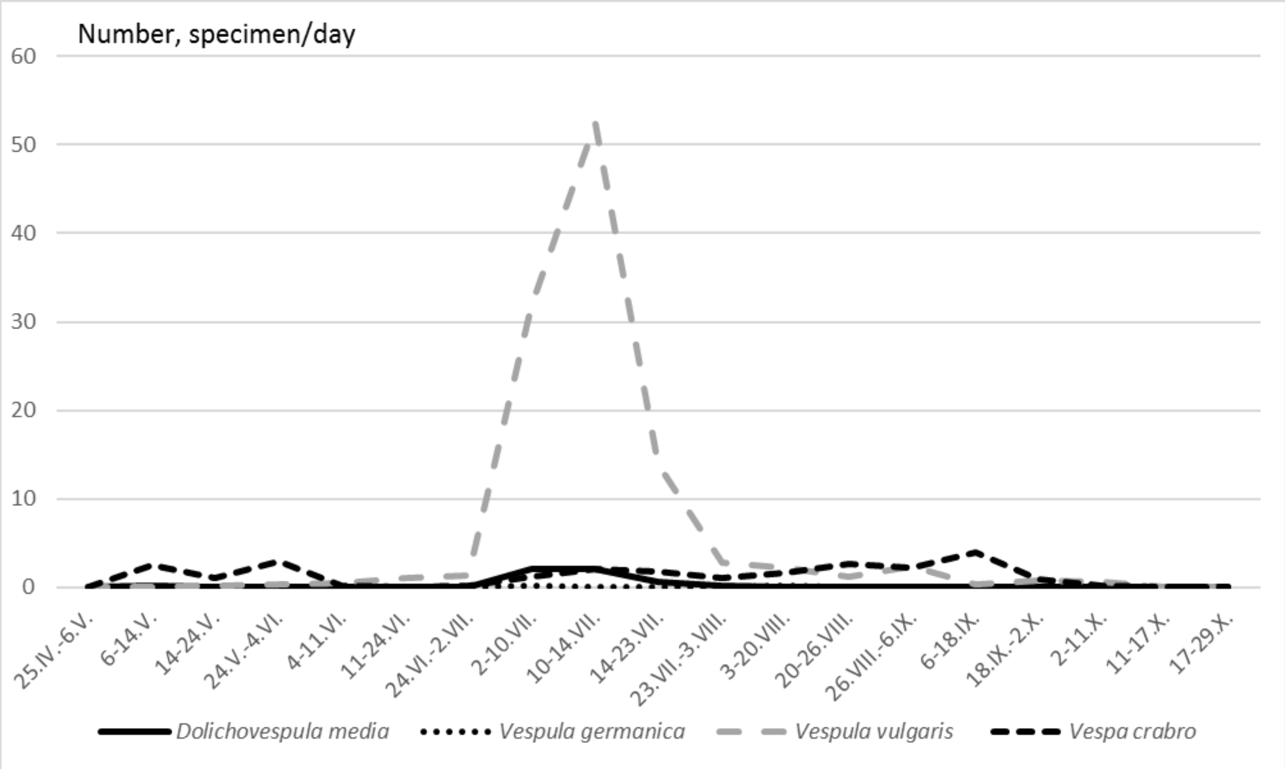

Figure 7. Seasonal dynamics of the number of Vespidae species in oak forests.

Figure 8 shows a general (summarized) graph of the number dynamics of 6 species of Vespidae for all five biotopes. This graph is related to day and night temperature.

