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Research Article

Seasonal dynamics of Coleoptera abundance in the second year after fires

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Abstract

In forest ecosystems, fires profoundly impact the habitat and seasonal dynamics of numerous Coleoptera species. The phenology of species and communities is particularly noteworthy in burned areas that were previously forest ecosystems. In 2023, research was conducted in the Mordovia State Nature Reserve on 11 burned plots in 2021 and control plots. The research employed the use of beer traps, which are baited with a combination of beer and sugar. In the second year after the fires, species from the families Nitidulidae, Cerambycidae, Scarabaeidae, and Elateridae exhibited the highest total number across all plots, accounting for 84.8% of all Coleoptera specimens collected. A single peak in the abundance of Coleoptera was observed on all plots during the month of May. The second peak in abundance during the autumn season was relatively modest in scale and was observed exclusively on unburned 2021 plots. Nitidulidae beetles appear in traps earlier than other beetles, with their number peaking in April and May. Thereafter, their number declined in June. The number of Cerambycidae and Scarabaeidae on all plots was relatively low in April but increased significantly in May and June. The peak abundance of Elateridae was observed in June, although the first individuals were recorded in April. A precipitous decline in the abundance of the species was observed in July, with only a single specimen being recorded in August. The Elateridae were observed to be particularly prevalent in burned areas where deadwood was present. There are variations in the observed differences between individual families, which are related to the location of plots, the condition of the vegetation cover, and the presence of flowering plants, deadwood, and dry trees on the plots.

Keywords: abundance, insects, forest fire, Mordovia State Nature Reserve

Introduction

Among abiotic factors, photoperiod, temperature, and precipitation are the primary factors that exert a continuous and direct influence on the seasonal activity of the vast majority of species of organisms (Marinoni, Ganho 2003; Linzmeier, Ribeiro-Costa 2008) In temperate zones, all organisms are subject to regular and predictable seasonal fluctuations in climatic conditions throughout the year. It is crucial to comprehend the range and temporal dynamics of these fluctuations in order to gain insight into the distribution of species and their capacity to survive and reproduce under specific habitat conditions (Wolf et al., 2017; Kataev et al., 2023; Vasilyev et al., 2023). The phenology of species and communities is a dynamic process that changes can influence abiotic and biotic factors (Forrest, 2016; Scranton, Amarasekare, 2017; Wolf et al., 2017; Ruchin et al., 2022; Zouaimia et al., 2022; Drago, Vrcibradic, 2023). Due to the varying phenological patterns exhibited by species across their geographic range, it is crucial to understand how specific environmental conditions can influence the seasonal dynamics of species within a specific area. This is possible if the phenological characteristics of species within their current ranges are known (Colautti et al., 2017; Damien, Tougeron, 2019; Tsuji et al., 2022).

The Coleoptera is one of the most diverse insect orders, with approximately 360,000 described species (Bouchard et al., 2009). The Coleoptera are found in various habitats across all climatic zones. They may be predators, saprophages, phytophagous, or consume various foods. Most of these insects are active and can travel considerable distances (Hodek et al., 1993; Venn, 2016; Jones et al., 2019; Dedyukhin, 2022, 2023). The seasonal changes in the abundance and activity of Coleoptera were studied in different temperate forest habitats. In the Czech Republic, *Adalia decempunctata* was the most prevalent species from May to June, after which it was superseded by *Harmonia axyridis* as the most common species in late summer (Honek et al., 2015). In Canada, the most common species of Carabidae exhibited a peak in capture activity during the months of May and June (Niemelä et al., 1992). The abundance of *Carabus coriaceus* was observed to increase in late summer in both mixed and pine forests of Central Russia (Alekseev et al., 2021). In the Tenebrionidae community in Central Italy, the timing of activity of individual species differed, but in most species, abundance increased during the spring and autumn months (Carpaneto, Fattorini, 2001). In Poland, the seasonal dynamics of saproxylic species was characterized by an increase in abundance during the spring season and a subsequent decrease during the autumn season (Sawoniewicz, 2015). The abundance of different Coleoptera families in selected forest habitats increased mainly during the period from late spring to early summer, and then decreased by autumn (Ruchin et al., 2021; Ruchin, Egorov, 2022).

