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Bark Beetles (Coleoptera: Curculionidae: Scolytinae) in the Marjan Forest Park: Species Composition and Associations Between *Orthotomicus erosus* and Predatory Arthropods

Potkornjaci (Coleoptera: Curculionidae: Scolytinae) u Park-šumi Marjan: sastav vrsta i povezanost vrste *Orthotomicus erosus* s predatorskim člankonošcima

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Abstract

The Mediterranean pine engraver, *Orthotomicus erosus*, has recently caused widespread mortality of Aleppo pine (*Pinus halepensis*) in the Marjan Forest Park (Croatia), following two major outbreaks over the last decade. This study investigated the population dynamics of *O. erosus* and associated predatory beetles during two outbreak periods (2020–2022 and 2025–2026) using pheromone trap monitoring. Ten pheromone traps baited with Erosowit® dispensers were installed throughout the study area, and captured insects were identified and quantified. A total of 142,395 *O. erosus* individuals and 6,965 predatory beetles were recorded. Three predator species were consistently associated with *O. erosus*: *Temnoscheila caerulea*, *Thanasimus formicarius*, and *Aulonium ruficorne*. *Te. caerulea* was the most abundant predator throughout the study and exhibited seasonal dynamics closely corresponding to those of *O. erosus*. In contrast, *Ta. formicarius* occurred at relatively low abundance, while *A. ruficorne* became increasingly abundant during the second outbreak period and showed distinct spring and autumn activity peaks. Predators represented approximately 22.5% of total *O. erosus* catches during the first outbreak period but only 0.15% during the second, largely due to modified trap design and differences in outbreak phase. The results demonstrate substantial temporal variation in predator–prey relationships and highlight the importance of long-term monitoring for understanding the potential regulatory role of natural enemies in Mediterranean bark beetle outbreaks.

Keywords: *Aulonium ruficorne*; insect population dynamics; Mediterranean pine engraver; *Pityogenes calcaratus; Temnoscheila caerulea*; *Thanasimus formicarius*; *Tomicus destruens*

Sažetak

Mediteranski potkornjak *Orthotomicus erosus*, nedavno je uzrokovao opsežno sušenje stabala alepskog bora (*Pinus halepensis*) u Park šumi Marjan (Hrvatska), gdje su tijekom posljednjeg desetljeća zabilježene dvije gradacije. Upotrebom feromonskih klopki istraživala se dinamika populacije *O. erosus* i s njim povezanih predatorskih vrsta kornjaša tijekom dva razdoblja izbijanja zaraze odnosno gradacije mediteranskog potkornjaka (2020. – 2022. i 2025. – 2026.). Deset feromonskih klopki s mamcima od Erosowit® raspršivača postavljeno je diljem područja istraživanja. Svi uzorkovani kukci su identificirani i kvantificirani. Zabilježeno je ukupno 142 395 jedinki *O. erosus* i 6 965 predatorskih vrsta kornjaša. Tri vrste predatora bile su dosljedno povezane s *O. erosus*: *Temnoscheila caerulea*, *Thanasimus formicarius* i *Aulonium ruficorne*. Vrsta *Te. caerulea* bila je najbrojniji predator tijekom cijelog razdoblja istraživanja i pokazala je sezonsku dinamiku koja je blisko odgovarala vrsti *O. erosus*. Nasuprot tome, *Ta. formicarius* se javljao u relativno malom broju, dok je *A. ruficorne* postajao sve brojniji tijekom drugog razdoblja izbijanja zaraze i pokazivao je različite proljetne i jesenske pikove aktivnosti. Predatori su predstavljali otprilike 22,5% ukupnog ulova *O. erosus* tijekom prvog razdoblja gradacije, ali samo 0,15% tijekom drugog, uglavnom zbog modificiranog dizajna klopki i razlika u fazi gradacije. Rezultati pokazuju značajne vremenske varijacije u odnosima predatora i plijena te ističu važnost dugoročnog praćenja za

razumijevanje potencijalne regulatorne uloge prirodnih neprijatelja u epidemijama sredozemnih potkornjaka.

Ključne riječi: *Aulonium ruficorne*; dinamika populacije kukaca; mediteranski potkornjak; *Pityogenes calcaratus*; *Temnoscheila caerulea*; *Thanasimus formicarius*; *Tomicus destruens*