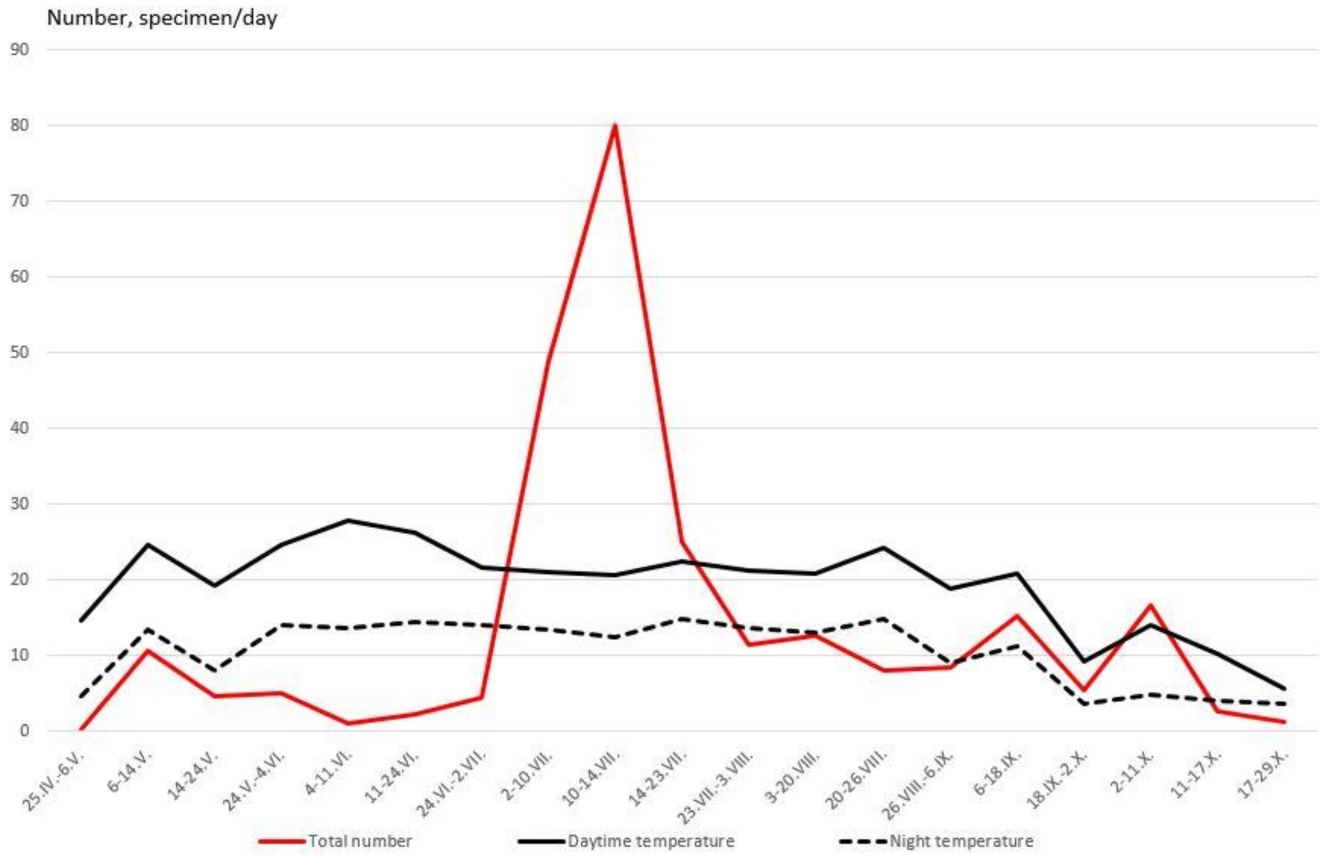

Figure 8. Seasonal dynamics of the total number of Vespidae species in all biotopes with the conjugate graph of day and night temperature.

The highest number of species was observed in early July. It can also be seen that there was a marked increase in day and night temperatures from 24 May to 24 June. A significant number of new-generation workers left the nests at this time. Figure 8 also shows that small peaks in Vespidae number in early spring, September and early October correlate with maximum daily temperatures at that time. According to some authors, in temperate latitudes, the abundance of Vespidae increases sharply in mid-season, reaching a peak in late July and early August (Spradbery 1971; MacDonald & Matthews 1981; Ulyshen et al., 2011; Guédot et al., 2018). For example, studies on *Vespa crabro* (Nadolski, 2013) under open breeding conditions showed that individuals did not leave the nest even in late autumn if the wasps had sufficient food. Apparently, similar data were obtained in our experiments. This is confirmed by the appearance of *Vespa crabro* in early spring in rather significant numbers (see Fig. 3–7). In autumn, under natural conditions, food becomes scarce because the number of workers carrying food decreases and both females and drones have to leave the nest. The consequences of this phenomenon are most evident in late autumn, when reproductive castes leave the nest suddenly and in large numbers (Nadolski, 2013). There is also evidence that colonies of *Vespula germanica* survive the winter and produce sexual individuals for the following season (Plunkett et al., 1989). This statement is probably true for New Zealand, as in our studies the number of this species in spring was zero in all habitats. Moller et al (1991) recorded the nesting activity of *Vespula vulgaris* and *Vespula germanica* in each season, with numbers of this species gradually increasing towards the middle of the activity season and then gradually decreasing. Spradbery (1971) also found that nests of *Vespula germanica* hatched males and queens earlier in the season than *Vespula vulgaris* in his study area in England.

