

## ENTOMOLOGY

## Analysis of non-target beetle species collected on pheromone-baited adhesive panels in two mixed oak forest stands infested with *Lymantria dispar* (Lepidoptera: Erebidae) in southern Romania

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### Abstract

Amid the ongoing decline of oak forests across Europe, implementing measures to detect, monitor, and prevent infestations by defoliating insect species has become increasingly urgent. Among these species, *Lymantria dispar* (Linnaeus, 1758) represents one of the most significant threats to oak forests. Adhesive panel traps baited with pheromone lures are commonly used for monitoring, but their non-selective nature leads to unintended captures of non-target insects, including Coleoptera. This study was conducted during the 2023 flight season (June-August) in two outbreak-affected oak stands in southern Romania (Baba Ana and Tatina). Twelve atraDISPAR-baited sticky panels were installed per sample plot, arranged in three replicates of four panels each in a square layout. A total of 1,844 beetles from 21 non-target beetle species belonging to 11 families were collected and classified by feeding preference. *Agrilus angustulus* (Illiger, 1803) (Buprestidae), one of the species associated with oak decline in Western Europe, was the most abundant among the species identified. Species richness was comparable (13 in Tatina, 12 in Baba Ana), but abundance varied greatly (139 specimens in Tatina vs. 1,705 in Baba Ana). The observed attraction of several secondary pest beetles suggests that adhesive panel traps may serve not only in *L. dispar* monitoring but also as a potential tool for assessing broader forest health.

### Introduction

Over the past century, the decline of oak forests across Europe has prompted the implementation of systematic measures for detecting, monitoring, and mitigating the biotic and abiotic factors driving this phenomenon. Among the primary contributors are pathogenic fungi and primary insect pests, while secondary pests play a complementary role in the degradation process (Sinclair, 1965). One of the most significant primary pests associated with oak decline is *Lymantria dispar* (Linnaeus, 1758) (Lepidoptera: Erebidae), widely recognized as the most prolific defoliator of oak forests (Elkinton & Liebhold, 1990; Tomescu *et al.*, 2010; Milanović *et al.*, 2014). Recurrent outbreaks of this species create optimal conditions for population surges of secondary pests, further intensifying forest decline (Frațian, 1973; Nețoiu, 1998). In Romania, where oak forest decline has been documented since the early to mid-20th century, *L. dispar* has been identified as a critical driver in both the initiation and amplification of this process (Marcu, 1966).

Forest-pest monitoring provides key information on the presence, population density, and spatial spread of pests (Allison & Redak, 2017). Although no officially standardized national protocol

exists for detecting *L. dispar* in Romania (Mihalache, 2000), methodologies for related species offer valuable reference points. For instance, studies on the congeneric species *Lymantria monacha* (Linnaeus, 1758) suggest that one of the most used detection methods involves the use of adhesive panel traps measuring 30×40 cm, baited with species-specific pheromonal lures (Mihalciuc, 2000; Mihalciuc *et al.*, 2000). These traps serve as passive monitoring tools, providing data on adult emergence periods, peak flight activity, and relative population densities across different forest stands.

Although extensive research has been conducted on the biology, ecology, monitoring, and management of *L. dispar*, little attention has been given to the incidental capture of non-target species, particularly Coleoptera, on adhesive panel traps. To the best of our knowledge, we found no prior studies that directly analyzed the diversity, abundance, or ecological roles of beetles and other arthropods unintentionally trapped alongside *L. dispar*. In entomological monitoring, such species are collectively referred to as “bycatches” or non-target species, a phenomenon often regarded as an unintended consequence of low trap selectivity (Hellrigl & Schwenke, 1985). Bycatches occur mainly due to two factors: the general attractiveness of the trap itself, particularly its color, shape, or surface area, and adhesivity, which can capture insects independent of olfactory cues, and the semiochemicals used as attractants, which may accidentally lure species other than the target pest species (Allison & Redak, 2017). This incidental capture of non-target species has been a recurring issue in pest monitoring programs, as noted by Tamutis & Zolubas (2001). While often considered an undesirable side effect, bycatch can also provide valuable insights into local insect communities, particularly regarding species associated with forest