Introduction – *Uvod*

Bark beetles play an important ecological role under endemic population conditions, primarily colonizing dead or severely weakened trees, and thereby contributing to wood decomposition, nutrient cycling, and the maintenance of forest biodiversity and natural ecosystem dynamics (Raffa et al., 2008; 2015). However, only a few species possess the biotic potential to cause extensive forest damage, sometimes with catastrophic consequences. Consequently, bark beetles are recognized as some of the most serious forest pests (Wermelinger et al., 2004; Benz et al., 2009; Pernek et al., 2019; Hlasny et al., 2025). A combination of favorable conditions is required for populations to transition into outbreak phases and attain the status of primary pests, among which the accumulation of suitable breeding material is considered the most important factor. Bark beetle populations in nature undergo cyclical fluctuations characterized by periods of increase and decline. Population growth may slow due to resource depletion (e.g., intraspecific competition) or because of increasing abundance of natural enemies. According to their feeding habits, bark beetles are monophagous or oligophagous organisms, meaning that individual species pose a threat only to specific host plant species or groups of closely related hosts. For example, bark beetles attacking pines are specialized on species within the genus *Pinus*. The high rates of tree mortality caused by bark beetles directly affect forest structure, thereby negatively impacting the fundamental functions of forest ecosystems. In Aleppo pine (*Pinus halepensis* Mill.) forests, climatic conditions have deviated from long-term averages, shifting toward a warmer and drier (more arid) climate regime (Pernek et al., 2019; Camarero et al., 2020). Such changes significantly influence bark beetle population dynamics, where changes occur in insect bionomics, including survival, reproduction, number of generations per year (voltinism), and spatial distribution (Battisti and Larsson, 2015). These changes favor bark beetle development while simultaneously reducing the resistance of pine trees, potentially resulting in epidemic outbreaks. In recent history, the Marjan Forest Park has experienced two outbreak events involving the Mediterranean pine engraver, *Orthotomicus erosus* (Wollaston, 1857). It should be emphasized that, until then, this bark beetle had not been considered a significant pest, nor had substantial damage to Aleppo pine been recorded. The first outbreak occurred between 2018 and 2021 (Pernek et al., 2019), while the second began in 2025 and is still ongoing (Pernek et al., 2026, in press). Following a prolonged endemic period, the severe storm in July 2025 once again generated an abundance of suitable breeding material through extensive windthrow and stem breakage of Aleppo pine trees. This newly created substrate provides ideal conditions for bark beetle reproduction and may trigger a new outbreak of *O. erosus* populations (Pernek et al., 2026, in press). The effectiveness of natural enemies in regulating bark beetle populations depends not only on their abundance but also on their numerical response relative to prey density. During bark beetle outbreaks, predator populations often increase more slowly than prey populations, resulting in reduced regulatory pressure (Reeve, 1997). Therefore, predator-to-prey relationships provide a useful indicator of the potential contribution of natural enemies to population regulation. In addition, studies based on semiochemical trapping have demonstrated that predators and bark beetles differ in their behavioral responses to attractants, which may influence observed capture ratios and the interpretation of monitoring data (Aukema et al., 2000). Recent investigations in Croatia have further demonstrated that trap modifications can substantially reduce captures of predatory beetles associated with *O. erosus*, emphasizing the importance of evaluating predator–prey relationships when interpreting monitoring results (Pernek et al., 2024).

This study aimed to determine which bark beetle species are predominantly present in Marjan Forest Park, with particular emphasis on the highly destructive *O. erosus*, and to identify and present its natural enemies. It also aims to describe the population dynamics of predator species whose biology has not been well studied or is not well understood.

Bark Beetle Species Associated with Aleppo Pine and Their Importance – *Vrste potkornjaka povezane s alepskim borom i njihova važnost*

A total of 40 bark beetle species associated with conifers have been recorded in the Mediterranean region (Lieut-

ier et al., 2016). These species can be classified into three groups:
i) Endemic species, e.g. *Phloeosinus acatayi* Schedl, 1958, *Pityophthorus pinsapo* Pfeffer, 1982, *Orthotomicus tridentatus* (Eggers, 1921);
ii) Species widely distributed throughout the Mediterranean region (e.g., *Tomicus destruens* (Wollaston, 1865));
iii) Widely distributed species occurring not only in the Mediterranean but also in Central and Eastern Europe (e.g., *Hylurgus* spp., *Hylastes* spp., *O. erosus*).
According to a publication review, 11 bark beetle species have been recorded on Aleppo pine. In addition to the previously mentioned *O. erosus* and *T. destruens*, these include *Carphoborus pini* Eichhoff, 1881, *Crypturgus cribrellus* Reitter, 1895, *Crypturgus numidicus* Ferrari, 1867, *Hylastes attenuatus* Erichson, 1836, *Hylastes linearis* Erichson, 1836, *Hylurgus ligniperda* (Fabricius, 1787), *Hylurgus micklitzi* Wachtl, 1881, *Pityophthorus pubescens* (Marsham, 1802), and *Pityogenes calcaratus* (Eichhoff, 1878).
According to their level of aggressiveness, defined as their ability to colonize healthy trees rather than only physiologically weakened or recently dead hosts, *O. erosus* (Figure 1) is the most important and abundant species. This species has already caused extensive damage in the Aleppo pine forests of Marjan (Pernek et al., 2019; Pernek et al., 2026). Two species are considered facultatively aggressive, whereas the remaining species are classified as non-aggressive (Table 1).



Figure 1 Adult beetles of *Orthotomicus erosus*
Slika 1. Odrasli kornjaši vrste *Orthotomicus erosus.*

Table 1 Bark beetles on Aleppo pine and their aggressiveness and danger to the forest according to publication review (Lieutier et al. 2016)
Tablica 1. Potkornjaci na alepskom boru i njihova agresivnost i opasnost za šumu sukaldno pregledu literature (Lieutier i dr. 2026).

