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Seasonal Dynamics of *Carabus Coriaceus* Linnaeus, 1758 "Coleoptera, Carabidae" Activity in the Areal's Eastern Part

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ABSTRACT

Seasonal dynamics of the activity of *Carabus coriaceus* (Carabidae) imago was studied in the eastern part of the areal (in mixed and pine forests in Mordovia State Nature Reserve and National Park "Smolny", Republic of Mordovia). Seasonal activity varied by year. It started from late April in 2018 and early May until mid-September and October. The peak number was recorded in the second half of July-August. In the warm spring of 2018, the timing of the start of activity was shifted to April, while in the cold spring of 2019, the ground beetle began activity only in early May. The catchability of *C. coriaceus* was higher within the territory of Mordovia State Nature Reserve comparing to the National Park "Smolny". This may be due to the fact that Mordovia State Nature Reserve ecosystems have been protected for a longer time. In this protected area, anthropogenic activity ceased more than 80 years ago and the ecosystems have fully recovered.

Keywords: Carabidae, imago, *Carabus coriaceus*, Mordovia State Nature Reserve, National Park "Smolny".

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INTRODUCTION

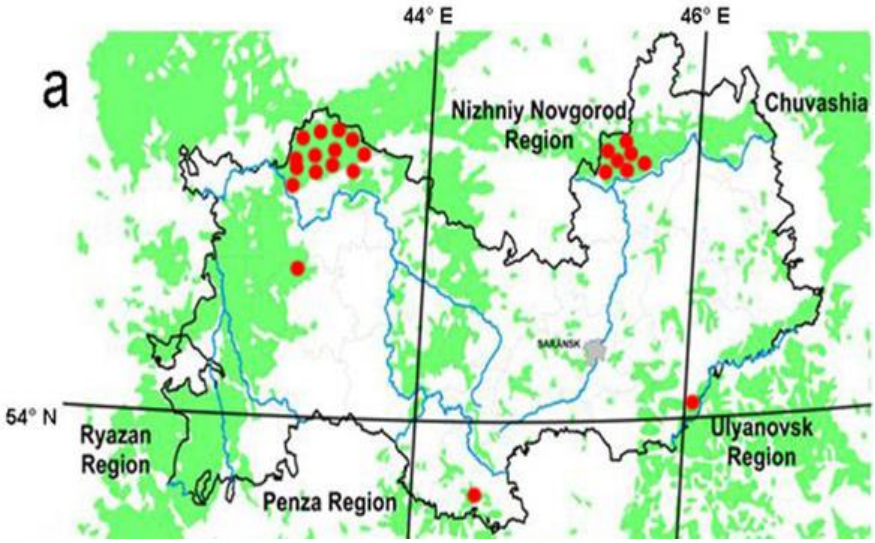
Coleoptera, Carabidae are widely distributed from the Arctic and alpine tundras to seacoasts, deserts, and rainforests, and they may be common in these environmental conditions [1-4]. They play a significant role in biocenoses as entomophages that regulate the number of terrestrial invertebrates, and they are considered economically useful: both imago and larvae destroy some pests of forestry and agriculture, limiting their numbers [5-8]. Carabidae is a convenient model object for ecological and faunal studies. This family is used for zoological diagnostics of soils, zoogeographic characterization of biocenoses, and assessment of anthropogenic impacts on the biocenosis [9-14].

Carabus species are large, often colorful, well-recognized, and well-studied members of the Carabidae. They are usually polyphagous predators that consume various invertebrates [15-17]. Some of them are common for forests. But there are species that can be rare, especially in conditions of severe anthropogenic pressure [7, 18-20]. *Carabus* (*Procrustes*) *coriaceus* Linnaeus, 1758 is a very large species of ground beetle with larval or imaginal diapause. The life cycle lasts one year and it is recyclic with autumn reproduction or obligately two-year recyclic with late-summer or autumn reproduction [21]. Females lay their eggs in September. Most larvae overwinter in the first and second stages. The species has a two-year development cycle [22]. The species is widely distributed in Europe [6, 22-26]. In some places, it is considered rare and is included in the lists of protected species [27-30]. The main factors leading to a low population of the species are habitat degradation (deforestation), the use of pesticides, and the weak ability of the species to settle. Recently, the areal has been described in detail within central Russia [31]. The eastern border of the species' areal

passes through the Chuvash Republic and the Ulyanovsk region. The Republic of Mordovia is located close to the eastern border of the species' areal [32, 33]. The objective of the present study was to investigate the seasonal dynamics of *Carabus coriaceus* activity in the eastern part of its areal.