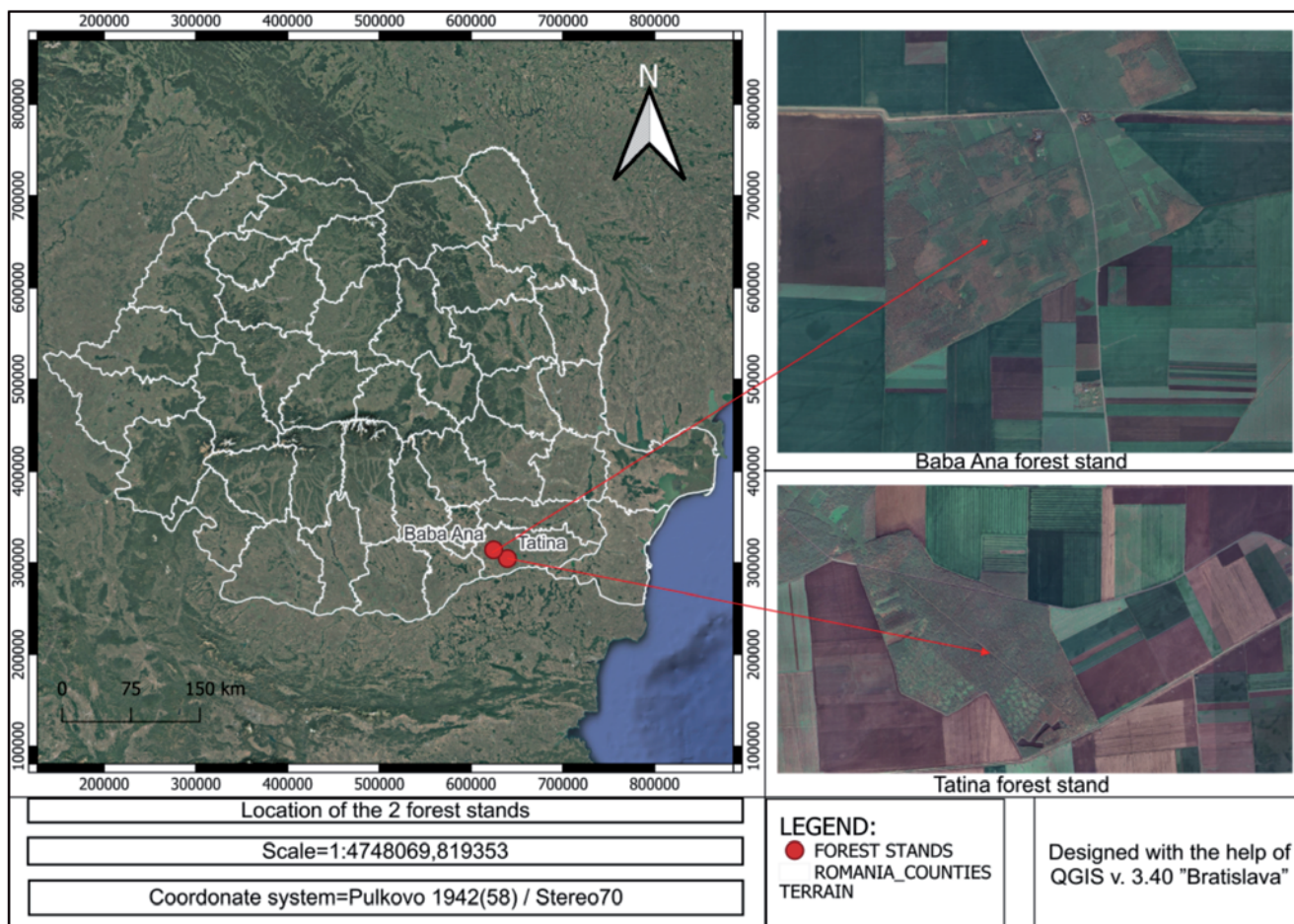
ecosystems. Non-target beetles, for example, may include saproxylic species, mycetophagous taxa, and predatory insects that play critical ecological roles in forest health and nutrient cycling (Hellrigl & Schwenke, 1986; Sellenschlo, 1986; Avtzis, 1991; Tamutis & Zolubas, 2001; Ostrauskas & Ferenca, 2010). Consequently, while reducing bycatch remains an important objective in improving trapping efficiency, its occurrence presents an opportunity to assess broader biodiversity patterns within monitored habitats.

Thus, in this study, we assess the diversity of non-target Coleoptera captured on adhesive panel traps baited with pheromone lures used for monitoring the defoliator *L. dispar* in Romania. We hypothesized that stands affected by oak dieback would exhibit a higher abundance of non-target beetles, particularly xylophagous species associated with declining host trees, as physiologically weakened or stressed oaks provide increased availability of breeding substrates, diminished defensive responses, and favorable microhabitat conditions that facilitate colonization by secondary pest agents.

## Materials and Methods

### Study areas

Fieldwork was conducted in 2023, in Baba Ana 44.19.03.3 N, 26.33.40.9 E and Tatina 44.13.41.3 N, 26.44.49.1 E, two adjacent mixed oak forest stands dominated by *Quercus pedunculiflora* (K.Koch, 1967) Menitsky and *Quercus cerris* Linnaeus, 1753, or alternatively by *Acer tataricum* Linnaeus, 1753, in Călărași County, southern Romania (Figure 1).



**Figure 1.** Baba Ana and Tatina forest stand locations.

**Table 1.** Forest stands characteristics (taken from the forest management plans) (Popescu *et al.*, 2004; Achim *et al.*, 2024).