Studies of the vertical distribution of arthropods in temperate broad-leaved forests have revealed non-uniform vertically distributed communities. These patterns are determined by multiple factors acting simultaneously (Ulyshen 2011). Many studies have been carried out on the distribution of different insect orders in the forest canopy (Sutton & Hudson 1980, Rubik 1993, Fukuyama et al. 1994). Toda (1977) studied the community of Drosophilidae in the temperate forest canopy. He found two types of communities: an upper sap-consuming community and a forest fungus-consuming community. The vertical stratification of *Apterygida media* (Dermaptera) differed in developmental stages and abundance among tree species (Kirstová et al., 2017).

We also carried out studies examining the distribution of Vespidae at two altitudes. Of the common Vespidae, 6 species were recorded (see Fig. 9). However, only 4 species (*Vespula vulgaris, Vespa crabro, Dolichovespula media*, and *Vespula germanica*) had representative samples for statistical analysis. It appeared that the number of individuals of these species was slightly higher in the understorey traps than in the canopy traps. However, according to the Mann-Whitney test, the differences between samples taken above and below ground were not significant for all species.

In Kalimantan rainforests, the majority of Hymenoptera were also captured in the canopy and upper canopy (Koike et al., 1998). In contrast, Torretta and Marrero (2019) found no reliable differences in the vertical distribution of some Hymenoptera groups in Argentine forests. Parasitoid families of Hymenoptera (Braconidae and Ichneurnonidae) in temperate forests were more abundant in the forest floor than at the 20 m level (Preisser et al., 1998). A similar relationship was found in the experiments of Karem et al. (2006). A study by Giovanni et al. (2017) shows that the main part of the Sphecidae community in the understorey consists of species that prey on Diptera and spiders. At the same time, the species that are more abundant in the forest canopy are mainly predators of phytophages. *Augochlora pura* (Halictidae) was on average 40 times more abundant in the canopy (above 15 m) than in the understorey at 0.5 m (Ulyshen et al. 2010). Ulyshen et al. (2011) collected almost all specimens in two traps, one in the canopy and one near the ground in the upper trap.

Many different trapping methods and traps have been used to study the distribution of insects in the forest canopy. The studies mentioned above (Preisser et al., 1998; Karem et al. 2006; Ulyshen et al. 2011; Torretta & Marrero, 2019) were carried out using window traps, Malaise traps or their modifications. These are traps without bait. We used a baited trap. It is possible that wasps fly to the bait (fermented beer with sugar) from a certain area and from different heights, and can go both up and down to the undergrowth. This assertion requires further experimentation. However, it is known that UV light traps are often used to assess insect fauna in canopies (Sutton & Hudson 1980, Koike et al., 1998; Preisser et al., 1998). Light spreads over a wide area and if there is open space around the trap, a wide range of insects will be caught. Because light can disrupt the spatial distribution of insects as well as attract individual groups, it is difficult to obtain comparable insect distribution data using this method (Koike et al., 1998). It is possible that something similar occurs during bait capture in our studies.