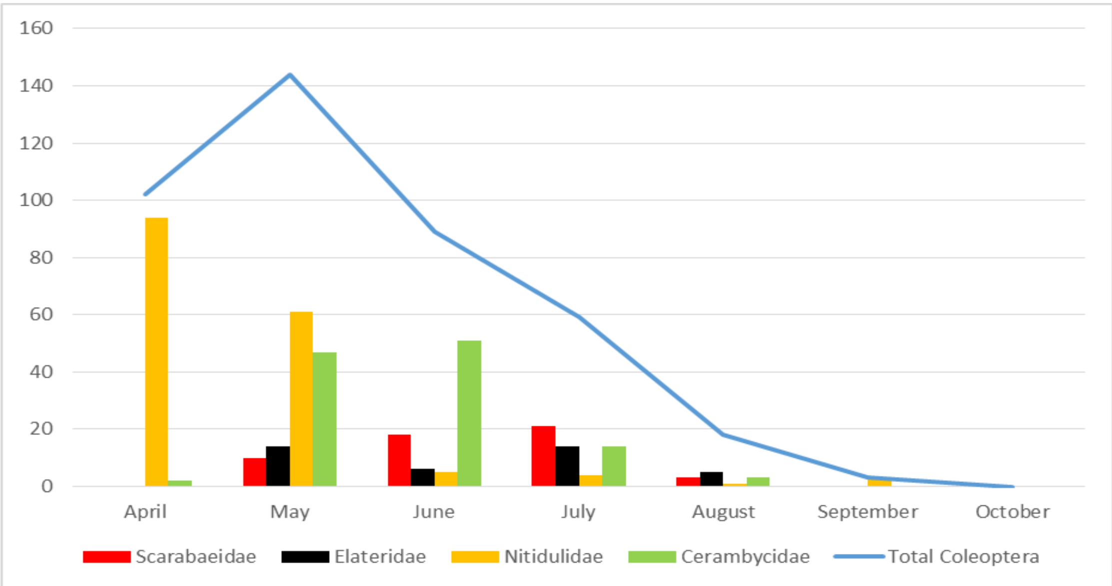
One factor that affects the Coleoptera in forest ecosystems is fire. In recent years, large fires have become increasingly frequent occurrences in forests across Europe, Asia, and North America (Geraskina et al., 2021; Filimonova, 2021; Kharitonova, Kharitonova, 2021; Wagner et al., 2021; Atutova, 2023). After a fire, a multitude of phenomena can be observed in the lives of organisms as a result of post-fire successions (Wikars, 2002; Johnson et al., 2008; Ruchin et al., 2019; Kastridis et al., 2022; Tiberio et al., 2022; Trujillo-Arias et al., 2023). It has been observed that certain insect groups of insects may experience an increase in abundance after fires (Reinhard et al., 2019; Palusci et al., 2021). Nevertheless, insects are able to evade the effects of fire by actively seeking out areas that are not in immediate danger. They have the ability to burrow into the soil, under rocks, and in rodent burrows and crevices (Wikars, 2002; Campbell et al., 2007; Andrade et al., 2011; Boulanger et al., 2013; Reinhard et al., 2019). After fires, adult insects can repopulate the affected areas immediately or after a period of time (Gongalsky et al., 2003; Ruchin et al., 2021c). The recovery of insect fauna and biotic connectivity in communities after fires depends on abiotic and organismal characteristics. The traits of organisms can be divided into two main categories: the migration of organisms from the unburned area and the presence of soil fauna or eggs on the burned area (Gongalsky et al., 2012). Abiotic factors that influence the recovery ability of a fire-affected area include the fire season, the severity of the fire, the topography of the plot, the heterogeneity of the fire, and the weather conditions. The properties of the plant community and edaphic conditions that existed before the fire are also affected (Hellberg et al., 2004; Zaitsev et al., 2016; Ruchin et al., 2021c). Pitfall traps, which capture soil invertebrates, are a more commonly employed method for studying the recovery of communities after fires. The implication is that soil Coleoptera is most sensitive to the effects of fires. To a lesser extent, other methods of study are employed. This research aimed to examine the Coleoptera dynamics on burned plots within the Mordovia State Nature Reserve using beer traps.

Material and methods

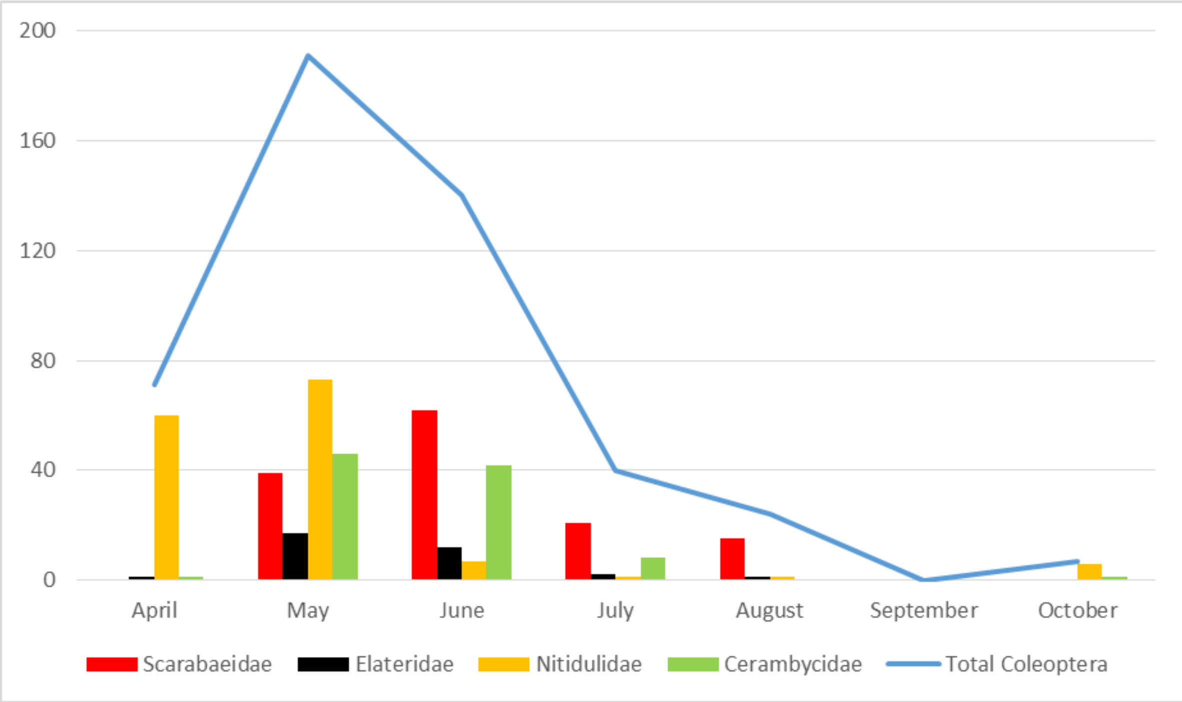
The material was collected on the territory of Mordovia State Nature Reserve (center of European Russia) from April to October 2023 using traps with bait made of beer and sugar. The design of the traps has been previously described (Ruchin et al., 2020). Each trap was suspended at a height of 1.5 m on a wooden tripod, one for each trial plot. This method has previously been employed and has demonstrated satisfactory results (Ruchin et al., 2023). 11 plots were selected for analysis, representing a range of fire intensities observed in 2021, distances from the fire edge, and degrees of vegetation recovery from the 2010 fires. The research employed forest plots that had not experienced fires as controls. A detailed description and photographs of all plots have previously been published (Ruchin, 2024). The first author conducted the identification of the Coleoptera using a variety of guides. In order to analyze seasonal activity, the obtained data were grouped by months of the growing season, specifically April to October.

