ŽELJKO TOMANOVIĆ[a,b] - VLADIMIR ŽIKIĆ[c] - FRANCESCO PIETRA[d] - ELENA EUSTACCHIO[d] - MARCO BONELLI[d,e] *

BRACONIDAE (HYMENOPTERA) IN THE CENTRAL SOUTHERN ALPS: THE FIRST ALPINE RECORD OF THE ALIEN PARASITOID *LYSIPHLEBUS TESTACEIPES* (CRESSON) AND NEW SPECIES FOR ITALY

[a]*University of Belgrade, Faculty of Biology, Institute of Zoology, 11000 Belgrade, Serbia*
[b]*Serbian Academy of Sciences and Arts, 11000 Belgrade, Serbia*
[c]*Faculty of Sciences and Mathematics, University of Niš, 18000 Niš, Serbia*
[d]*Department of Biosciences, University of Milan, 20133 Milan, Italy*
[e]*Research and Museum Collections Office, Climate and Ecology Unit, MUSE—Science Museum, 38122 Trento, Italy*
*Corresponding Author: Marco Bonelli, e-mail: marco.bonelli@unimi.it

Tomanović Ž., Žikić V., Pietra F., Eustacchio E., Bonelli M. - Braconidae (Hymenoptera) in the Central Southern Alps: the first Alpine record of the alien parasitoid *Lysiphlebus testaceipes* (Cresson) and new species for Italy.

Despite the ecological importance of parasitoid wasps for the stability of Alps ecosystems, the available knowledge about braconid wasps for these environments is still very limited. Here, we explored the diversity of Alpine braconid parasitoids in the Southern Central Alps. We recorded 18 species of braconids, 12 of which are from the subfamily Aphidiinae. In particular, we detected for the first time the alien parasitoid species *Lysiphlebus testaceipes* (Cresson) in the Alps, providing information that could be considered to evaluate the invasiveness of this species. The second most diverse subfamily was Microgastrinae with two detected species, while one species was recorded from each of the subfamilies Alysiinae, Braconinae, Cheloninae and Euphorinae. Four braconid species from the subfamily Aphidiinae – *Aphidius hieraciorum* Starý, *Aphidius schimitscheki* (Starý), *Harkeria angustivalvus* (Starý) and *Monoctonus crepidis* (Haliday) – are new records to the fauna of Italy. This work contributes to the knowledge of braconid diversity in the Alps. Moreover, it can be a starting point both to explore complex tritrophic interactions potentially threatened by climate change and the role of early flowering Alpine plants on braconid diversity.

Key Words: Alps, Alpine ecosystems, biotic interactions, braconids, Italian fauna, parasitoids.

INTRODUCTION

Research on Alpine ecosystems is related to the conservation and natural protection of unique biodiversity at high altitudes. Exploring Alpine biodiversity can lead to an understanding of its ecosystem functions, and to predict possible threats from global climate changes (Körner, 2001; Ernakovich *et al.*, 2014). Parasitoid insects consist of the dominant component of terrestrial ecosystems belonging to tritrophic associations which include host plants and usually host insects feeding on those plants (Godfray, 1994). Due to the high degree of plant endemism in the European Alps (Menchetti *et al.*, 2021; Parisod, 2022), Alpine ecosystems might consequently support unique tritrophic associations and parasitoid diversity (Starý *et al.*, 1971; Pennacchio and Tremblay, 1988).

In recent decades, many new species of braconid parasitoid wasps (Hymenoptera: Braconidae), mainly from the subfamily Aphidiinae, have been described or registered from Alpine and high mountains areas throughout Europe (Starý *et al.*, 1971 – western Europe; Halme, 1992 – northern Europe; Starý *et al.*, 1998, Tomanović and Kavallieratos, 2002, Tomanović *et al*., 2002, 2004, 2007; Kavallieratos *et al*., 2004 – south-eastern Europe; Lozan *et al.*, 2010 – southern and central Europe; Havelka *et al.*, 2014). However, despite the ecological importance of parasitoids for the stability of Alps ecosystems (Kenis *et al.*, 2005), the available knowledge about braconid wasps on these mountains is still very limited (Starý *et al.*, 1971; Kenis *et al.*, 2005; Bonelli *et al.*, 2022).

The goal of our research is to detect new braconid species for Alpine ecosystems; this could lead to future conservation programs and to a deeper understanding of the biotic interactions occurring in these fragile environments, especially under pressure of climatic changes. Our research on braconid diversity focused on the Central Southern Alps and it is related to a broader research on the ecology of the vulnerable narrow endemic plant *Androsace brevis* (Hegetschw.) Cesati (Primulaceae). This plant is one of the few floral resources available for arthropods in the early season – when snow cover is still present – and braconids have been identified among its most abundant flower visitors (Bonelli *et al.*, 2020; Bonelli *et al.*, 2022), therefore it serves as a good starting point to search for braconid species and to investigate their role in high mountain ecological networks.