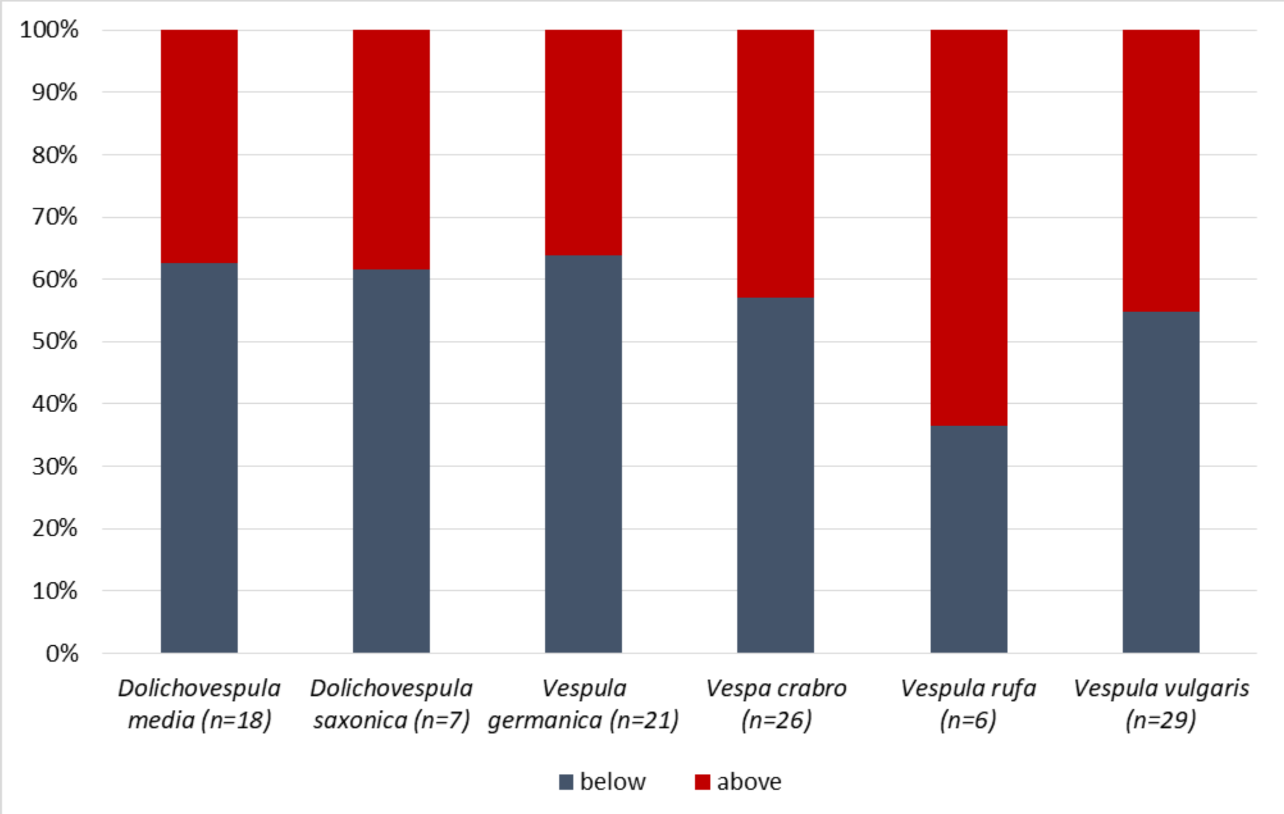

Figure 9. Ratio of the number of Vespidae individuals in beer traps located 1.5 m from the ground level (below) and in the forest canopy at a height of 7-8 m (above). n is the number of trees with traps.

Conclusion

In our studies using beer traps in the forests of Central European Russia, 32 species from 4 families of Hymenoptera were recorded. The most abundant family was Vespidae. The dominant species in this order were *Vespula vulgaris*, *Vespa crabro*, *Dolichovespula media*, and *Vespula germanica*. The occurrence of these species was also quite high. The numbers of the remaining species were much lower, and some were recorded as single individuals. In addition to hunting invertebrates, these species are active consumers of nectar, honeydew and juice from a variety of fruits. Among the Crabronidae, *Mellinus arvensis* and *Ectemnius cephalotes* were the most abundant species. It is interesting to find in beer traps species of the Chrysididae and Pompilidae families, which frequently visit the flowers of various plants and feed on nectar and pollen. In five different biotopes, the highest abundance of Vespidae was found in oak forests, while the lowest abundance was observed in pine forests. Among all captured individuals, *Vespula vulgaris* was the most prevalent species, particularly in birch and oak forests. On the other hand, *Vespa crabro* was dominant in pine and linden forests. These two species were almost equally abundant in the aspen forest. We also note a high abundance of *Vespula germanica* in the aspen forest. The seasonal dynamics of abundance was characterised by a large peak at the beginning of July. This peak was formed after a significant increase in air temperature during the day and night. We assume that a significant number of new generation workers left the nests at this time. The number of Vespidae in traps placed lower in the undergrowth was slightly higher than in canopy traps. However, according to the Mann-Whitney criterion, the differences between upper and lower samples were not significant for all species. The results presented here provide a better understanding of Vespidae communities in temperate forests of European Russia and describe the seasonal phenology of dominant species. The use of beer traps for monitoring and mass trapping can target specific species of social wasps.

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