Results

A total of 5,135 Coleoptera specimens were observed due to the material processing. The families Nitidulidae (1884 specimens, 36.7%), Cerambycidae (1337, 26.0%), Scarabaeidae (587, 11.4%), and Elateridae (552, 10.7%) exhibited the highest total number across all plots during the study period. Consequently, these families constituted 84.8% of the total Coleoptera specimens collected. The seasonal activity of the Coleoptera was determined by examining the four families as representative examples. The Coleoptera exhibited a single peak in abundance, recorded in May (Fig. 1). The second peak in abundance during autumn was relatively modest in size. Another smaller peak was observed only on plot 3 in July. The observed increase in abundance was attributed to a notable expansion in the population of Scarabaeidae, particularly *Cetonia aurata*. Plots 10 and 11 exhibited particularly high abundance in April and May, with the family Nitidulidae being the primary contributor.



Plot1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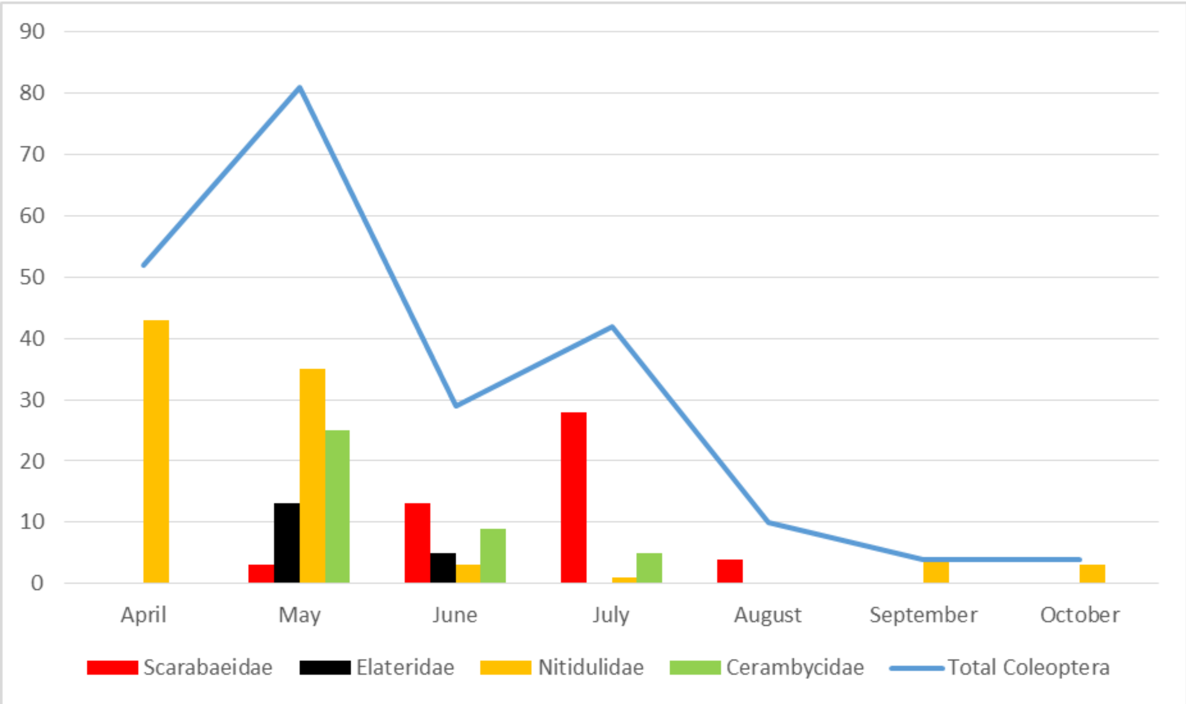
Elateridae
Nitidulidae
Cerambycidae
Total Coleoptera

Plot2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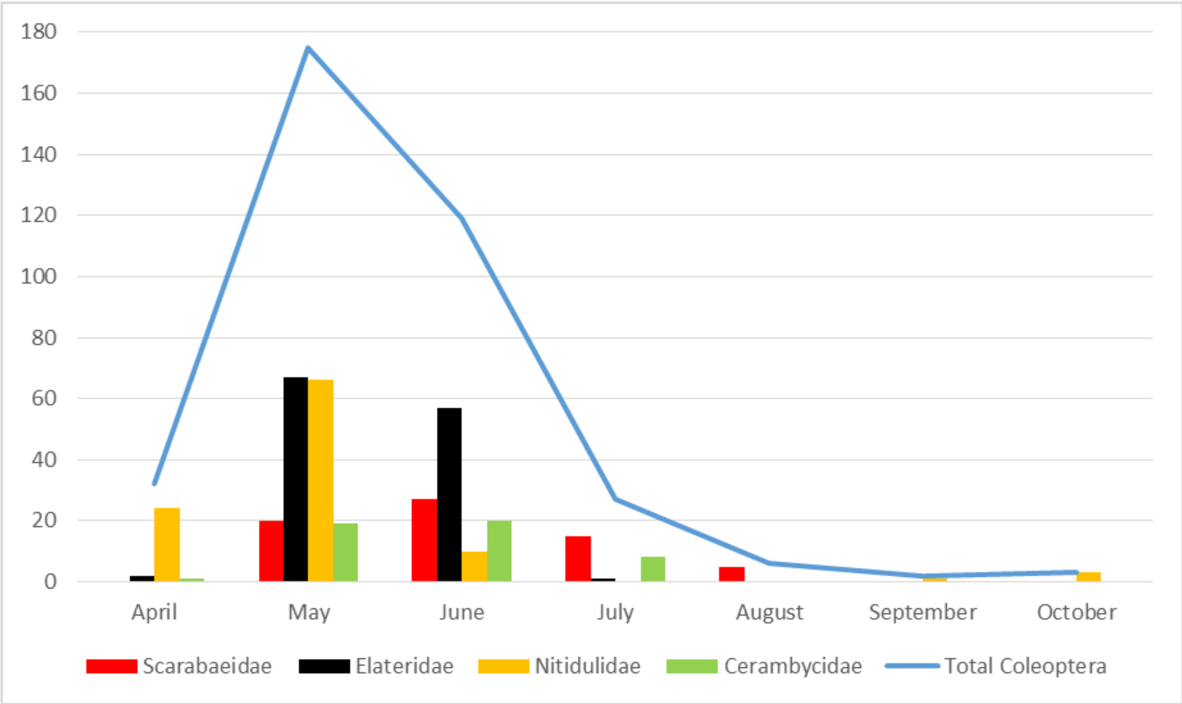
Total Coleoptera

