Number of different insecta groups and its dynamics on burned areas after megafires (second year of study)

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Abstract. The paper describes the results of studying the insect fauna after the megafires of 2021. Studied of 30,721 individuals from 10 insect orders were obtained for study in 2023, the second year after the megafires. We have established that in the traps were dominated by taxa from the orders Lepidoptera, Coleoptera, Neuroptera, and Hymenoptera. It is shown that the remaining orders were relatively few in number and occurred as single specimens. It is noted that the number of species belonging to the orders Heteroptera, Neuroptera, Lepidoptera, Hymenoptera, Mecoptera, and Trichoptera increased in 2023 in comparison to the previous year. As a result of this the number of individuals of the Heteroptera (4.8 times), the Neuroptera (3.2 times), and the Lepidoptera (2.0 times) increased significantly in the second year after megafires. It is shown that the seasonal dynamics was characterized by the configuration observed in insects native to temperate zones, with a single maximum observed in either July or August.

1 Introduction

Forest fires are a phenomenon that occurs in countries with significant forest resources. The primary challenge associated with wildfires is observed in countries with a continental climate and a predominance of coniferous species in forests [1–4]. The number of fires, their area, and their frequency are influenced by a multitude of factors. The primary factors contributing to this phenomenon include specific climatic conditions, the level of forest protection, anthropogenic transformation of landscapes, human recreational activities, the spread of invasive species, and the importance of forest resources in the country's economy. In recent years, the phenomenon of global warming and the influence of human factors have been identified as the primary causes of large wildfires [5–8]. The designation "megafire" is often applied to wildfires covering an area of more than 10,000 hectares [7, 9]. Previously, megafires were rare events in forest ecosystems [5, 10]. Nevertheless, the rising frequency and complexity of megafires have led to the imminent threat to a vast range of invertebrate animal groups. In this context, the complexity of megafires refers to their "diversity" within a significant area in which they occur. In such cases, the fires

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become multi-day fires, with serious top fires appearing on different areas, while other areas experience severe lowland fires that destroy all living things. Consequently, this threat primarily increases for the most extensive and diverse group of insects. The significant proliferation of megafires in recent years and the associated extreme transformations have resulted in a wide variety of changes to insect behavior [11–13].

In the event of a fire, insects seek refuge in a multitude of structures, including shelter, burrows, crevices, stumps, unburned areas, logs, moist deadwood, and more. Such shelters are designated as refugiums [14-15]. After fires, they facilitate the repopulation of burned areas with surviving insects. Nevertheless, due to the considerable intensity, frequency, and duration of megafires, the number of such shelters has become exceedingly limited. This ultimately results in a reduction in the recovery capacity of different insect populations on burned areas. For instance, 2010 wildfires in forests resulted in the recovery of terrestrial insect fauna only on sparsely burned areas [16-17].

The objective of our research was to investigate the potential for flying insect forms to repopulate burned areas of forest ecosystems in the second year after megafires.

2 Materials and methods

The studies were conducted in 2023, the second year after the megafires in Mordovia. The Republic of Mordovia is situated in the European part of Russia, and the Mordovia State Nature Reserve is a notable site of interest. The Mordovia State Nature Reserve is situated within the zone of coniferous-broadleaved forests. In 2010, the area had already experienced megafires covering an area of 120 km². A diverse range of ecosystems has subsequently developed on the burned areas. In locations with small fires, forest ecosystems demonstrated a gradual recovery. Areas that experienced fires of considerable intensity and duration subsequently produced a considerable quantity of deadwood and dried pine and birch trees. A diverse range of young trees, including birches, aspens, and pines, was observed on such areas. The 2021 megafires were observed to be 90% concentrated on areas with a high prevalence of deadwood and dried wood. These components of the environment and vegetation cover were destroyed [6, 17-18].