Forest stand	Management units	Area (ha)	Altitude (m)	Age (Years)	Canopy cover (%)	Composition (%)	Status of dieback
Baba Ana	25A	13.24	60	65	80	80 <i>Q. pedunculiflora</i> 20 <i>Q. cerris</i>	Slight dieback
Tatina	53	15.1	40	80	80	90 <i>Q. pedunculiflora</i> 10 <i>A. tataricum</i>	Healthy

The Baba Ana and Tatina forest stands are located in the Romanian Plain, in the southwestern part of Călărași County, at an elevation ranging between 40 and 60 m, with a general southern exposure and situated on cambic chernozem soil. The vegetation consists of xerophilous oak forests mixed with various broadleaf species. The climate is typical of the forest-steppe zone, with an average annual rainfall of approximately 521.3 mm (Tatina) to 479 mm (Baba Ana), and an average annual temperature between 10.6°C (Baba Ana) and 11°C (Tatina) (Popescu *et al.*, 2004; Achim *et al.*, 2024).

The forest stands selected for this study include management units 25A and 53, covering a total area of 28.34 ha. The Baba Ana stand (Figure 1 and Table 1) is predominantly composed of *Q. pedunculiflora* (80%) mixed with *Q. cerris* (20%). This is an even-aged forest stand with trees approximately 65 years old and an average canopy cover of 80% (Achim *et al.*, 2024). Similarly, the Tatina stand (Figure 1 and Table 1) shares a comparable composition and structure, with *Q. pedunculiflora* (90%) as the dominant species, mixed with *A. tataricum*. This stand is also even-aged, with trees around 80 years old and an average canopy cover of 80% (Popescu *et al.*, 2004). The health status of oak trees also varies between the two stands: trees in the Tatina forest stand show no signs of decline (Popescu *et al.*, 2004), whereas those in the Baba Ana forest stand exhibit mild symptoms of oak dieback (Achim *et al.*, 2024).

In the two forest stands, the defoliator *L. dispar* caused infestations of varying intensity during the year the experiment was conducted. More specifically, in the Baba Ana forest stand, the pest was found to be in the late latency-early progradation phase, with a relatively low population density, resulting in minimal defoliation effects. In contrast, in the Tatina forest stand, the population had reached its peak in the culmination phase, leading to severe defoliation, particularly in pure oak areas (Bălăcenoiu *et al.*, 2024).

### Collection and identification of non-target beetle species

Twelve adhesive panels were installed in each of the two stands, arranged in three replicates. Each replicate consisted of four panels placed in a square device with a side length of 100 m, and the distance between replicates was 200 m.

The panels were made of white polypropylene, measuring 120×40 cm, and were positioned at 1.5 m above the ground. All panels were coated with adhesive on one side and baited with a commercial atraDISPAR pheromone lure containing disparlure (cis-7,8-Epoxy-2-methyloctadecane), developed by the “Raluca Ripan” Institute for Chemical Research in Cluj-Napoca, Romania.

The panels were installed on 26 June 2023, coinciding with the onset of the adult flight period of *L. dispar* (Mihalache, 2000; Ponomarev *et al.*, 2023). Sampling continued until 23 August 2023, when no further captures of male *L. dispar* were recorded, marking the end of the monitoring period. Non-target Coleoptera specimens were collected at 7-day intervals, individually stored in separate containers, and preserved at -5°C. The processing protocol involved thawing the specimens, followed by a clarification step to remove adhesive residue and enhance the visibility of morphological characteristics, achieved by immersing the specimens in a gasoline bath.

For the identification of individuals, a Kern binocular microscope type OZL-46 with a maximum magnification of 45x was used along-

side identification keys developed by Freude *et al.* (1967, 1969, 1979, 1981), Panin *et al.* (2015), and Witzgall (1999). To address nomenclatural issues related to synonymy, the Catalogue of Palearctic Coleoptera (Mazur, 2004; Löbl & Smetana, 2006, 2007, 2008, 2011, 2013) was consulted. Ecological traits for all the captured species were sourced from Böhme (2005) and Koch (1989a, 1989b, 1992).

### Data analysis

To evaluate the diversity between the two populations of non-target beetle species, four diversity indices were calculated: Shannon 1-D, Simpson, Evenness, and Berger-Parker, following the methodology outlined by Magurran (2004). In addition, individual-based rarefaction curves were generated to assess the adequacy of sampling effort and to compare the expected species richness between the two study sites (Chao *et al.*, 2014). Data preprocessing was performed in Excel (version 2021; Microsoft Corp., Redmond, WA, USA). Diversity indices were calculated using PAST version 4.03 (Hammer & Harper, 2001), while statistical analyses and graphical illustrations were conducted in R (R Core Team, 2020). The statistical analyses began with testing the assumption of normality using the Shapiro-Wilk test and assessing homogeneity of variances with Levene's test. The assumption testing revealed that the data do not meet the criteria for parametric analysis. The Shapiro-Wilk test indicated significant deviations from normality for both Baba Ana ( $W=0.204$ ,  $p<0.001$ ) and Tatina ( $W=0.286$ ,  $p<0.001$ ). Additionally, Levene's test showed unequal variances between the two sites ( $F=4.92$ ,  $p=0.027$ ). These results confirm that non-parametric methods are more appropriate for comparing the two forests.

To provide an exploratory comparison of capture distributions between the two stands, a Mann-Whitney U test was applied to panel-level capture counts, with effect size quantified using rank-biserial correlation.