Plot3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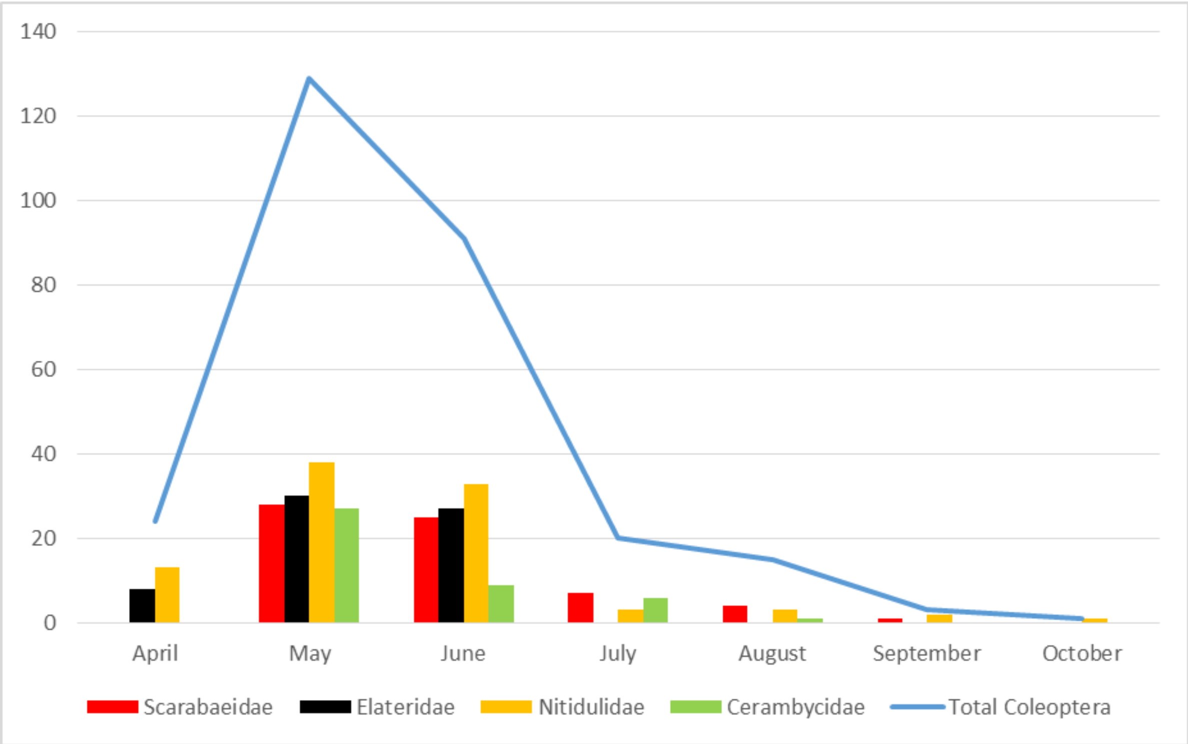
Cerambycidae
Total Coleoptera

Plot4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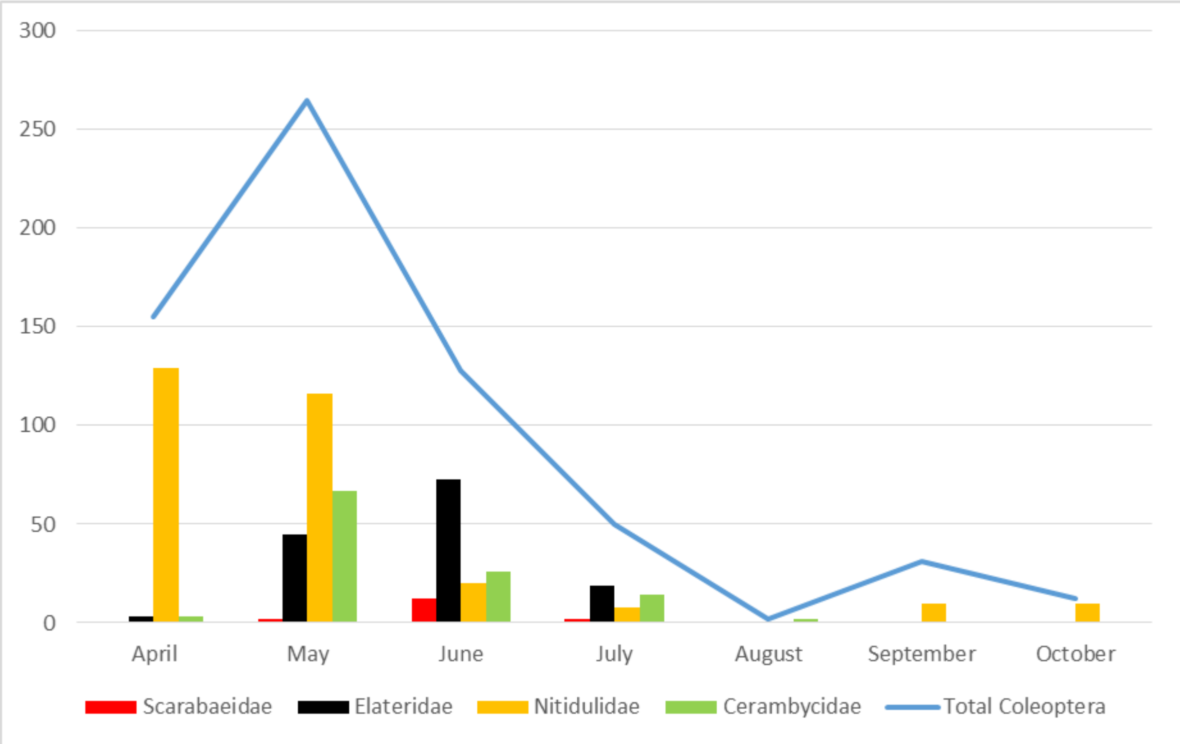
Cerambycidae
Total Coleoptera