Aggressiveness Category *Kategorije agresivnosti*	**Bark Beetle Species** *Vrste potkornjaka*	**Capacity for Population Outbreaks** *Kapacitet za populacijske epidemije*	**Tolerance to Host Tree Resistance** *Tolerancija na otpornost stabla domaćina*	**Ability to Kill Healthy Trees** *Sposobnost uništavanja zdravih stabala*
Aggressive	*Orthotomicus erosus*	High	High	Yes
	Pityogenes calcaratus	High	Medium	Yes
	Tomicus destruens	High	Medium	Yes
Non-Aggressive	*Carphoborus pini*	Low	Low	No
	Crypturgus cribrellus	Low	Low	No
	Crypturgus numidicus	Low	Low	No
	Hylastes attenatus	Low	Low	No
	Hylastes linearis	Low	Low	No
	Hylurgus ligniperda	Low	Low	No
	Hylurgus miklitz,	Low	Low	No
	Pityophthorus pubescens	Low	Low	No

Natural Enemies of Mediterranean Bark Beetles - *Prirodni neprijatelji mediteranskih potkornjaka*

Natural enemies, or antagonists, of bark beetles include all organisms that directly or indirectly reduce bark beetle population density. They may feed directly on bark beetles, use them as hosts for the development of their offspring, or cause diseases and physiological weakness in the host, often resulting in death. These organisms play an important role in the population dynamics and ecology of bark beetles (Wegensteiner et al., 2015). Although there are instances in which natural enemies play a decisive role in the collapse of pest populations, it would be incorrect to generalize this assumption. First and foremost, it is important to recognize that the life cycles of insects and the organisms associated with them are highly complex, and our current understanding remains incomplete. In general, enemies of bark beetles can be classified as: predators, parasites/parasitoids, and pathogens. However, it should be noted that this classification is not entirely accurate. Although entomological studies frequently focus on predatory insects, birds should also be considered important predators. Species of bark- and phloem-feeding insects are particularly targeted by woodpeckers (family Picidae), including *Picoides tridactylus* (L., 1758), *Dryobates minor* (L., 1758), *Dendrocoptes medius* (L., 1758), *Dendrocopos major* (L., 1758), *Dryocopus martius* (L., 1758) and others (Schildberger, 1991).
Many arthropod species that feed on the eggs and larvae of bark beetles belong to several beetle families, including Carabidae, Cucujidae, Rhizophagidae, Histeridae, and Tenebrionidae (Nierhaus-Wunderwald, 1997; Schroeder, 2003). Other significant predator groups belong to the orders Acari, Heteroptera, Raphidioptera, and Diptera.
Three predator species of the Mediterranean bark beetle that belong to the group of regulatory organisms are *Temnoscheila caerulea* (Olivier, 1790) (Figure 2 a-b), *Thanasimus formicarius* (L., 1758) (Figure 2c-d), and *Aulonium ruficorne* (Olivier, 1790) (Figure 2e-f). Trap catches indicate their abundance and, consequently, their regulatory potential. While *Th. formicarius* plays a highly significant role in regulating spruce bark beetles, it is not very common on the Mediterranean bark beetle. The other two predatory insect species, *Te. caerulea* and *A. ruficorne,* are much more prevalent and are probably of greater importance in this context.

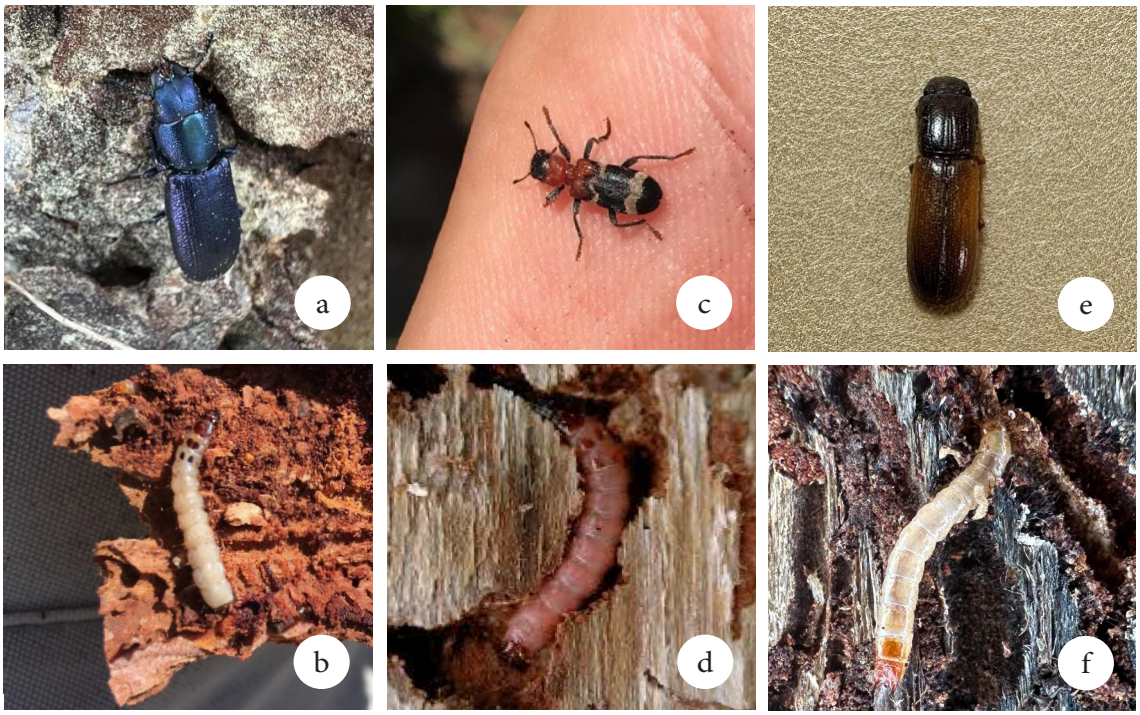


Figure 2 *Temoscheila caerulea* a) imago b) larvae; *Thanasimus formicarius* c) imago d) larvae; *Aulonium ruficorne* e) imago f) larvae (Photo M. Pernek)

Slika 2. *Temoscheila caerulea* a) imago b) ličinka; *Thanasimus formicarius* c) imago d) ličinka; *Aulonium ruficorne* e) imago f) ličinka (Slikao: M. Pernek).