MATERIAL AND METHODS

The Republic of Mordovia is located in the center of the East European Plain between 42°11' and 46°45' East longitude and 53°38' and 55°11' North latitude. The Sura and Moksha Rivers (tributaries of the Volga and Oka Rivers, respectively) are the main rivers in the basin where the Republic of Mordovia is located. The territory of the republic is situated in the forest and forest-steppe zone of Central Russia. There are several small steppe areas within the territory. The eastern part of Mordovia is located in the northwest of the Volga Upland, and the western part in the Oka-Don lowland **(Figure 1)**. In this regard, a variety of habitats is observed in the studied area. Boreal coniferous and mixed forests are common in the west, northwest, and north of the region [34]. Deciduous forests cover the central and eastern parts of the republic [12, 35]. Forest-steppe landscapes prevail in the east and south-east.



a)

b)

Figure 1. Study sites of *C. coriaceus* (shown with red dots).

The collection was carried out using pitfall traps in different regions of the Republic of Mordovia in 2018-2019. The distribution of ground beetles was studied during 2008-2020. The pitfall

traps consisted of plastic cups with a volume of 0.5 liters with a 4% formalin solution poured into them. In order to study seasonal population dynamics, traps were placed in the forests of the Mordovia State Nature Reserve in four localities (Temnikov district of the Republic of Mordovia) and the National Park "Smolny" in three localities (Ichalki and Bolshoe Ignatovo districts of the Republic of Mordovia). In each locality, there were 10 traps (from the end of April to September), which were installed in one line with a distance between them of 2-3 m. The evaluation of accounting results was expressed in dynamic density (ex./100 trap-days).

RESULTS AND DISCUSSION

The Republic of Mordovia is part of the range and is located close to the eastern border of the distribution of this species. The main biotopes of this species are forest edges, forest meadows, forest roads, and clearings in mixed and pine forests [33, 36]. Despite the fact that there are a lot of forests in the region, the findings of *C. coriaceus* are mainly confined to protected areas. In such conditions, the forest landscapes where *C. coriaceus* lives remain untouched.

Nevertheless, we note that the number of species in Mordovia State Nature Reserve was almost three times higher than the number of species from biotopes from the forests of National Park "Smolny". The first protected area is protected for a longer time and all the landscapes have been untouched for more than 80 years. Ecosystems in the National Park "Smolny" have been protected for only 25 years, and before that, intensive forestry activities were carried out on this territory. It is possible that anthropogenic activity has caused some damage to the populations of *C. coriaceus* and they are now in the recovery stage.

The activity of ground beetles is influenced by several factors, including temperature, humidity, microclimatic conditions, etc. [37, 38]. The temperature has long been considered the most important abiotic factor affecting the activity of Carabidae [39, 40]. The seasonal and life-history fluctuations strongly influence the observed abundances and distributions of Carabidae in certain biotopes [1, 21, 41].

Seasonal activity of *C. coriaceus* began in late April-early May and lasted until mid-September – the first half of October **(Figure 2).** Only one peak of abundance was recorded, which occurred in the second half of July – August.