Plot5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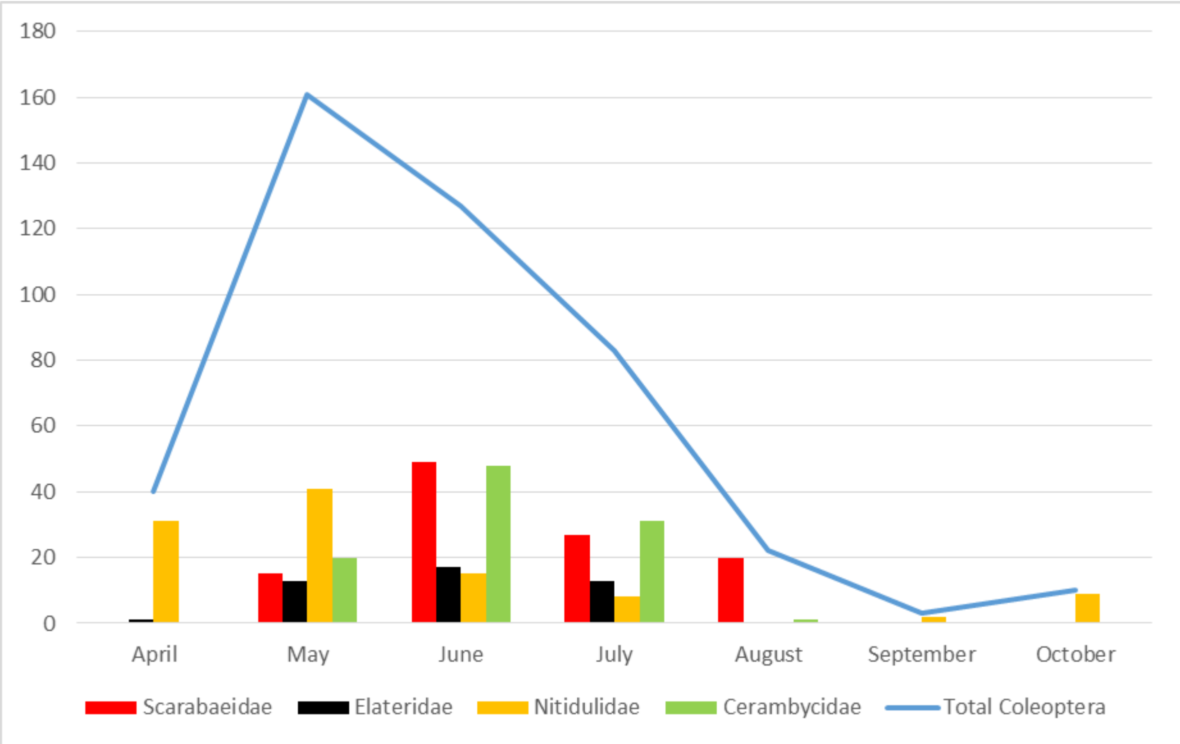
Total Coleoptera

Plot6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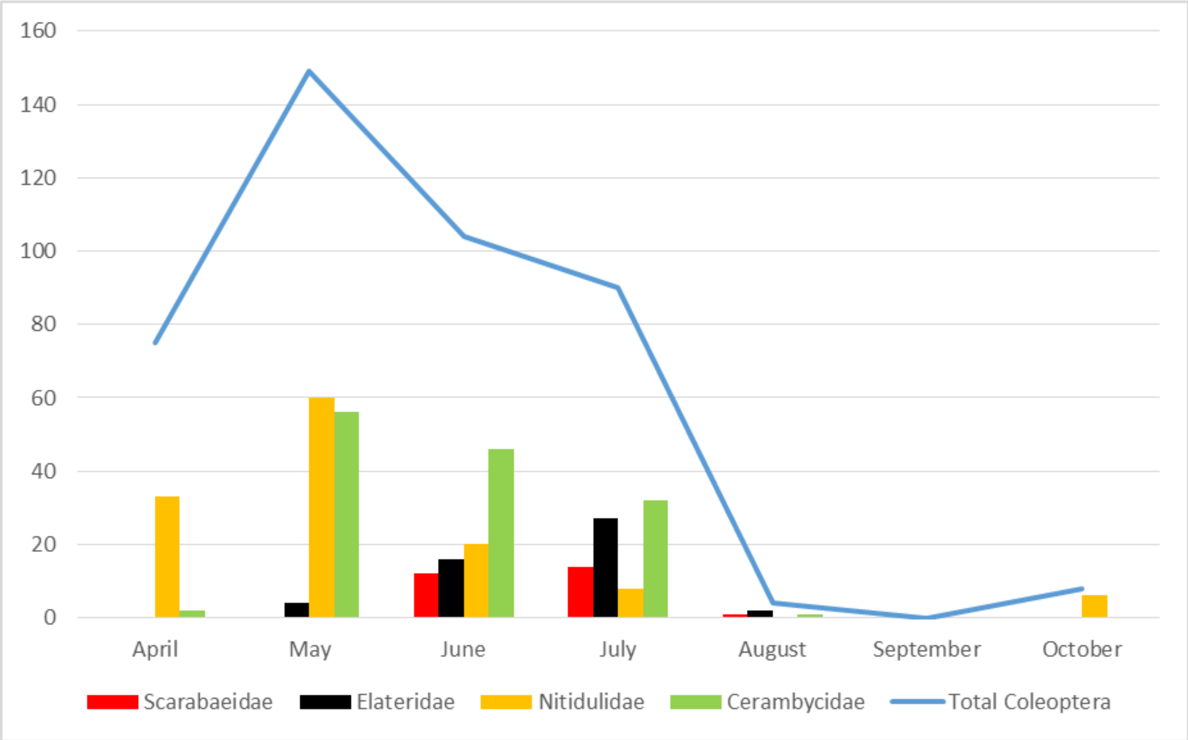
Cerambycidae
Total Coleoptera