Materials and methods – *Materijali i metode*

Study area – *Područje istraživanja*

This study was conducted on the Marjan Peninsula near the city of Split, within the boundaries of Marjan Forest Park (43° 30' 39.6432" N 16° 24' 39.6468" E). The park covers a total area of 300.29 ha, of which 196.24 ha is forested. The dominant forest type is an Aleppo pine plantation. The primary functions of this forest are water resource protection, erosion control, and hydrological regulation.

Installation of pheromone traps and counting of captured insects – *Postavljanje feromonskih klopki i brojanje uzorkovanih kukaca*

Since *O. erosus* is considered a harmful species on Marjan and forest protection measures were required, the installation of pheromone traps was one of the measures within the framework of integrated forest protection, primarily used for population monitoring. However, trap catches also contained a certain number of predatory arthropods attracted to the *O. erosus* pheromone lure. Although predatory species in the catches were counted, they were not analyzed, despite their potential to provide valuable information on predator population dynamics. Ten pheromone traps were deployed during two separate outbreak periods: i) First outbreak: traps were installed on 1 April 2020, and population monitoring was conducted until 13 October 2022, ii) Second outbreak: traps were installed on 8 May 2025, and population monitoring was conducted until 13 May 2026. As 2026 is still in progress, this study is limited to the period from autumn 2025 to spring 2026, during which the hypothesis of a rapid increase in the bark beetle population was confirmed. Accordingly, the results should be interpreted within that context. Traps were mounted on specially designed metal frames with collection containers positioned approximately 1 m above ground level and were baited with commercially available Erosowit® pheromone dispensers (Witasek, Austria) (Pernek et al., 2024). Trap locations were selected according to operational forest protection guidelines: a minimum distance of 20 m from healthy standing pines, and a minimum spacing of 50 m between neighboring traps. Trap contents were collected weekly, captured insects were preserved in 70% ethanol and transported to the Croatian Forest Research Institute for laboratory processing. Samples were dried, sorted, identified, and counted under stereomicroscopes in the laboratory of the Croatian Forest Research Institute.

Modified traps fitted with a mesh barrier to prevent the capture of predatory insects were used in 2025 and 2026 according to Pernek et al. (2024). Consequently, the results should be interpreted with caution and in the context of this methodological modification.

Results – *Rezultati*

In the ten pheromone traps, a total of 30,166 individuals were captured during the first outbreak period (2020-2022), comprising 14,878 individuals in 2020, 14,468 in 2021, and 875 in 2022 (Table 2, Figure 3). During the second outbreak period (2025-2026), trap catches were substantially higher, reaching a total of 112,229 individuals, with 19,945 captured in 2025 and 92,284 in 2026 (Table 2, Figure 4).

Table 2 Total numbers of *Orthotomicus erosus* and predatory arthropods (Combined total of *Temnoscheila caerulea*, *Thanasimus formicarius*, and *Aulonium ruficorne*) captured in ten pheromone traps during two outbreak periods (2020–2022 and 2025–2026) on Marjan. The proportion of predatory species (PPS) is expressed as a percentage of the total *O. erosus* catch for each outbreak period.
Tablica 2. Ukupan broj *Orthotomicus erosus* i grabežljivih člankonožaca (ukupno *Temnoscheila caerulea, Thanasimus formicarius* i *Aulonium ruficorne*) uhvaćenih u deset feromonskih klopki tijekom dva razdoblja gradacija (2020. – 2022. i 2025. – 2026.) na Marjanu. Udio grabežljivih vrsta (PPS) izražen je kao postotak ukupnog ulova *O. erosus* za svako razdoblje izbijanja.

Category *Kategorija*	2020	2021	2022	Total (2020–2022)	PPS (%)	2025	2026	Total (2025–2026)	PPS (%)
Orthotomicus erosus	14,878	14,468	875	30,166	–	19,945	92,284	112,229	–
Predatory species (total) *Predatorske vrste (ukupno)*	3,175	1,804	1,819	6,798	22.54	49	118	167	0.15

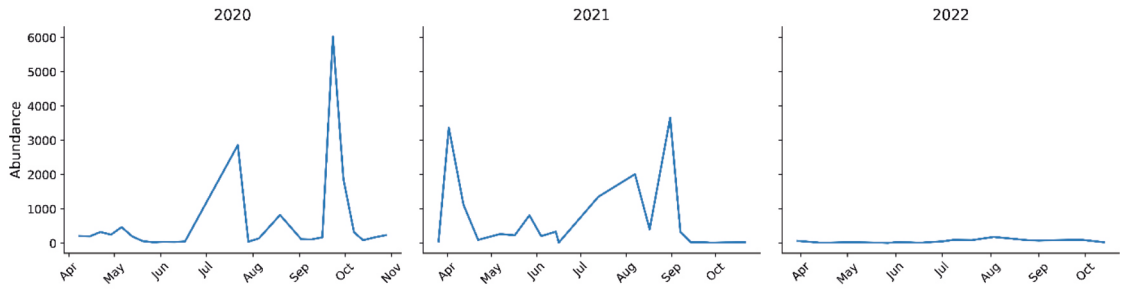


Figure 3 *Orthotomicus erosus* catches in pheromone traps 2020-2022
Slika 3. Ulovi vrste *Orthotomicus erosus* u feromonskim klopkama 2020.-2022.

