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Temporal Dynamics of *Carabus coriaceus* (Coleoptera: Carabidae) in the Eastern Areal: A Seasonal Perspective

Sergei Alekseev[1], Alexander Ruchin[2]*, Gennady Semishin[2]

[1]Ecological club «Stenus», Kaluga, Kaluga region, Russia.
[2]Joint Directorate of the Mordovia State Nature Reserve and National Park «Smolny», Saransk, Republic of Mordovia, Russia.

***E-mail** ✉ ruchin.alexander@gmail.com

ABSTRACT

This study investigated the seasonal activity of *Carabus coriaceus* imagos in the eastern portion of their distribution range, particularly in mixed and pine forests located in the Mordovia State Nature Reserve and National Park "Smolny" (Republic of Mordovia). The period of activity varied between years, commencing in late April in 2018 and early May in 2019, and extending until mid-September and October. Population density peaked between mid-July and August. The warmer spring of 2018 led to an earlier start of activity, whereas the colder spring of 2019 delayed the appearance of ground beetles until early May. Capture rates were significantly higher in the Mordovia State Nature Reserve than in the National Park "Smolny," which is likely due to the long-term ecological protection of the reserve. With more than 80 years free from anthropogenic disturbances, the ecosystems in this area have undergone complete recovery.

Keywords: Imago, *Carabus coriaceus*, Carabidae, National park "smolny," Mordovia state nature reserve

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Introduction

Beetles from the Carabidae family are found across a diverse range of environments, spanning from Arctic tundras and high-altitude regions to coastal areas, deserts, and rainforests [1-4]. They serve a crucial ecological role as entomophagous predators, helping regulate terrestrial invertebrate populations. Due to their predatory nature, both the adult and larval stages contribute to controlling certain agricultural and forestry pests, making them beneficial in ecosystem management [5-8]. Additionally, Carabidae species are widely used in ecological and faunal research, serving as bioindicators for soil conditions, zoogeographic classifications, and anthropogenic impact assessments on biocenoses [9-14].

Among Carabidae, species belonging to the genus Carabus are particularly notable for their large size, distinct coloration, and well-documented ecological behaviors. These beetles are primarily polyphagous predators, preying on a variety of invertebrates [15-17]. While some Carabus species are commonly found in forested habitats, others are rare, especially in regions subjected to significant human-induced environmental pressures [7, 18-20].

One such species, *Carabus* (*Procrustes*) *coriaceus* Linnaeus, is a large ground beetle characterized by imaginal or larval diapause. Its life cycle follows a one-year pattern with autumn reproduction or an obligate two-year cycle with reproduction occurring in late summer or autumn [21]. Egg-laying typically takes place in September, with

most larvae overwintering at early developmental stages. The species requires two years to complete its development [22].

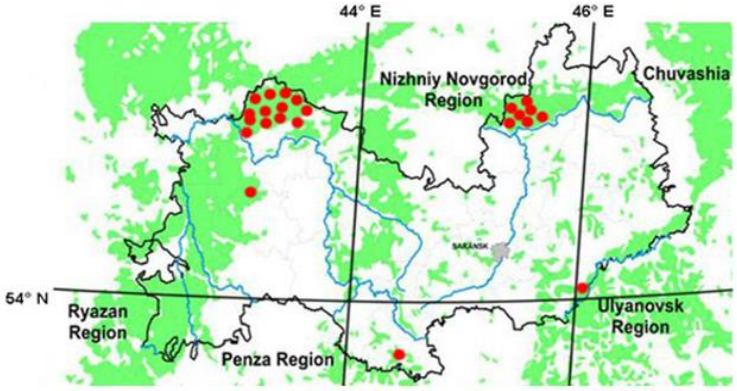
Widely distributed across Europe, *C. coriaceus* has been documented in various habitats [6, 22-26]. However, in certain regions, its populations are declining, leading to its inclusion in conservation lists as a protected species [27-30]. Habitat destruction, deforestation, pesticide exposure, and the species' limited dispersal ability are key factors contributing to its population decline. The geographic range of *C. coriaceus* has been extensively mapped in central Russia [31], with its easternmost boundary extending through the Chuvash Republic and Ulyanovsk region. The Republic of Mordovia is located near this eastern limit [32, 33].

The present study aims to analyze the seasonal activity patterns of *C. coriaceus* in the eastern portion of its range, providing insights into its population dynamics and ecological adaptations.

Materials and Methods

The Republic of Mordovia is centrally positioned within the East European Plain, extending between 42°11'–46°45' East longitude and 53°38'–55°11' North latitude. The region is characterized by the Sura and Moksha Rivers, which are tributaries of the Volga and Oka Rivers, respectively. Mordovia's landscape includes both forested and forest-steppe zones, with isolated steppe fragments scattered throughout.

Topographically, the Eastern parts of Mordovia lie on the northwestern edge of the Volga Upland, whereas the western portion is situated within the Oka-Don Lowland **(Figure 1)**. This variation contributes to a rich diversity of habitats. Boreal coniferous and mixed forests are predominant in the northern, northwestern, and western sections of the region [34], while deciduous forests dominate the eastern and central areas [12, 35]. In contrast, the southeastern and eastern regions are characterized by forest-steppe landscapes.



a)

b)

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

Ground beetles were collected using pitfall traps across various locations in the Republic of Mordovia between 2018 and 2019. Additionally, their distribution patterns were monitored from 2008 to 2020. The pitfall traps were made from 0.5-liter plastic cups filled with a 4 percent formalin solution.