Plot7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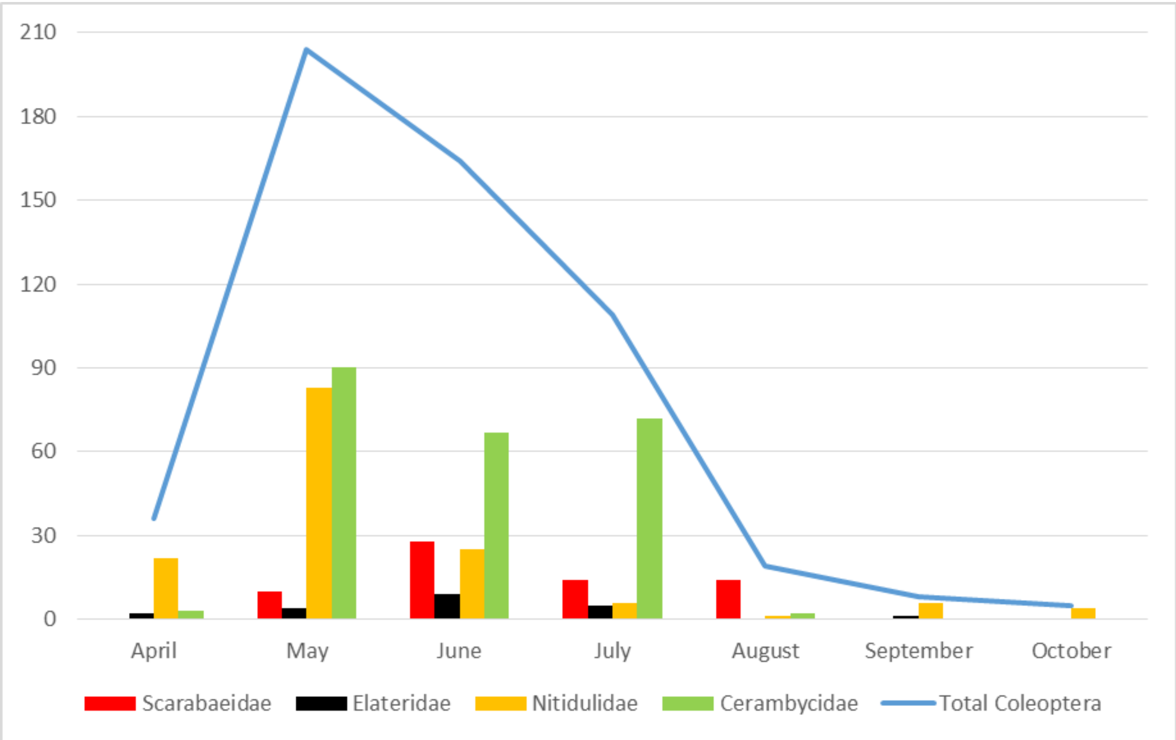
Elateridae
Nitidulidae
Cerambycidae
Total Coleoptera