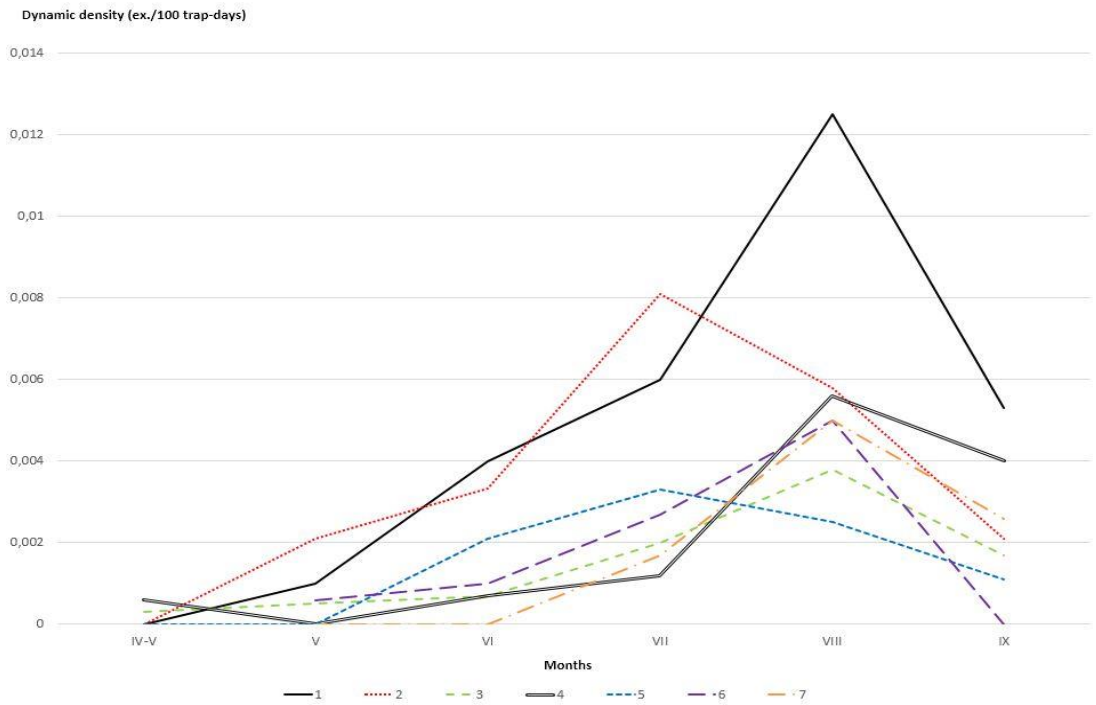


Figure 2. Dynamics of seasonal activity of *Carabus coriaceus*. The territory of Mordovia State Nature Reserve (1 – sq. 86; 2 – sq. 18; 3 – sq. 34; 4 – sq. 435) and the territory of National Park "Smolny" (5 – sq. 10; 6 – sq. 1; 7 – sq. 3). The relative abundance is indicated on the ordinate axis (ex./100 trap-days).

It is worth noting that in the relatively warm spring of 2018, the timing of the start of activity was shifted to April, while in the cold spring of 2019, the ground beetle began activity only in early May. However, subsequently, due to changes in the temperatures and cooling in the summer of 2018, the peak population was shifted to the beginning of August **(Figure 2, Graphs 1, 3, 4, 6, and 7)**. And vice versa, in 2019 **(Figure 2, Graphs 2 and 5)** the peak population was recorded in the second half of July.

In contrast to our studies in Hungary, two peaks of the seasonal activity of *C. coriaceus* were recorded: in late June-July and late August-early September [3, 42]. Slovakia also had two peaks of activity that were weather-dependent [43]. In the forests of Slovenia, the first specimens were caught in late April, and the last – in early November. The species becomes abundant in late May, mid-July, and especially between late August and late October [44]. In Croatia, this species was most active in late summer and autumn, but a small peak of activity was also observed in spring [45]. Since activity, in addition to the features of the life cycle, is associated with the weather conditions, it is obvious that the corresponding changes in the catch rate over the years and during the season will always be ambiguous.

CONCLUSION

The seasonal activity of *C. coriaceus* in the eastern part of the range varied by year. It began in late April or early May and lasted till mid-September and October. At the same time, the peak number fell in the second half of July – August. The beginning of activity was influenced by the ambient temperature. Thus, in the warm spring of 2018, the start dates of activity were shifted to April, and in the cold spring of 2019, *C. coriaceus* began its activity only in early May. At the same time, the catchability of *C. coriaceus* was higher in the Mordovia State Nature Reserve, in contrast to the National Park "Smolny". This may probably be due to the longer duration of the Mordovia State Nature Reserve ecosystem protection. In this protected area, anthropogenic activity ceased more than 80 years ago and the ecosystems have fully recovered.

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