To assess differences in the number of *A. angustulus* individuals across collection dates, as the most abundant species recorded, the Shapiro-Wilk test was applied to verify normality and Levene's test to examine variance homogeneity. The Shapiro-Wilk test of model residuals revealed a significant deviation from normality ( $W=0.29$ ,  $p<0.001$ ), whereas Levene's test confirmed homogeneity of variances among groups ( $F=0.51$ ,  $p=0.80$ ). A non-parametric Kruskal-Wallis test was employed to evaluate overall differences among collection dates, followed by Dunn's post hoc test with Holm correction for pairwise comparisons, with significant differences annotated on the plots.

## Results

Throughout the entire collection period, a total of 1,844 non-target Coleoptera individuals belonging to 21 species were recorded. The species richness between the two sampling sites did not differ significantly, with 12 species identified in the Baba Ana sampling site and 13 species in the Tatina site.

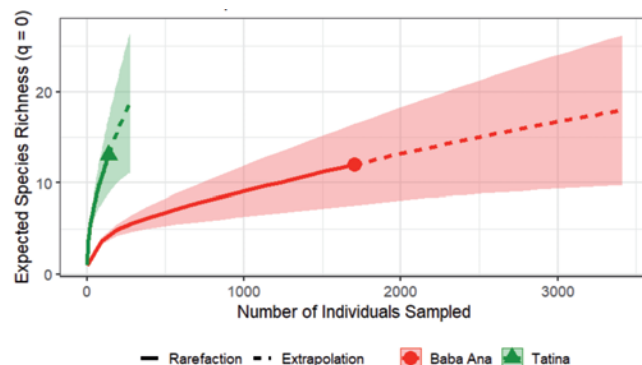
Overall, the most abundant species was *Agrilus angustulus* (Illiger, 1803) (Buprestidae), summing up to 1682 individuals, which accounted for 91% of the total non-target Coleoptera population. This species exhibited particularly high abundance in the Baba

Ana site, where 1628 individuals were captured. The next most abundant species were *Xyleborinus saxesenii* (Ratzeburg, 1837) (Curculionidae) and *Oligomerus brunneus* (Olivier, 1790) (Ptinidae), with 82 and 39 individuals, respectively. In the Baba Ana sampling site, *A. angustulus* was the dominant species, with all other species collectively representing about 5% of the total non-target beetles captured on the adhesive panels. In contrast, in the Tatina sampling site, *X. saxesenii* and *A. angustulus* together accounted for 78% of the total identified individuals. Excluding the populations of the two most abundant species across the two forest stands (*A. angustulus* and *X. saxesenii*), the remaining beetle species collectively accounted for less than 5% of the total captures, distributed among 19 non-target Coleoptera species.

Non-target beetles accounted for 15% of the total insects captured on the panels across both forests, with the remaining 85% consisting of *L. dispar* individuals (unpublished data). However, large differences were observed between the two forests: in Baba Ana, non-target beetles represented 30% of the total captures, while in the Tatina forest they comprised only 2% (unpublished data).

The 21 captured species belong to 11 families, with Buprestidae and Curculionidae being the most representative. Regarding feeding guilds, 43% of the total species identified on the panels are xylophagous insects, followed by entomophagous, mycetophagous, phytophagous, saprophagous, and xylo-mycetophagous species. Although the forest stands where the sampling sites were established consist of nearly pure oak stands (Tatina) or mixed stands (Baba Ana), only 25% of the xylophagous and mycetophagous non-target species are primarily associated with oak species. The remaining species are linked to other tree species or exhibit a generalist behavior concerning host trees (Table 2).

Significant differences were observed between the two sampling sites across all four diversity indices (Simpson 1-D, Shannon, Evenness, and Berger-Parker). Both the Shannon (Tatina=1.479 vs. Baba Ana=0.2551) and Simpson (Tatina=0.6825 vs. Baba Ana=0.0877) indices indicate greater diversity at Tatina compared to Baba Ana. The Berger-Parker index highlights the strong dominance of a single species at Baba Ana (0.9584), in contrast to the more balanced community structure at Tatina (0.3957), a pattern also reflected in the Evenness values. The individual-based rarefaction and extrapolation curves (q=0) revealed contrasting patterns between the two forest stands (Figure 2). Although



**Figure 2.** Individual-based rarefaction (solid lines) and extrapolation (dashed lines) curves (q=0, species richness) for Baba Ana (red) and Tatina (green). Shaded areas indicate 95% confidence intervals (iNEXT, 200 bootstrap replicates).

**Table 2.** The non-target Coleoptera species identified in the two forest stands, along with their feeding guild preferences and tree host species.