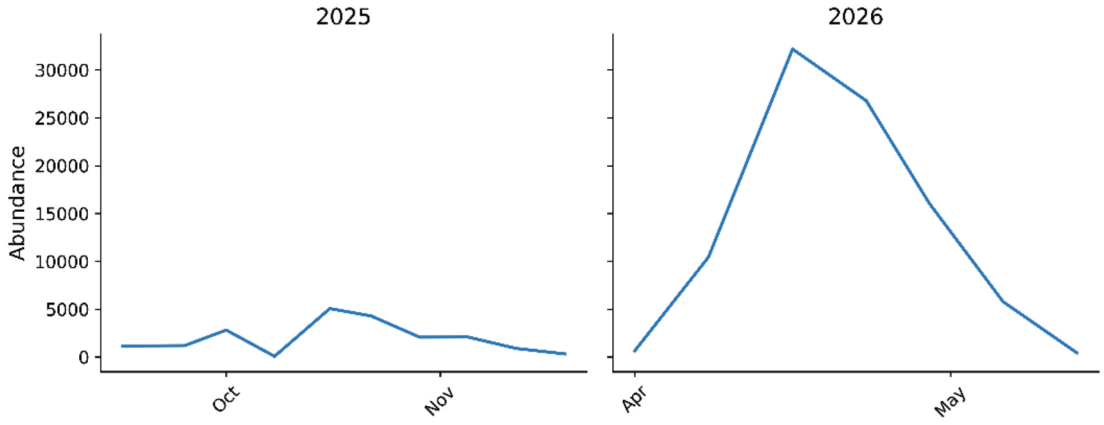


Figure 4 *Orthotomicus erosus* catches in pheromone traps 2025-2026
Slika 4. Ulovi vrste *Orthotomicus erosus* u feromonskim klopkama 2025.-2026.

Figures 5 and 6 show that *Te. caerulea* was the most abundant predator species in every year of the study. *Thanasimus formicarius* was more abundant during the first outbreak phase, when *A. ruficorne* did not appear to play a significant role (Figure 5). In the second outbreak phase, however, *A. ruficorne* became considerably more abundant and prominent within the predator community (Figure 6). Moreover, this species exhibited higher abundances in both spring and autumn (Figures 5 and 6).

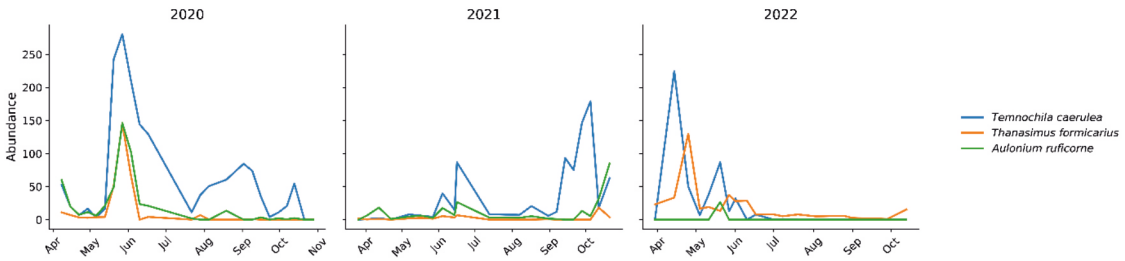


Figure 5 Relationship of predators to the target species *Orthotomicus erosus* between 2020 and 2022
Slika 5. Odnos predatora prema ciljanoj vrsti *Orthotomicus erosus* između 2020. i 2022.

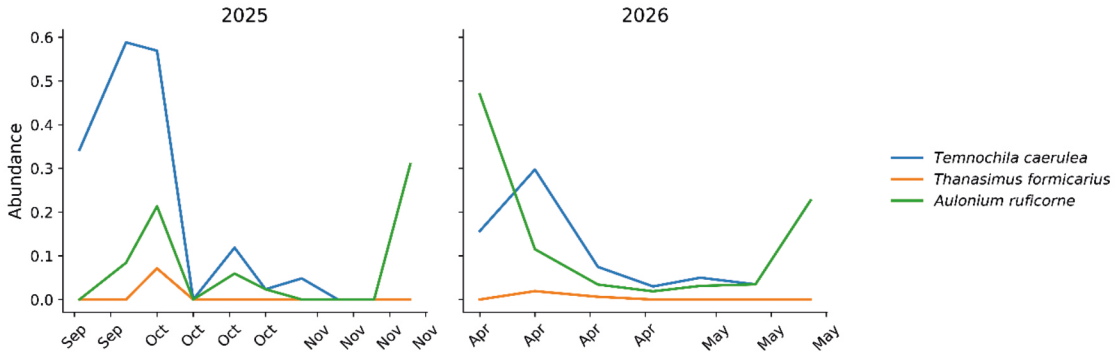


Figure 6 Relationship of predators to the target species *Orthotomicus erosus* between 2025 and 2026
Slika 6. Odnos predatora prema ciljanoj vrsti *Orthotomicus erosus* između 2025. i 2026. godine.