The material for the work was collected between April and October. The specimens were collected using beer traps baited with beer and sugar [19]. Each trap was a 5-liter plastic container with a window cut out for insects to enter. The traps were suspended on tripods at a height of 1.5 m from the soil surface. The efficacy of this method of trapping using beer traps was evaluated in a variety of biotopes, demonstrating satisfactory outcomes [20]. A total of one trap was set on every one of the 11 plots. A detailed description of the plots was previously provided [18]. Figure 1 illustrates the status of the plots in August 2023. For comparative purposes, photographs of the plots in 2021 and 2022 can be found in the appendix of the publication [18]. It can be observed that the grass cover is regenerating on areas affected by fire. Nevertheless, numerous areas of uncovered soil (sand), which have not been colonized by vegetation yet, are visible on the heavily burned plots (4-5). Concurrently, plot 6, situated in the depth of the burned area, demonstrates a more rapid recovery of the ecosystem. This is attributed to its proximity to the swampy area, which is characterized by higher moisture levels. The plots that did not burn in 2021 (1, 2, 8, 10, and 11) have exhibited minimal change over the two-year period since the fires. The vegetation cover at the fire boundaries (plots 3, 7, and 9) is comparable to plots 4 and 5. However, they are situated in close proximity to the unburned plots (plots 2, 8, and 10, respectively), which allows for a slightly faster recovery.


Plot 1


Plot 2


Plot 3


Plot 4


Plot 5


Plot 6


Plot 7


Plot 8

Plot 9

Plot 10

Plot 11

Fig. 1. Photos of the studied plots in August 2023 (Center of European Russia).

In 2023, a total of 15 trap exposures were conducted on each of the plots (165 samples). The analysis was based exclusively on order abundance data. A pre-species determination was not conducted as part of this study.

3 Results

A total of 30,721 individuals from 10 insect orders were captured and observed in 2023 (Table 1). The highest abundance was observed on plots 1 (12.1% of the total number of specimens), 10 (12.0%), and 11 (9.9%). The lowest abundance during the study period was obtained on plots 3 (6.4%), and 5 (6.9%). The traps were dominated by taxa from the orders Lepidoptera (69.6%), Coleoptera (16.7%), Neuroptera (6.8%) and Hymenoptera (6.2%). The remaining orders were relatively insignificant in number and occurred as single specimens.

Table 1. The total number of different insect groups in traps in the plots in 2023.

Order	Plots											Total
	1	2	3	4	5	6	7	8	9	10	11	
Orthoptera	2	0	0	1	0	0	1	0	1	0	0	5
Blattodea	9	2	0	0	0	0	1	33	3	12	21	81
Heteroptera	14	10	5	6	10	9	18	8	11	6	4	101
Rhaphidioptera	1	0	0	0	0	0	1	0	1	1	0	4
Neuroptera	372	211	128	118	75	101	119	372	145	410	30	2081
Coleoptera	415	473	222	364	283	643	446	430	545	526	788	5135
Lepidoptera	2695	1341	1376	1781	1556	1921	1914	1908	2095	2664	2130	21381
Hymenoptera	195	211	248	417	191	126	162	114	91	76	72	1903
Mecoptera	0	0	0	0	0	0	0	12	0	0	0	12
Trichoptera	0	0	0	0	1	2	4	8	2	1	0	18
Total	3703	2248	1979	2687	2116	2802	2666	2885	2894	3696	3045	30721

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In comparison to the 2022 data, the studies revealed the presence of taxa belonging to the order Orthoptera. The number of individuals belonging to the Heteroptera, Neuroptera, Lepidoptera, Hymenoptera, Mecoptera, and Trichoptera orders increased in 2023 relative to the previous year (Figure 2).