Received 2 October 2023 Accepted 28 November 2023

MATERIALS AND METHODS

The two investigated sites host two different representative populations of *Androsace brevis*, within its distribution range (Eustacchio *et al.*, 2023). The first site is in the Lepontine Alps (Como, Lombardy, Italy) on the Cugn Peak (UTM WGS84–32T E 512338 N 5112905, 2193 m asl), while the second site is in the Orobic Alps (Bergamo, Lombardy, Italy) near the Mountain Hut "Cesare Benigni" (UTM WGS84–32T E 543496 N 5096577, 2222 m asl). A more detailed description of the two selected sites is given in Bonelli *et al.* (2020) and Bonelli *et al.* (2022). Timed-observation samplings on *A. brevis* flowers were performed in May-June from 2016 to 2021. More information about the sampling effort and methods are reported by Bonelli *et al.* (2022). Finally, to increase the amount of available data, a further period of sampling was performed by sweeping in June-July 2022 in both sites. As the Cugn Peak site is more easily accessible, in this site we also sampled plants infested with aphids, as they are possible hosts of Aphidiinae. Plants were identified on-site during fieldwork. Plant parts, mainly leaves infested with aphids, and aphid mummies were transferred to plastic containers with perforated lids and kept under laboratory conditions until the parasitoid emergence. Some collected winged and wingless adult aphids were preserved in 70% ethyl alcohol and later identified by a specialist in the laboratory. After emergence, parasitoids were fixed in 96% ethyl alcohol and preserved for later examinations. Braconids were identified using existing identification keys (Starý, 1973; Tobias *et al.*, 1986; Tomanović *et al.*, 2018). Additionally, morphological identification of some specimens has been confirmed by barcoding COI gene – *Aphidius ervi* Haliday (OQ029512), *A. schimitscheki* (Starý) (OQ029508), *A. uzbekistanicus* Luzhetzki (OQ029509, OQ029510), *Diaeretiella rapae* (M'Intosh) (OQ029511). The external morphology of the specimens was studied using a ZEISS Discovery V8 stereomicroscope. Aphidiinae specimens are deposited in the collection of the Institute of Zoology, Faculty of Biology, University of Belgrade, Serbia. The rest of the parasitoid specimens are stored at the Faculty of Sciences and Mathematics, University of Niš, Serbia.

RESULTS

A total of 18 parasitoid species were recorded, with four species new to the fauna of Italy and with the first record of the alien species *Lysiphlebus testaceipes* (Cresson) in the Alps.

The overview of the recorded braconids is given below. For each species, collection data and general biological distributions are reported. Records marked with an asterisk [*] represent new species for the Italian fauna. Abbreviations for legators: MB = Marco Bonelli, ŽT = Željko Tomanović.

Subfamily Alysiinae

Aspilota fuscicornis (Haliday, 1838)

Material examined: 1♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 01-02.VII.2022, leg. ŽT (sweeping).

Remarks: Recorded mainly as parasitoid of *Euleia heraclei* (L.) (Diptera: Tephritidae), as reported by Frost (1924), and *Spiniphora bergenstammi* (Mik) (Diptera: Phoridae) (Yu, 2019), but also of necrophagous dipterans (Frederickx *et al.*, 2013).

Distribution: Europe (van Achterberg, 2014).

Subfamily Aphidiinae

Aphidius avenae Haliday, 1834

Material examined: 3♀, Mountain Hut "Cesare Benigni" (Orobic Alps, Bergamo, Lombardy, Italy), 2222 m, 31.V-01.VI 2017, *leg*. MB (collected *ex A. brevis* flowers).

Remarks: Polyphagous parasitoid of various aphid species, of which the most important are pea aphid – *Acyrthosiphon pisum* (Harris), rose aphid – *Macrosiphum rosae* (L.), green peach aphid – *Myzus persicae* (Sulzer), and many species of cereal aphids e.g., *Rhopalosiphum padi* (L.), *Sitobion avenae* (F.) and *Schizaphis graminum* (Rondani) (Tomanović *et al.*, 2021).

Distribution: Palaearctic (van Achterberg, 2014); introduced to Africa (Burundi) and America (Brazil, Chile, United States of America) (Peñalver-Cruz *et al.*, 2017).