Discussion – *Rasprava*

Bark beetles are currently regarded as one of the most important causes of conifer decline worldwide (Bright, 1993; Hartmann et al., 2025; Hlásny et al., 2025). Although more than 7,500 bark beetle species have been described globally (Wood, 1982), only a small proportion can attack healthy, vigorous trees and pose a serious threat to forest stands. In forestry, particular concern is associated with species that can overcome the natural defense mechanisms of their hosts, often with the assistance of symbiotic microorganisms (Human et al., 2017). These microorganisms, including blue-stain fungi (order Ophiostomatales), accelerate host tissue deterioration and increase tree susceptibility to bark beetle attack (Kovač et al., 2022).

Very little research has been conducted on the impact of predatory arthropods on bark beetle populations (Aksu and Mol, 2011), making it difficult to assess the extent to which they influence population dynamics or contribute to outbreak collapse. One reason for this is that these natural enemies are generally polyphagous and often compete with one another (e.g., parasitoids and predators). Furthermore, the number of bark beetles that an individual predator of a given species can eliminate during its life cycle remains unknown. All three aforementioned species are important regulators of *O. erosus* populations (Pernek et al., 2024).

When considering the proportion of predators relative to the total catches of *O. erosus*, a substantial difference was observed between the first and second outbreak periods. During the first outbreak (2020–2022), predatory arthropods accounted for approximately 22% of the total *O. erosus* catch, whereas during the second outbreak (2025–2026) their proportion declined to below 1%. Several factors may explain this discrepancy. First, during the 2025–2026 monitoring period, a modified trap design was used, which significantly reduced the capture of predatory entomofauna, as reported by Pernek et al. (2024). Pernek et al. (2024) tested the hypothesis that the number of predatory beetles would be significantly reduced by the installation of the mesh modification. They found that the average number of *O. erosus* captured in standard traps was statistically significantly higher than the average number captured in the modified traps, indicating that the abundance of the target bark beetle also decreased. The present study compares the relationship between bark beetles and their predatory species, where trap catches changed for both groups of organisms. Therefore, interannual comparisons of predator-to-prey relationships can be made, but the results should be interpreted with caution. Secondly, the two monitoring periods represented different phases of the population cycle. The years 2025–2026 corresponded to the initial phase of the outbreak, whereas the period 2020–2022, particularly 2022, represented the retrogradation phase and the transition toward endemic population levels. Predator populations typically exhibit a delayed numerical response to increases in prey abundance (Podoler et al., 1990). Therefore, during the early stages of an outbreak, predator densities have not yet reached levels sufficient to exert substantial regulatory pressure. At the same time, their relative abundance tends to increase during later outbreak phases. Nevertheless, even after predator populations adapt to increased prey availability, the proportion of predators in *O. erosus* catches is unlikely to reach the levels observed during the first outbreak period. To enable more reliable comparisons between outbreak cycles, future monitoring should include unmodified pheromone traps. Continued monitoring of predator catches in the coming years will provide valuable insights into predator population dynamics and their potential role in regulating *O. erosus* outbreaks. The results indicate that predator populations did not increase at the same rate as *O. erosus* between autumn 2025 and spring 2026. Although predator abundance increased in absolute terms, the relative abundance of predators compared with *O. erosus* decreased for all three predatory species. This pattern suggests that the numerical response of predators lagged behind the rapid increase of *O. erosus* populations. Consequently, biological control pressure was relatively weaker during the spring 2026 flight period than during autumn 2025. Previous studies have shown that differences in behavioral responses to pheromones and kairomones can substantially influence predator-to-prey capture ratios, and that trap design or lure composition may selectively affect predator catches (Aukema et al., 2000). Therefore, trap catches represent an index of relative abundance rather than a direct measure of predator pressure in the field. No data are available for the 2018–2019 outbreak phase of progradation, as pheromone traps were not installed during that period.

T. caerulea was the most abundant predator species throughout all years of the study. Some previous studies have consistently reported *T. caerulea* among the dominant predator species associated with *O. erosus* infestations (Pernek et al., 2024). The results indicate that the population dynamics of *T. caerulea* closely follow those of *O. erosus*. The abundance of *T. caerulea* peaked in spring, coinciding with the highest captures of *O. erosus*. Captures