Plot8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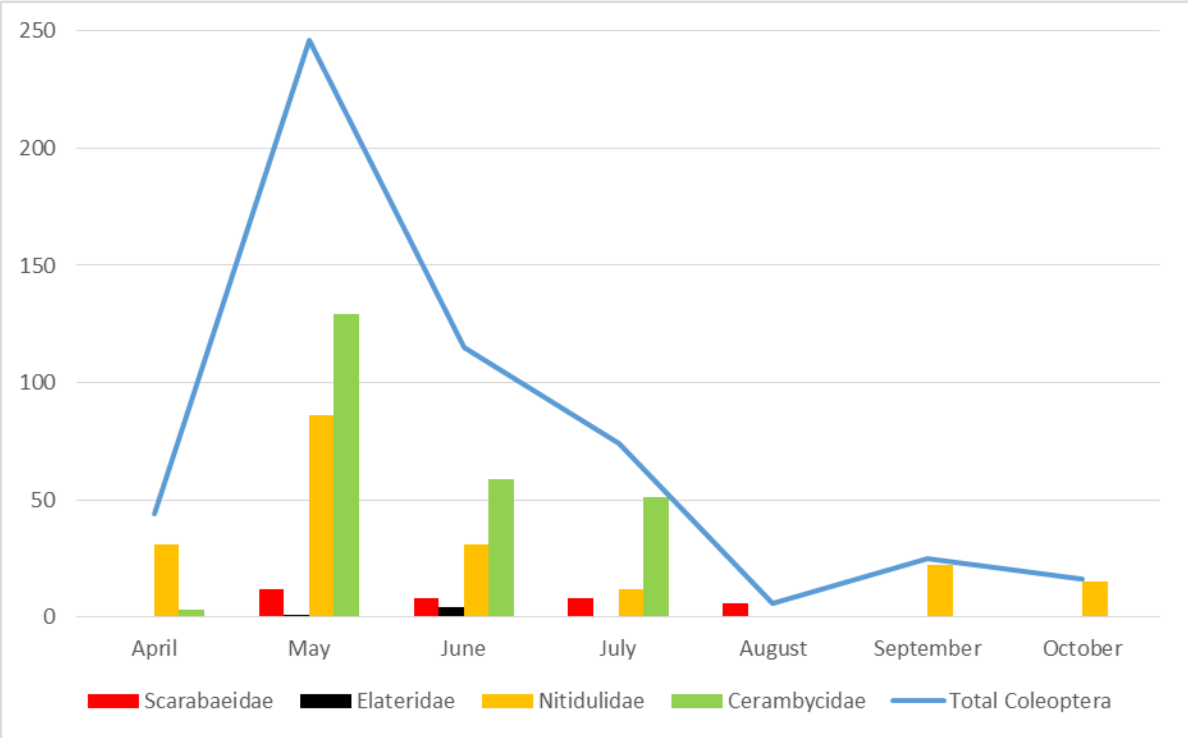
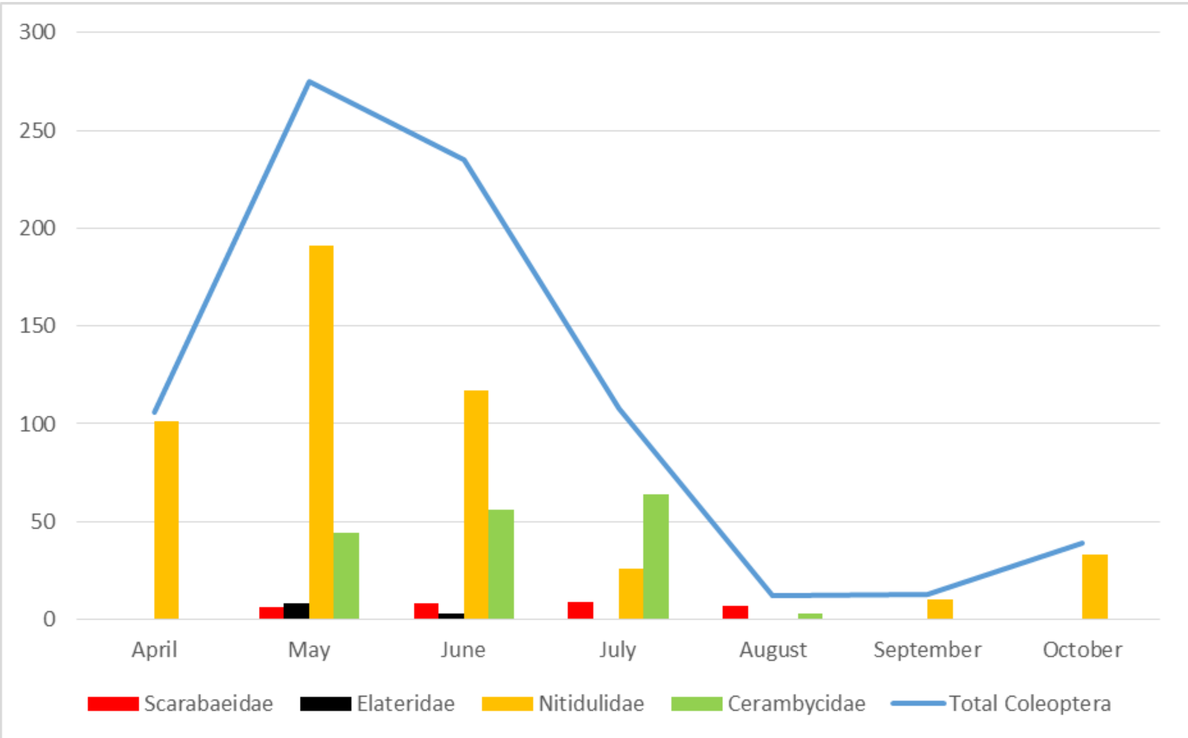
Scarabaeidae
Elateridae
Nitidulidae
Cerambycidae
Total Coleoptera

Plot9



Plot10



Plot11

Figure 1. Seasonal dynamics of Coleoptera abundance on experimental plots in 2023. The absolute abundance of Coleoptera is indicated on the OY axis.

Concurrently, the original seasonal dynamics of abundance on distinct plots were obtained for each family. Nitidulidae beetles are observed in traps at an earlier stage than other beetle species and exhibit the highest abundance during the months of April and May. Their population then declines in June. However, this increases again in September. The abundance of this family was particularly notable on the control plots, specifically plots 10 and 11, where the abundance was observed to be quite high in October. Concurrently, the abundance of Nitidulidae was notably low within the burned areas.

The abundance of Cerambycidae on all plots was low in April, increased in May-June (with the exception of plot 11, where abundance peaked in July), and then declined. No taxa of this family were present in traps in September-October. Notably, the greatest abundance of Cerambycidae was observed in boundary habitats and plots that did not burn in 2021. The abundance of this family was found to be low on control plots and burned plots. A similar abundance dynamic was observed in the family Cerambycidae, which was also found in the Scarabaeidae family. Taxa of this family were absent from plots in April, September, and October. The initial specimens were observed in May, with a peak abundance observed in June. Thereafter, abundance decreased from July to August. The highest abundance of taxa was observed at the boundaries of burned areas. On plots 10 and 11, Scarabaeidae's abundance was significantly lower than on plots located in the depth of burned areas (plots 4 and 5). Control plots, specifically plots 10 and 11, exhibited a significantly reduced abundance of Scarabaeidae compared to plots located in the depth of burned areas, specifically plots 4 and 5.

The peak abundance of Elateridae was observed in June, although the first individuals were recorded in April. A precipitous decline in the species' abundance was observed in July, with only one specimen recorded in August. Taxa of this family were not detected during the months of September and October. In plots 10 and 11, the number of Elateridae caught in traps was low despite the abundance of this family in burned areas.

Discussion

The Coleoptera communities that inhabit forest ecosystems are distinguished by the quantitative and qualitative dynamics that occur throughout the year. The seasonal dynamics of Coleoptera abundance may be attributed to the intrapopulation characteristics of species within a given community. Furthermore, seasonal dynamics can be influenced by photoperiod, temperature, and humidity. These factors may affect a given taxon directly or indirectly, such as a host plant (Aneni et al., 2014; Keszthelyi et al., 2017; Wolf et al., 2017; Rodríguez et al., 2019; Ruchin, 2021; Ruchin, Egorov, 2023). It can be observed that areas affected by large, long-lasting fires are typically characterized by the complete destruction of insect forms that have limited mobility. In contrast, active insects tend to avoid fires and may subsequently return to the area to colonize new habitats (Moretti et al., 2006). In these movements and return to biotopes, the primary factors will be the opportunities for feeding, egg laying, shelter, etc. These factors are primarily related to the vegetation communities that remain and/or are regenerating in fire areas (Gongalsky, 2017; Lazarina et al., 2019; Ward et al., 2020). Consequently, the entomofauna observed in the burned areas is contingent upon the plant community present (Moretti et al., 2006; Ruchin et al., 2021c).