Aphidius ervi Haliday, 1834

Material examined: 8♀, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 25-26.V.2016, leg. MB (collected ex *A. brevis* flowers); 1♀, Mountain Hut "Cesare Benigni" (Orobic Alps, Bergamo, Lombardy, Italy), 2222 m, 01.VI.2017, leg. MB (collected ex *A. brevis* flowers); 1♀, Mountain Hut "Cesare Benigni" (Orobic Alps, Bergamo, Lombardy, Italy), 2222 m, 01-04.VI 2022, leg. MB (sweeping); 2♀ and 2♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 01-02.VII.2022, leg. ŽT (sweeping).

Remarks: This is a polyphagous species recorded on approximately 120 hosts worldwide. Among them, pea aphid – *A. pisum*, and English grain aphid – *S. avenae*, are very common hosts (Yu, 2019). The host range for this parasitoid is displayed in Žikić *et al.* (2017).

Distribution: cosmopolitan (van Achterberg, 2014).

Aphidius hieraciorum Starý, 1962

Material examined: 1♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 02.VII.2022, leg. ŽT (emerged from *Nasonovia* sp. collected on *Hieracium* sp.).

Remarks: A specialized aphid parasitoid of the genus *Nasonovia* Mordvilko, that mainly attacks *Hieracium* spp. (Tomanović *et al.*, 2008).

Distribution: Europe (van Achterberg, 2014).

Aphidius schimitscheki (Starý, 1960)

Material examined: 1♀ and 1♂, Mountain Hut "Cesare Benigni" (Orobic Alps, Bergamo, Lombardy, Italy), 2222 m, 01-04.VI.2022, leg. MB (sweeping).

Remarks: A monophagous parasitoid that develops in *Elatobium abietinum* (Walker) a spruce-feeding aphid on *Abies alba* Mill., *Picea abies* (L.) H. Karst., *P. pungens* Engelm., and *P. sitchensis* (Bong.) Carr. (Starý, 1973; Tomanović *et al.*, 2021).

Distribution: Europe (Czech Republic, Germany, Hungary, Serbia, Slovakia, United Kingdom), Asia (India, Pakistan) (van Achterberg, 2014; Das and Chakrabarti, 2023).

Aphidius urticae Haliday, 1834

Material examined: 1♀, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 26.V.2016, leg. MB (collected ex *A. brevis* flowers).

Remarks: An oligophagous parasitoid primarily related to the aphid hosts of the genera *Macrosiphum* Passerini, *Acyrthosiphon* Mordvilko, but also *Amphorophora* Buckton, *Microlophium* Mordvilko, etc. (Jamhour *et al.*, 2016).

Distribution: Holarctic, Oriental, Oceania (van Achterberg, 2014).

Aphidius uzbekistanicus Luzhetzki, 1960

Material examined: 1♀ and 1♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 04.VI.2021, leg. MB (collected ex *A. brevis* flowers).

Remarks: This oligophagous species attacks aphids that infest cereals, such as *Diuraphis* Aizenberg, *Metopolophium* Hille Ris Lambers, *Rhopalosiphum* Koch, *Schizaphis* Börner, *Sipha* Passerini, *Sitobion* Mordvilko (Kos *et al*., 2011).

Distribution: Palaearctic, Nearctic, Neotropical, and Oriental (van Achterberg, 2014); introduced in Argentina, Brazil, Chile, and USA (Starý, 1993).

Diaeretiella rapae (M'Intosh, 1855)

Material examined: 1♀, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 26.V.2016, leg. MB (collected ex *A. brevis* flowers).

Remarks: The primary host for *D. rapae* is the aphid *Brevicoryne brassicae* (L.) from cultivated and uncultivated crucifers (Pike *et al.*, 1999; Kavallieratos *et al.*, 2004).

Distribution: Palaearctic, Oriental, Neotropical, Oceania, Afrotropical (van Achterberg, 2014); introduced to North America, and Australia (Baer *et al.*, 2004).

Harkeria angustivalvus (Starý, 1959)

Material examined: 6♀ and 1♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 02.VII.2022, leg. ŽT (emerged from *Nasonovia* sp. collected on *Hieracium* sp.).

Remarks: Like *Aphidius hieraciorum*, *H. angustivalvus* is a specialized aphid parasitoid of *Nasonovia* spp. (Tomanović *et al.*, 2008).

Distribution: Europe (van Achterberg, 2014).

Lysiphlebus confusus Tremblay *et* Eady, 1978

Material examined: 177♀ and 25♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 02.VII.2022, leg. ŽT (emerged from *Brachycaudus cardui* (L.) collected on *Cirsium spinosissimum* (L.) Scop.).

Remarks: Genetically and morphologically, this polyphagous species is very close to the below mentioned *Lysiphlebus fabarum* (Marshall). It has a largely overlapping host range with *L. fabarum*. European populations are mostly asexual; this finding is one of the few sexual populations of *L. confusus* in Europe (Tomanović *et al.*, 2018).