To analyze seasonal population fluctuations, traps were deployed in the forests of the Mordovia State Nature Reserve at four sites (Temnikov district) and in the National Park Smolny at three sites Each site contained 10 traps, set in a straight line with 2–3 meters between them, operating from late April to September. Population density was assessed based on dynamic density (individuals per 100 trap days).

Results and Discussion

The Republic of Mordovia falls within the distribution range of *C. coriaceus*, situated near its easternmost boundary. This species primarily inhabits forest edges, forest roads, meadows, and clearings within pine and mixed forests [33, 36]. Although the region contains extensive forested areas, the presence of *C. coriaceus* is largely restricted to protected zones, where forest ecosystems remain undisturbed.

Notably, the population density of *C. coriaceus* in the Mordovia State Nature Reserve was nearly three times greater than in the forests of the National Park Smolny. This difference may be attributed to the duration of protection, as the Mordovia State Nature Reserve has remained undisturbed for over 80 years. In contrast, the National Park "Smolny" has only been under protection for 25 years, with prior intensive forestry operations likely impacting beetle populations. The current population dynamics suggest a recovery phase following past anthropogenic disturbances.

Several environmental factors, such as temperature, humidity, and microclimatic conditions, influence the activity of ground beetles [37, 38]. Among these, temperature is widely recognized as a key abiotic factor affecting Carabidae activity [39, 40]. Seasonal variations and life-history traits significantly shape their abundance and distribution within specific habitats [1, 21, 41].

The seasonal activity of *C. coriaceus* commenced between late April and early May, continuing until mid-September or early October **(Figure 2)**. Only a single peak in population density was observed, occurring from mid-July to August.

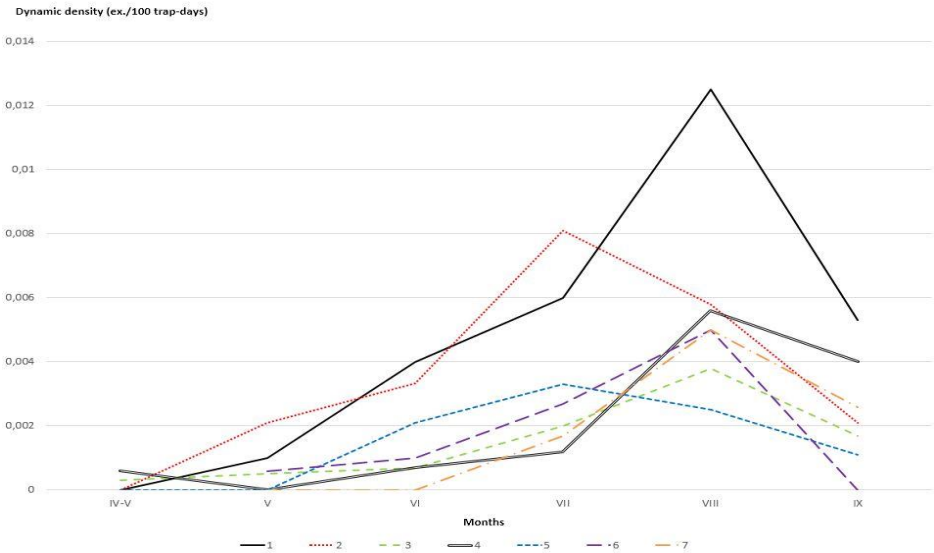


Figure 2. shows the seasonal activity of *C. coriaceus* across different locations in the Mordovia State Nature Reserve and National Park "Smolny." The x-axis represents the sampling sites, while the y-axis shows relative abundance (individuals per 100 trap days). The data reveal variations in activity levels across these areas.

It is important to highlight that in the warmer spring of 2018, the onset of *C. coriaceus* activity was earlier, starting in April, whereas in the colder spring of 2019, it began only in early May. However, in 2018, following a drop in temperatures during summer, the peak of the population shifted to early August **(Figure 2)**. Conversely, in 2019, the peak was observed in the second half of July **(Figure 2)**. Unlike our findings, studies from Hungary noted two peaks in *C. coriaceus* activity, one in late June to July and another in late August to early September [3, 42], while Slovakia observed similar weather-dependent activity peaks [43]. In Slovenia, activity began in late April and continued through early November, with peaks in late May, mid-July, and late August to October [44]. In Croatia,

the species showed heightened activity in late summer and autumn, along with a small peak in spring [45]. Given that activity is influenced by both the life cycle and weather conditions, fluctuations in capture rates over different years and seasons are likely to be variable.

Conclusion

The seasonal activity of *C. coriaceus* in the eastern part of its range showed annual variations. Activity began either in early May or late April and continued through mid-September to October, with the highest population observed from late July to August. The onset of activity was closely linked to temperature, as evidenced by the earlier start in the warm spring of 2018, while in the cooler spring of 2019, it was delayed until early May. Additionally, the population density of *C. coriaceus* was higher in the Mordovia State Nature Reserve compared to the National Park Smolny. The difference is likely because of the longer protection of the ecosystems in the Mordovia State Nature Reserve, where anthropogenic influences ceased over 80 years ago, allowing the ecosystem to fully recover.

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