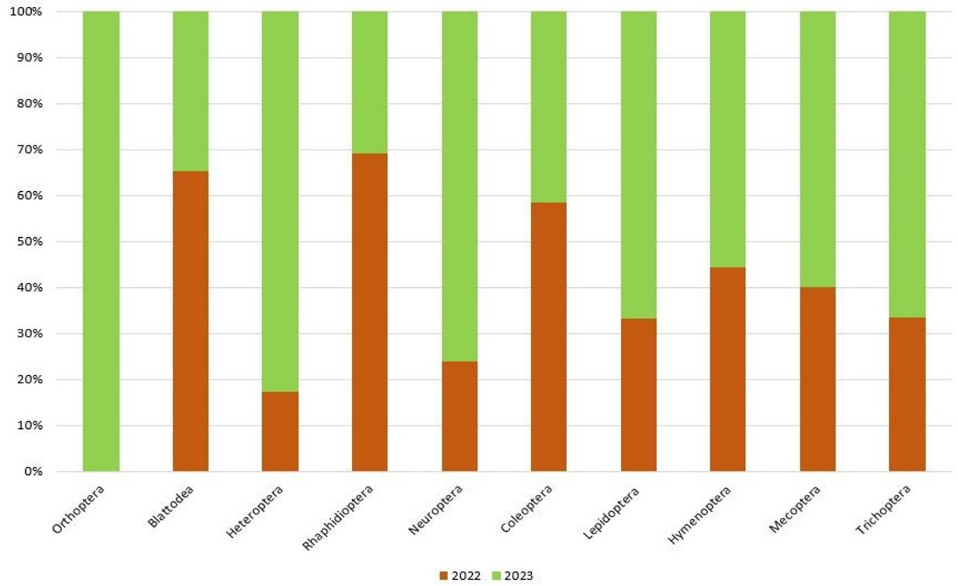

Fig. 2. The ratio of the number of insects in 2022 and 2023 in the burned plots (Center of European Russia).

In contrast, the abundance of Blattodea, Rhaphidioptera, and Coleoptera was higher in 2022. The abundance of Heteroptera (4.8 times), Neuroptera (3.2 times), and Lepidoptera (2.0 times) increased significantly in the second year after megafires.

The abundance of Lepidoptera on all plots increased in 2023. Nevertheless, the observed increase varied considerably between plots. For example, the increase on plot 6 was 3.5 times higher than that observed on plot 2, which was no more than 1.1 times higher. The highest increase in the abundance of Lepidoptera was observed on plots located on completely burned areas and on boundary habitats (edges of burned areas). The same data were obtained for another group of insects, the Neuroptera. In 2023, an increase in abundance was observed on all plots. Nevertheless, on the control plot (11), the abundance exhibited a change of only 1.1 times.

On plots with intense fires and located far from preserved forests (plots 4, 5, 6), Coleoptera abundance was observed to be higher in the second year after the fire. In contrast, Coleoptera abundance was observed to be higher in 2022 on the other plots. Five of the plots (1, 3, 4, 5, and 6) exhibited an increase in the abundance of Hymenoptera in 2023. Of these, the last four plots were megafire areas, with no vegetation remaining after the fires. A notable decline in the abundance of Hymenoptera was observed in 2023 on plots 8, 10, and 11. The abundance of Heteroptera was found to be higher on all plots in 2023.

The seasonal dynamics was characterized by the configuration typical of insects in temperate zones. From April, there was a gradual increase in insect abundance, reaching a maximum in July (plots 1, 3, 6, 7, 8, 9, 10) or August (plots 2, 4, 5). Subsequently, the abundance exhibited a decline, reaching a minimum by October (Figure 3).

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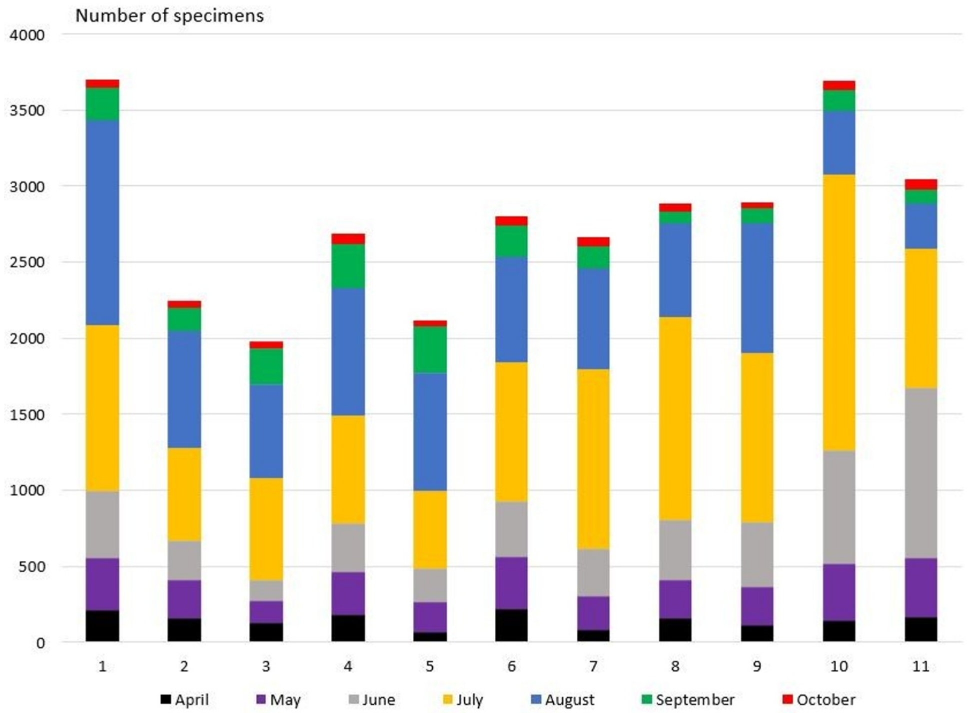