increased again in autumn, suggesting a renewed period of activity later in the season. However, whether this pattern reflects the occurrence of a second generation remains unclear and has not been confirmed by previous studies (Bracalini et al., 2021). Considering the potential multivoltinism of *O. erosus* (Mendel, 1988; Pernek et al., 2019), *Temnoscheila caerulea* may exhibit a population-level adaptation to its prey. The predator *A. ruficorne* has been described as a species capable of destroying up to 90% of the larval stage of *O. erosus* (Podoler et al., 1990). Some authors have identified this predator as the most prominent one associated with *O. erosus* infestations (Cebeci and Baydemir, 2018). While it was scarcely represented in pheromone trap catches in 2019 (Pernek et al., 2020), it increased substantially in 2020, with similarly high numbers recorded in 2021. An exceptionally large increase in population abundance was observed between 2025 and 2026. This pattern is likely related to the biology and seasonal phenology of the species. At the beginning of the year, adults (imagines) emerge and become highly active, increasing trap catches. Population levels subsequently decline during part of the growing season before increasing again in autumn, when new generations emerge and dispersing adults seek suitable host material. Consequently, the marked increase in catches recorded in 2026 most likely reflects both the seasonal dynamics of *O. erosus* and the ongoing expansion of the outbreak population. The predator species *Th. formicarius* appeared to be the least abundant species in the trap catches. This species is very common in spruce forests, where it contributes to the reduction of *Ips typographus* (L., 1758) populations (Weslien and Regnander, 1992) and is considered one of the most important natural enemies of this bark beetle. *Thanasimus formicarius* does not constitute a single large panmictic European population, but instead comprises several regionally differentiated evolutionary lineages (Papek et al., 2025). Consequently, populations of this important predator may exhibit distinct ecological and behavioral characteristics across different parts of Europe, meaning that results obtained in one region cannot always be directly extrapolated to another. The present study demonstrates that predator communities associated with *O. erosus* undergo substantial changes during different outbreak phases. These findings highlight the need for further research on the biology, ecology, and population dynamics of predatory species associated with bark beetles. A better understanding of their life-history traits and predator–prey interactions is essential for assessing their potential role in regulating populations of *O. erosus* and other bark beetles that can cause extensive damage to forest ecosystems.

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References – *Literatura*

Aksu, Y., Mol, T. 2011. *Temnochila caerulea* (Olivier) (Trogositidae, Coleoptera)'nin ve *Clerus mutillarius* (Fabricius) (Cleridae, Coleoptera)'nin biyolojisi, morfolojisi ve biyolojik mücadeledeki önemi. (Biology, morphology and importance in biological control of *Temnochila caerulea* and *Clerus mutillarius*). *Türkiye I. Orman Entomolojisi ve Patolojisi Sempozyumu*, 23–25 November, Antalya, Turkey, pp. 295–297.

Aukema, B.H., Dahlsten, D.L., Raffa, K.F. 2000. Exploiting behavioral disparities among predators and prey to selectively remove pests: maximizing the ratio of bark beetles to predators removed during semiochemically based trap-out. *Environmental Entomology*, 29: 651–660.

Battisti, A., Larsson, S. 2015. Climate change and insect distribution range, in Björkman. C., Niemelä, P. (eds) *Climate change and insect pests*. Wallingford: CABI, pp. 1-16.

Bentz, B. J., Régnière, J., Fettig, C. J., Hansen, E. M., Hayes, J. L., Hicke, J. A., Kelsey, R. G., Negrón, J. F., Seybold, S. J. 2009. Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects, in *Bark Beetle Outbreaks in Western North America: Causes and Consequences.* Proceedings of a Symposium, Snowbird, Utah, 15–18 November 2005. Salt Lake City, UT: University of Utah Press.

Bright, D. E. 1993. Systematics of bark beetles, in Schowalter, R.D., Filip, G.M. (eds) *Beetle-Pathogen Interactions in Conifer Forests*. New York: Academic Press, pp 23-33.

Bracalini, M., Croci, F., Ciardi, E., Mannucci, G., Papucci, E., Gestri, G., Tiberi, R., Panzavolta, T. 2021. *Ips sexdentatus* Mass-Trapping: Mitigation of Its Negative Effects on Bark Beetle Predators and Other Non-Target Saproxylic Beetles. *Forests*, 12: 175. https://doi.org/10.3390/f12020175

Camarero, J. J., Gazol, A., Sangüesa-Barreda, G., Oliva, J., Vicente-Serrano, S. M. 2020. Biogeographic, atmospheric and climatic factors influencing tree growth in Mediterranean Aleppo pine forests. *Forest Ecology and Management*, 458: 117723. https://doi.org/10.1016/j.foreco.2019.117723

Cebeci, H. H., Baydemir, M. 2018. Predators of bark beetles (Coleoptera) in the Balikesir region of Turkey. *Revista Colombiana de Entomología*, 44: 283–290. https://doi.org/10.25100/socolen.v44i2.7326

Hartmann, H., Battisti, A., Brockerhoff, E.G., Bełka, M., Hurling, R., Jactel, H., Oliva, J., Rousselet, J., Terhonen, E., Ylioja, T., Melin, M., Olson, Å., De Prins, F., Zhang, K., Åslund, M.S., Davydenko, K., Menkis, A., Elfstrand, M., Zúbrik, M., Kunca, A., Galko, J, Paulin, M., Csóka, G., Hoch, G., Pernek, M., Preid, S., Fischer, R. 2025. European forests are under increasing pressure from global change-driven invasions and accelerating epidemics by insects and diseases. Journal für Kulturpflanzen. 77: 6–24. https://doi.org/10.5073/JfK.2025.02.02

Hlásny, T., Modlinger, R., Gohli, J., Seidl, R., Krokene, P., Bernardinelli, I., Blaser, S., Brazaitis, G., Brazaitytė, G., Brockerhoff, E. G., Csóka, G., Dobor, L., de Groot, M., Duduman, M.-L., Faccoli, M., Georgieva, M., Georgiev, G., Grodzki, W., Hartmann, H., Hirka, A., Hoch, G., Jabłoński, T., Jactel, H., Jonsell, M., Kolšek, M., Melin, M., Milanović, S., Nețoiu, C., Nieberg, M., Økland, B., Pernek, M., Perunová, M., Schafstall, N., Schroeder, M., Steyrer, G., Vakula, J., Wohlgemuth, T., Ylioja, T., Liebhold, A. M. 2025. Divergent Trends in Insect Disturbance across Europe's Temperate and Boreal Forests. *Global Change Biology*, 31: e70580. https://doi.org/10.1111/gcb.70580