Species	Family	Feeding guild	Host species	Number of individuals		Total individuals
				Baba Ana	Tatina	
1. <i>Agrilus biguttatus</i> (Fabricius, 1776)	Buprestidae	Xylophagous	<i>Quercus</i> spp.	1	-	1
2. <i>Agrilus angustulus</i> (Illiger, 1803)		Xylophagous	<i>Quercus</i> spp.	1628	54	1682
3. <i>Anthaxia signaticollis</i> (Krynicky, 1832)		Xylophagous	<i>Crataegus/ Prunus</i> spp.	1	-	1
4. <i>Lamprodila mirifica</i> (Mulsant, 1855)		Xylophagous	<i>Ulmus</i> spp.	-	1	1
1. <i>Lichenophanes varius</i> (Illiger, 1801)	Bostrichidae	Xylophagous	Polyphagous	-	1	1
1. <i>Ennearthron pruinosum</i> (Perris, 1864)	Ciidae	Mycetophagous	-	-	1	1
2. <i>Ropalodontus</i> sp.		Mycetophagous	-	-	1	1
1. <i>Denops albofasciatus</i> (Charpentier, 1825)	Cleridae	Entomophagous	-	1	-	1
1. <i>Gasterocercus depressirostris</i> (Fabricius, 1792)	Curculionidae	Xylophagous	<i>Quercus</i> spp.	4	3	7
2. <i>Orchestes quercus</i> (Linnaeus, 1758)		Phytophagous	<i>Quercus</i> spp.	1	-	1
3. <i>Platypus cylindrus</i> (Fabricius, 1792)		Xylophagous	Polyphagous	12	-	12
4. <i>Scolytus multistriatus</i> (Marsham, 1802)		Xylophagous	<i>Ulmus</i> spp.	-	3	3
5. <i>Xyleborinus saxesenii</i> (Ratzeburg, 1837)		Mycetophagous	Polyphagous	27	55	82
1. <i>Melanotus rufipes</i> (Herbst, 1784)	Elateridae	Entomophagous	-	-	1	1
2. <i>Stenagostus rhombeus</i> (Olivier, 1790)		Entomophagous	-	1	-	1
1. <i>Thambus frivaldszkyi</i> Bonvouloir, 1871	Eucnemidae	Xylo-mycetophagous	-	-	5	5
1. <i>Platysoma compressum</i> (Herbst, 1783)	Histeridae	Entomophagous	-	-	1	1
1. <i>Tomoxia bucephala</i> Costa, 1854	Mordellidae	Phytophagous	-	-	1	1
1. <i>Oligomerus brunneus</i> (Olivier, 1890)	Ptinidae	Xylophagous	Polyphagous	27	12	39
2. <i>Ptinus sexpunctatus</i> Panzer, 1789		Saprophagous	Synanthrope	1	-	1
1. <i>Colydium elongatum</i> (Fabricius, 1787)	Zopheridae	Entomophagous	-	1	-	1
<b>Total</b>				<b>1705</b>	<b>139</b>	<b>1844</b>

Baba Ana yielded a substantially higher number of individuals (1705) compared to Tatina (139), the observed species richness was nearly identical (12 vs. 13 species, respectively). When standardized to the same sampling effort (139 individuals), Tatina exhibited higher species richness than Baba Ana, as indicated by the rarefaction curves and their overlapping 95% confidence intervals, although this result is greatly influenced by the number of singletons and the difference in the number of individuals captured between the two stands. Extrapolation further showed a slow increase in richness for Baba Ana, approaching an asymptote of 18 species at 3,000 individuals. In contrast, Tatina displayed a steeper slope and the potential to exceed 20 species with additional sampling. The confidence intervals for Tatina were wider, reflecting the lower sample size and thus reduced precision, but the overall trend consistently suggested higher richness potential.

Although there were no notable differences in the number of non-target beetle species identified between the two sampling sites, important differences were observed in the number of individuals captured. This discrepancy is also reflected in the mean number of individuals captured per panel (Figure 3a). In the Baba Ana stand, the average number of beetles captured per panel was 11.59, compared to an average of 0.94 individuals per panel in Tatina. A Mann–Whitney U test conducted on pooled panel  $\times$  date observations revealed a significant difference in capture distributions between the two sites ( $U=6,254$ ,  $p < 0.001$ ), indicating substantially higher capture intensity in the Baba Ana stand.

The seasonal dynamics of *A. angustulus* captures, expressed as the mean number of adults per panel, varied significantly across collection dates (Figure 3b). Activity began in late June, increased dur-

ing early to mid July, and reached a distinct peak in late July (26 July), followed by a sharp decline in August (23 August). The unimodal peak is consistent with a univoltine life cycle, typical of many *Agrilus* species. Considerable variability among dates was recorded, particularly at the seasonal peak, as indicated by wide confidence intervals, suggesting spatial heterogeneity in beetle emergence driven by local habitat conditions. Statistical analyses confirmed these patterns: the Kruskal–Wallis test revealed significant differences among sampling dates ( $p=0.0014$ ), while Dunn's post hoc test identified the strongest contrast between early July (D2) and late August (D7) (adjusted  $p \approx 0.0056$ ). These results demonstrate that beetle activity in July was significantly higher compared to the very low captures observed by the end of the season.