Fig. 3. The seasonal dynamics of insects abundance in 2023 in a burned plots (Center of European Russia).

4 Discussion

In forest ecosystems, the number of intact areas of habitat after megafires is significantly reduced, which is a critical factor in the subsequent recovery of individual species populations [17, 21]. In the case of the Mordovia State Nature Reserve, megafires have been observed to have a destructive impact on herbaceous vegetation, dry wood, deadwood, shrubs, and young trees. Consequently, a significant number of ecological forms of insects, which depend on these objects for survival, would have to be adversely affected by the immediate aftermath of megafires. This was the case in the first year after the fires, when the majority of insect groups exhibited a clear inferiority to the control plots [18]. Flying insects are typically the most active, actively seeking suitable new habitats [22–24]. Beer traps are designed to attract flying insects and serve as a marker of their activity [17, 25-26]. It has been observed that the primary recolonization of flying forms occurs from the unburned perimeter, with insects gradually moving into the burned area. Other authors have also obtained similar data [7, 27]. This behavior can be evidenced by data on the abundance of active flying forms such as butterflies. The taxa from this order began to spread rapidly in the second half of 2022 [18]. The activity continued with a notable increase in butterfly abundance on fully burned areas, and a continuation of the general trend of increased abundance on boundary areas in the second year after the fires.

Furthermore, we observed the recolonization of Hymenoptera and Neuroptera on separate burned areas in the first and second year after the fires. This is evidenced by the significant increase in the abundance of these groups particularly in the second year after the burning of the areas. Despite a general decline in the abundance of Coleoptera in 2023 compared to 2022, we observed an increase in the total number of beetles on burned plots.

It is possible that additional refugia for subsequent dispersal may be some forms of landscape that have allowed entomofauna to persist. For example, such areas can be defined as low-lying regions with an inherent capacity for the accumulation and retention of water. During the 2021 megafires, these habitats experienced rapid fires that did not affect the litter, moss, or tree and shrub understory. Consequently, the presence of vegetation and refuges may have contributed to the long-term survival of certain insect groups [28]. The recovery of the plant community after a fire is a crucial factor in determining the subsequent presence of entomofauna on burned areas. In any case, after a certain period of time there is a recovery of biodiversity in ecosystems affected by fires. It is important to note that the process of fauna recovery is contingent upon numerous factors and occurs at varying rates in each case [28,29]. The number of potential refugia, their spatial separation, and their distance from unburned areas are crucial considerations at such locations [28,30]. The data indicates that the recovery of entomofauna after megafires is likely to be a protracted process. Over the course of two years, the recovery of vegetation cover is accompanied by a gradual increase in the number of entomofauna representatives on burned areas.

5 Conclusion

The flying entomofauna of 11 plots in the second year after the megafires was investigated using beer traps. Data were obtained on the abundance and seasonal dynamics of 10 orders. The traps were dominated by taxa belonging to the orders Lepidoptera, Coleoptera, Neuroptera, and Hymenoptera. The remaining orders were relatively insignificant in number and occurred as single specimens. A significant increase in the abundance of Heteroptera, Neuroptera, Lepidoptera, Hymenoptera, Mecoptera, and Trichoptera was observed in the second year after the fires. A notable increase was observed in the abundance of Heteroptera (4.8 times), Neuroptera (3.2 times), and Lepidoptera (2.0 times) in the second year after the megafires. It is observed that a significant recolonization of burned areas occurs in the second year after the fires. The seasonal dynamics was characterized by the configuration typical of insects in temperate zones, with a single maximum occurring in July or August. Consequently, within a two-year period, accompanied by a simultaneous recovery of vegetation cover, there is a gradual increase in the number of entomofauna representatives. The recovery of entomofauna after megafires will be a protracted process.

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