Human, Z.R., Slippers, B., Wilhelm de Beer, Z., Wingfield, M.J., Venter, S.N. 2017. Antifungal actinomycetes associated with the pine bark beetle, *Orthotomicus erosus*, in South Africa. *South African Journal of Science*, 113: 1-7. https://doi.org/10.17159/sajs.2017/20160215

Kovač, M., Rigling, D., Pernek, M. 2022. Ophiostomatales Associated with Mediterranean Pine Engraver, *Orthotomicus erosus* (Coleoptera, Curculionidae) in Dalmatia, Croatia. *Journal of Fungi*, 8: 788. https://doi.org/10.3390/jof8080788

Lieutier, F., Mendel, Z., Faccoli, M. 2016. Bark Beetles of Mediterranean Conifers, in Paine, T. D., Lieutier, F. (eds) *Insects and Diseases of Mediterranean Forest Systems.* Cham: Springer International Publishing, pp. 105-197. https://doi.org/10.1007/978-3-319-24744-1_6

Mendel, Z. 1988. *The biology and ecology of the pine bark beetle Orthotomicus erosus (Wollaston) in Israel.* PhD Thesis.Rehovot: Hebrew University of Jerusalem, Faculty of Agriculture.

Papek, E., Derlič, A., Melin, M., Roques, A., Cocos, D., Schroeder, M. L., Nardi, D., Faccoli, M., Kerdelhué, C., Lakatos, F., Markalas, S., Jurc, M., Bažok, R., Kunca, A., Zúbrik, M., Galko, J., Avtzis, D. N., Stauffer, C. 2025. Complex population genetic structure of the bark beetle predator *Thanasimus formicarius* (L.) (Coleoptera: Cleridae) across its European range. *Agricultural and Forest Entomology*, 27: 437–451. https://doi.org/10.1111/afe.12677

Pernek, M., Lacković, N., Lukić, I., Zorić, N., Matošević, D. 2019. Outbreak of *Orthotomicus erosus* (Coleoptera, Curculionidae) on Aleppo Pine in the Mediterranean Region in Croatia. *South-east European forestry*, 10: 19-27. https://doi.org/10.15177/seefor.19-05

Pernek, M., Kovač, M. Lacković, N. 2020. Testiranje biološke učinkovitosti feromona i klopki za ulov mediteranskog potkornjaka *Orthotomicus erosus* (Coleoptera, Curculionidae). *Šumarski list*, 7-8: 339-350. https://doi:10.31298/sl.144.7-8.1

Pernek, M., Milas, T., Kovač, M, Lacković, N., Koren, M., Hrašovec, B. 2024. Effective Reduction in Natural Enemy Catches in Pheromone Traps Intended for Monitoring *Orthotomicus erosus* (Coleoptera, Curculionidae). *Forests*, 15: 1298. https://doi.org/10.3390/f15081298

Podoler, H., Mendel, Z., Livne, H. 1990. Studies on the biology of a bark beetle predator, *Aulonium ruficorne* (Coleoptera: Colydiidae). *Environmental Entomology*, 19: 1010–1016. https://doi.org/10.1093/ee/19.4.1010

Raffa, K.F., Aukema, B.H., Bentz, B.J., Carroll, A.L., Hicke, J.A., Turner, M.G., Romme, W.H. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions. *BioScience*, 58: 501–517. https://doi.org/10.1641/B580607

Raffa, K.F., Grégoire, J.C., Lindgren, B.S. 2015. Natural history and ecology of bark beetles, in Vega, F.E., Hofstetter, R.W. (eds) *Bark Beetles: Biology and Ecology of Native and Invasive Species*. San Diego: Academic Press, pp. 1–40. https://doi.org/10.1016/B978-0-12-417156-5.00001-0

Reeve, J.D. 1997. Predation and bark beetle dynamics. *Oecologia*, 112: 48–54. https://doi.org/10.1007/s004420050286

Schildberger, A. 1991. *Forstschutz und Forstentomologie*. Scriptum der Universität für Bodenkultur. Vienna, 302 pp.

Wegensteiner, R., Wermelinger, B., Herrmann, M. 2015. Natural Enemies of Bark Beetles: Predators, Parasitoids, Pathogens, and Nematodes, in Vega, F.E., Hoftetter, R. (eds) Bark Beetles, Biology and Ecology of Native and Invasive Species. San Diego: Academic press, pp. 247-304.

Wermelinger, B. 2004. Ecology and management of the spruce bark beetle *Ips typographus* - a review of recent research. *Forest Ecology and Management*, 202: 67–82. https://doi.org/10.1016/j.foreco.2004.07.018

Weslien, J., Regnander, J. 1992. The influence of natural enemies on brood production in *Ips typographus* (Col.: Scolytidae) with special reference to egg-laying and predation by *Thanasimus formicarius* (Col.: Cleridae). *Entomophaga*, 37: 333–342. https://doi.org/10.1007/BF02372316

Wood, S.L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Naturalist Memoirs, 6. Brigham Young University, pp. 1-1356.