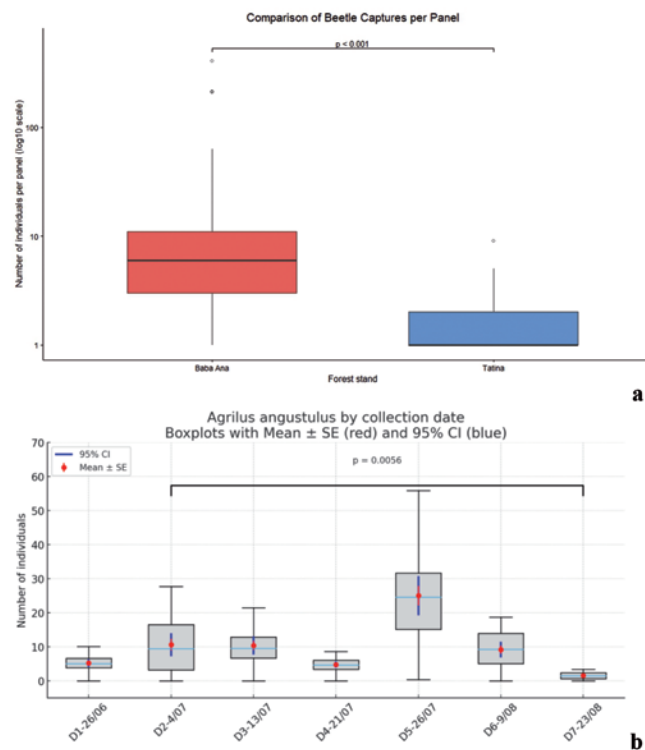
## Discussion

The research results provide important insights into the development of beetle populations in oak forests within the forest-steppe zone of Romania. The low number of non-target Coleoptera species captured throughout the entire flight period of *L. dispar* males suggests that monitoring this defoliator using sticky panels baited with the sexual pheromone *atraDISPAR* can be considered a less invasive method, with relatively minimal impact on the capture of rare or protected non-target beetle species.

Studies employing a similar experimental design to address this issue remain relatively scarce and are entirely absent in Romania. However, results from non-target beetle captures can be contextualized by comparing them with findings from other forest pest monitoring experiments. Notably, research conducted by Hellrigl & Schwenke (1986), Sellenschlo (1986), Avtzis (1991), Tamutis & Zolubas (2001), and Ostrauskas & Ferenca (2010) has documented between 24 (Avtzis, 1991) and 187 (Tamutis & Zolubas, 2001) non-target beetle species in monitoring programs for *Ips typographus* (Linnaeus, 1758). These studies highlight that a substantial proportion of captured beetles belonged to saproxylophagous, xylophagous, mycetophagous, entomophagous, and necrophagous guilds, alongside species incidentally trapped due to trap color or placement. Our results align with these previous findings, as a significant proportion of the captured non-target Coleoptera species are associated with woody resources. In contrast, a smaller fraction consists of predatory species or those that feed on fungi.

Numerous studies have indicated that, although the capture of non-target beetles represents an inherent aspect of forest pest monitoring, their abundance and diversity can vary according to experimental conditions and environmental factors, including trap design, attractant composition, habitat structure, and regional insect diversity (Tamutis & Zolubas, 2001; Allison & Redak, 2017).

Although the role of the lure in capturing Coleoptera species could not be directly verified, as no control unbaited variant of sticky panels was included, previous studies have shown that the pheromone *disparlure* is highly selective. Across more than five decades of research, all evidence consistently demonstrates that the sex pheromone (+)-*disparlure* (*cis*-7,8-Epoxy-2-methyloctadecane) is highly specific to the gypsy moth (*L. dispar*) and exhibits almost no cross-attraction to other species. The compound was first isolated and identified by Bierl *et al.* (1970, 1972), who showed that even minimal structural or positional modifications eliminated male response, proving extreme chemical and behavioral specificity. Later studies by Klimetzek *et al.* (1976) and Cardé *et al.* (1977) demonstrated that only the (+)-enantiomer elicits attraction, while the opposite (–)-form actively inhibits response. Field experiments confirmed that sympatric species such as the nun moth (*L. monacha*) either did not respond or reacted differently, depending on enan-



**Figure 3.** Mean number of non-target individuals per trap in the two forest stands. Data are presented on a log<sub>10</sub> scale; a Mann–Whitney U test conducted on pooled panel  $\times$  date observations indicated a significant difference between sites ( $p < 0.001$ ) (a), and the mean number of *Agrilus angustulus* individuals based on the collection date, mean  $\pm$  standard error (SE) (red), 95% confidence interval (CI) (blue), and significant difference ( $p=0.0056$ ) (b).

tiomeric composition, showing that chirality prevents interspecific confusion. Laboratory and flight-tunnel experiments (Miller & Roelofs, 1978) reinforced that (-)-disparlure suppresses *L. dispar* male orientation rather than attracting other insects. Geographic tests in Asia (Wallner *et al.*, 1984) verified that the same (+)-disparlure is effective across Eurasian and North American populations and that even congeneric *Lymantria* species, such as *Lymantria mathura* Moore, 1866, were not attracted. Later, Gries *et al.* (2005) identified a trace unsaturated analog in Asian populations but confirmed that it was only weakly active and did not broaden the species range, while Park *et al.* (2018) found a minor synergistic effect in Korean populations without altering the pheromone's species exclusivity. Collectively, these studies prove that the (+)-disparlure pheromone is one of the most species-specific insect attractants known, reliably attracting only *L. dispar* males and virtually no other Lepidoptera.