The results demonstrated that in the second year after the fires, the total number of Coleoptera on nearby plots (7 and 8, 9 and 10) and control plots (1, 11) was lower than in the first year after the fires. Concurrently, the abundance of beetles was higher in 2023 on plots that had experienced intense fires and were situated in areas devoid of extant forests (plots 4, 5, 6). The seasonal dynamics of Coleoptera abundance in virgin forests of the temperate zone of European Russia are typically characterized by two peaks of abundance (Ruchin et al., 2021b; Ruchin, Egorov, 2022). This is probably why two peaks of abundance were recorded on plot 11. A single peak in abundance was observed on plots that had been burned.

The abundance of Nitidulidae is lowest on plots that have burned. In temperate latitudes, taxa of this family appear to be more restricted to old-growth forests or to forests in which the percentage of deciduous trees in the first and second tiers is significant. It is not uncommon for Nitidulidae to be baited with substances derived from rotting fruits and vegetables, mushrooms, syrups, sugar, and sugar-containing liquids. This is due to the specific nutritional requirements of the adult insects and the breeding opportunities of some species in such substrates. Some species of beetles are known to be anthophiles. In such forest ecosystems, the primary peak of taxa belonging to this family occurs in May and June, with a second increase in abundance observed in the autumn (Dowd, Nelsen, 1994; Blackmer, Phelan, 1995; Hokkanen, Lipa, 1995; Hossain, Williams, 2003; Jagemann et al., 2018; Ruchin et al., 2021a, 2021b). Concurrently, the abundance of Nitidulidae was notably low on burned plots. It appears that the lack of suitable substrates for feeding both adults and larvae may be the reason.

The Cerambycidae family exhibited a higher abundance of edge biotopes. This phenomenon is likely a manifestation of the edge effect, which has also been previously observed in temperate forests (Allison et al., 2019; Ruchin et al., 2023b). Notably, in control plot 11, the peak abundance of this family was observed in July, while in other plots, it was observed in May and June. It has been observed that the development of species attracted to traps is slower on plot 11 under high shading. Most Cerambycidae, which primarily fly into beer traps, develop in old wood and are saproxylic, with the adults being anthophilic (Ruchin et al., 2023, 2023b). Consequently, the peak abundance of these species was observed on burned plots in June, coinciding with the blooming period of many plants in open habitats.

The initial specimens of Scarabaeidae were observed in May, with a peak abundance observed in June. Thereafter, the number of insects decreased from July to August. The majority of the species observed were anthophilous (*Cetonia aurata* (Linnaeus, 1758), *Protaetia marmorata* (Fabricus, 1792), *Protaetia cuprea volhyniensis* (Gory & Percheron, 1833)). Similar patterns in abundance dynamics have been identified in other studies (Bardiani et al., 2017; Ruchin et al., 2021, 2021b). The abundance of Scarabaeidae was found to be significantly lower on control plots (plots 10 and 11) than on burned and edge plots. This is attributable to the absence of well-developed flowering vegetation that serves as a food source for anthophilous species. The only plot where the July peak of abundance was recorded was plot 3. This phenomenon can be attributed to the increased abundance of Cetonia aurata, an anthophilous species.

Of particular interest are the fauna and the dynamics of Elateridae, which were first obtained in this abundance in beer traps. Previously, taxa of this family have been encountered in beer traps, but their abundance was limited. However, the fauna was extensive (Ruchin et al., 2021b, 2023, 2023b; Ruchin, Egorov, 2022; Egorov et al., 2022a, 2022b, 2024). It has been observed that the high diversity and abundance of Elateridae (at the expense of the genus Ampedus) on burned areas can be attributed to the peculiarities of their development. The larvae of numerous species were observed to develop in rotting wood (Ranius, 2002; Brunet, Isacsson, 2010; Johansson et al., 2007; Siitonen et al., 2012). The burned areas are particularly conducive to the growth of deadwood that has been lying around for a couple of years. It is evident that the abundance of click beetles increased significantly in the burned areas by two years, with the highest increase observed in the depth of the plots (4, 5, and 6) rather than at the edge of the burned areas. In the majority of plots, the peak abundance of Elateridae was observed in June. However, this peak was also observed in some plots in May and July (plot 8).

Conclusion

In the second year after the catastrophic fires, species from the families Nitidulidae, Cerambycidae, Scarabaeidae, and Elateridae exhibited the highest total number across all plots, accounting for 84.8% of all Coleoptera specimens collected. A single peak in the abundance of Coleoptera was observed on all plots during May. The second peak in abundance during the autumn season was relatively modest in scale and was observed exclusively on unburned 2021 plots. The highest abundance of Coleoptera in April and May was observed on the two control plots, with the family Nitidulidae being the primary contributor. This family of beetles is observed in traps at an earlier stage than other beetle species and exhibits the highest abundance during the months of April and May. Subsequently, their abundance declines in June. The abundance of Cerambycidae and Scarabaeidae on all plots was relatively low in April but increased significantly in May and June. The peak abundance of Elateridae was observed in June, although the first individuals were recorded in April. A precipitous decline in the abundance of the species was observed in July, with single specimens being recorded in August. The Elateridae were abundant in burned areas with deadwood present. Consequently, the seasonal abundance dynamics for all Coleoptera species exhibit a single peak on all plots. However, it is evident that differences are observed between individual families, which are related to the location of plots, the condition of the vegetation cover, and the presence of flowering plants, deadwood, and dry trees.

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