It is more likely that the non-target beetle species captured on the panels were attracted primarily by visual stimuli. For certain insect species, visual stimuli serve as important cues for locating host plants, mates, or prey (Obata, 1986; Fernandez & Hilker, 2007; Domingue *et al.*, 2011; Piersanti *et al.*, 2020; Freas & Spetch, 2023; Saitta *et al.*, 2024; Santoiemma *et al.*, 2024). Traps that use various visual cues, such as color, light, or shape, are commonly used to monitor and identify pest insect species (Epsky *et al.*, 2008; Allison & Redak, 2017). Numerous studies using sticky traps of different colors have reported significant captures of species belonging to the family Buprestidae (Domingue *et al.*, 2011, 2013; Haack *et al.*, 2013; Petrice & Haack, 2015; Matula *et al.*, 2023; Kuhn *et al.*, 2024). The sensitivity of certain Buprestidae species to visual stimuli (Crook *et al.*, 2009; Lelito *et al.*, 2007; Domingue *et al.*, 2011) may explain both the high number of species from this family recorded on the panels and the significant number of *A. angustulus* individuals captured. The most effective colors for capturing *Agrilus* species are green and purple (Crook *et al.*, 2009; Petrice & Haack, 2015; Kim *et al.*, 2016; Cavaletto *et al.*, 2020). Rodriguez-Saona *et al.* (2007) suggest that the sensitivity of *Agrilus* species, particularly to green traps, is due to their resemblance to foliage, where these insects locate mates and food. Some studies have reported *Agrilus* captures on white traps as well (Petrice & Haack, 2015; Cavaletto *et al.*, 2020), though with lower efficiency compared to other colors.

Other xylophagous insects, such as ambrosia beetles, also rely on visual cues (Gorzlancyk *et al.*, 2013; Cavaletto *et al.*, 2020). The two ambrosia beetle species captured in this experiment, *Platypus cylindrus* (Fabricius, 1792) and *X. saxesenii*, may have been attracted by the color of the panels used. This is supported by the findings of Abbasi *et al.* (2008), who recorded a significant number of ambrosia beetles on white sticky traps in an experiment conducted in Pakistan. Although both species are considered polyphagous, several studies suggest a marked preference for oaks (Tilbury, 2010; Inácio *et al.*, 2011; Cavaletto *et al.*, 2021).

Predatory insects also use visual cues to locate their prey (Strom *et al.*, 1999; Goyer *et al.*, 2004; Cavaletto *et al.*, 2020). However, the low number of entomophagous specimens captured indicates that their occurrence on the sticky panels was likely incidental rather than the result of active attraction.

Overall, these observations highlight that visual stimuli, rather than pheromonal attraction, likely governed most non-target captures on adhesive panels. The influence of trap design and color is therefore essential when interpreting capture data, as such factors can shape the apparent abundance of certain taxa and partially explain the presence of species with known affinities for visually conspicuous surfaces.

In addition, the spectrum of non-target species captured also has important ecological significance, as many of these beetles function

as secondary pests in declining oak stands. Beyond their incidental capture, several of the species, most notably *A. angustulus*, *Agrilus biguttatus* (Fabricius, 1776), *P. cylindrus*, *X. saxesenii*, and *Scolytus multistriatus* (Marshall, 1802), are recognized as secondary pests or pathogen vectors associated with oak decline throughout Europe. Their presence on adhesive panels, even in low numbers, is ecologically meaningful because these taxa exploit physiologically weakened trees and can accelerate decline through cambial damage and fungal transmission (Moraal & Hilszczański, 2000; Brown *et al.*, 2015; Sallé *et al.*, 2014).

The difference between the two sample sites in terms of the number of non-target Coleoptera species, as well as the abundance of each species, particularly the significantly higher number of *A. angustulus* individuals, can be explained by the fact that the two oak species present in the Baba Ana stand are affected by the oak dieback phenomenon (Achim *et al.*, 2024).

*A. angustulus* is considered the most common species within the *Agrilus* genus (Bilý 2002), particularly in oak forests affected by oak dieback (Moraal & Hilszczański, 2000; Vansteenkiste *et al.*, 2004; Hilszczański & Sierpiński, 2007; Sallé *et al.*, 2020). It preferentially develops in the upper parts of trees, especially on thin twigs (Bilý, 2002; Domingue *et al.*, 2013; Lupaștean, 2023). In its adult stage, the insect can be observed from April to August (Gallardo & Cárdenas, 2016); therefore, this study captures only the final part of its flight period, despite the significant number of individuals recorded on the panels. However, several studies indicate that the peak adult activity of this species occurs in June-July (Domingue *et al.*, 2011; Domingue *et al.*, 2013; Domingue *et al.*, 2016; Imrei *et al.*, 2020). The other species from this genus identified in the area affected by oak dieback, *A. biguttatus*, is found in almost all European countries (Bilý, 2002) and develops on all oak species present in Romania. However, it can also be found on common chestnut and beech (Panin *et al.*, 2015). This species prefers to develop in the lower third of trees with diameters of 30-40 cm (Moraal & Hilszczański, 2000; Lupaștean, 2023). In oak stands that are physiologically weakened by biotic or abiotic factors, *A. biguttatus* can cause significant outbreaks, eventually leading to host mortality within a few years (Bilý, 2002; Brown *et al.*, 2015; Lupaștean, 2023). Several studies indicate that *A. biguttatus* populations are favored by severe defoliation caused by *L. dispar* (Moraal & Hilszczański, 2000; McManus & Csóka, 2007; Domingue *et al.*, 2011; Sallé *et al.*, 2014). In addition to the damage caused by larval galleries beneath the bark, both species of *Agrilus* can act as vectors for various pathogenic agents (Tiberi & Ragazzi, 1998; Moraal & Hilszczański, 2000; Macháčová *et al.*, 2022; Tkaczyk *et al.*, 2024).

Also, the species *P. cylindrus*, *X. saxesenii*, and *S. multistriatus* can act as vectors for various pathogens. *P. cylindrus*, considered a secondary pest of oak species, introduces ambrosia fungi into its hosts via specialized mycangial structures in certain regions (Cassier *et al.*, 1996; De Lurdes Inácio *et al.*, 2008; Tilbury, 2010; Inácio *et al.*, 2011). A similar behavior has been observed in *X. saxesenii*, which is capable of transporting ambrosia fungi, bacteria, and other pathogenic agents (Biedermann *et al.*, 2013; Diehl *et al.*, 2023). *S. multistriatus* serves as a vector for the pathogenic fungus *Ophiostoma ulmi* (Buisman) Melin & Nannf. (1934), and its two subspecies, which have caused extensive mortality in elm populations, either directly through fungal transmission (Basset *et al.*, 1992; Faccoli & Battisti, 1997) or indirectly via the transport of mites carrying fungal spores (Moser *et al.*, 2005).

Collectively, these studies suggest that even non-target captures can yield valuable information about the composition and health status of forest ecosystems. The occurrence of xylophagous and ambrosia beetles known to colonize stressed oaks supports the idea

that adhesive panel traps may serve as indirect tools for forest health surveillance, complementing traditional pest monitoring programs. The marked difference in the abundance of such species between the two study sites further underscores the role of stand condition and oak dieback severity in shaping beetle community structure.

The contrasting abundance patterns observed between the Baba Ana and Tatina stands reflect their differing health conditions and degrees of oak dieback. The strong dominance of *A. angustulus* in the Baba Ana stand supports the view that xylophagous beetles respond positively to host stress, exploiting trees with reduced vigor, compromised defenses, and increased availability of breeding substrates (Gibbs & Greig, 1997; Macháčová *et al.*, 2022; Lupăștean, 2023). These results are consistent with European studies linking secondary beetle proliferation to defoliation episodes caused by *L. dispar* and to subsequent physiological weakening of oak stands (Moraal & Hilszczański, 2000; Sallé *et al.*, 2020).

Sallé *et al.* (2020) analyzed the impact of oak stand decline on the biodiversity of canopy-dwelling beetles in France using purple and green multi-funnel traps, identifying fifteen beetle species characteristic of declining oak forests. Four of these species, *A. biguttatus*, *A. angustulus*, *Gasterocercus depressirostris* (Fabricius, 1792), and *Stenagostus rhombeus* (Olivier, 1790) were also recorded in the Baba Ana stand, and only two, *A. angustulus* and *G. depressirostris*, in the Tatina stand. The detection of these indicator species, previously associated with oak decline in France, suggests that similar faunistic assemblages may accompany oak dieback processes across regions. Considering the potential role of secondary pest species in accelerating forest decline, further studies focused on early detection and monitoring methods for their populations would be of significant ecological and management relevance.

Overall, the correspondence between beetle abundance and stand health condition reinforces the connection between *L. dispar* outbreaks, host stress, and subsequent colonization by secondary xylophagous insects.

This study has a number of limitations. First, the number of traps per stand was limited, which may have reduced statistical power and the ability to detect subtle differences in species richness or abundance between sites. In addition, the study covered a single flight season (2023); therefore, interannual variation in beetle activity and community composition remains to be examined. Finally, because no unbaited or differently colored control panels were used, the relative contribution of visual versus chemical attraction could not be quantified.

## Conclusions

The findings provide insights into beetle populations inhabiting oak forests within the silvosteppe region of Romania. Among the 21 species captured, *A. angustulus* and *A. biguttatus* are believed to contribute to the phenomenon of oak decline in Western Europe. Additionally, *P. cylindrus*, *X. saxesenii*, and *S. multistriatus* can act as vectors for pathogens that threaten the health of host trees. While species richness was similar between the two forest stands, the total number of individuals varied significantly. These findings highlight differences in population dynamics between the two stands. The non-target Coleoptera species were most likely trapped by visual or physical cues (panel color, shape, or adhesivity) rather than through chemical attraction, since the lure is strongly specific to *L. dispar*. The study also suggests that adhesive panel-based survey methods could be further developed, as several Coleoptera species, particularly those considered secondary pest agents, responded positively to this capture method.

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