Distribution: Palaearctic, Oriental (van Achterberg, 2014; Tomanović *et al.*, 2018).

Lysiphlebus fabarum (Marshall, 1896)

Material examined: 206♀ and 41♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 02.VII.2022, leg. ŽT (emerged from *B. cardui* collected on *Carduus acanthoides* L.); 10♀, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 02.VII.2022, leg. ŽT (emerged from *B. cardui* collected on *C. spinosissimum*).

Remarks: This is one of the most polyphagous Aphidiinae, found on over 100 aphid hosts from many genera and the most common *Lysiphlebus* species in European crop and non-crop habitat. *L. fabarum* is very promising potential agent for the biological control of many agricultural pest aphids. Most important host of *L. fabarum*

in agroecosystems is *Aphis craccivora* Koch, on lucerne, clover, bean; *A. gossypii* Glover, on cucumber, potato; *A. fabae* Scopoli, on corn, bean, beet, parsnip; *A. idaei* van der Goot, on raspberry, blackberry; *A. pomi* De Geer and *Dysaphis plantaginea* (Passerini) on apple; *Brachycaudus helichrysi* (Kaltenbach) and *B. schwartzi* (Borner) on peach; *Myzus persicae* (Sulzer) on peppers (Tomanović *et al.*, 2018).

Distribution: Palaearctic, Australasia, Oceania, Oriental (van Achterberg, 2014; Tomanović *et al.*, 2018).

Lysiphlebus testaceipes (Cresson, 1880)

Material examined: 14♀ and 15♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 02.VII.2022, leg. ŽT (emerged from *B. cardui* collected on *C. acanthoides*); 196♀ and 93♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 02.VII. 2022, leg. ŽT (emerged from *B. cardui* collected on *C. spinosissimum*).

Remarks: It is already noted that this is an allochthonous and potentially invasive species in Europe, which started spreading on the east of the continent from the Mediterranean where competes with native *Lysiphlebus* species (Mitrović *et al.*, 2013; Žikić *et al.*, 2015) (Fig. I).

Distribution: Holarctic, Afrotropical, Neotropical (van Achterberg, 2014; Tomanović *et al.*, 2018).

****Monoctonus crepidis*** (Haliday, 1834)

Material examined: 2♀ and 2♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 02.VII.2022, leg. ŽT (emerged from *Nasonovia* sp. collected on *Hieracium* sp.).

Remarks: Another species that is primarily related to representatives of the genus *Nasonovia* e.g., *N. ribisnigri* (Mosley), *N. pilosellae* (Borner) associated with *Hieracium* spp., *Crepis* spp. and several other plants from the family Asteraceae (Tomanović *et al.*, 2008).

Distribution: Palaearctic (van Achterberg, 2014).

Subfamily Braconinae

Bracon intercessor Nees, 1834

Material examined: 1♀, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 01-02.VII.2022, leg. ŽT (sweeping).

Remarks: This species is ectoparasitoid recorded as generalist on coleopterans such as *Rhynchites bacchus* L. (Attelabidae), many weevils: *Microlarinus* Hochhuth, several *Anthonomus* Germar, e.g., *A. pomorum* (L.), *A. pedicularius* (L.), *A. sorbi* Germar, *Apion* Herbst spp., *Lixus* F. spp. (Curculionidae), then some Tenthredinidae (Hymenoptera), from the genus *Pontania* Costa, also Torticidae, e.g., *Sparganothis* Hübner spp. (Yu, 2019).

Distribution: Palaearctic (van Achterberg, 2014).

Fig. I - Lateral view of a female *Lysiphlebus testaceipes* recorded from Lepontine Alps.

Subfamily Cheloninae

Ascogaster varipes Wesmael, 1835

Material examined: 1♀, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 01-02.VII.2022, leg. ŽT (sweeping).

Remarks: This egg-larval parasitoid attacks microlepidoptera, e.g., Tortricidae, primarily several species of the genus *Cydia* Hubner, but also *Endothenia* Stephens, and *Epinotia* Hubner, (Tobias, 1976; Čapek and Hofmann, 1997).

Distribution: Palaearctic (van Achterberg, 2014).

Subfamily Euphorinae

Pygostolus falcatus (Nees, 1834)

Material examined: 1♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 01-02.VII.2022, leg. ŽT (sweeping).

Remarks: *P. falcatus* parasitizes Coleoptera Curculionidae, primarily *Phyllobius* Germar, and *Sitona* Germar, e.g., *S. lineatus* (L.), *S. hispidulus* (F.), and *S. humeralis* Stephens (Loan and Holdaway, 1961).

Distribution: Holarctic (van Achterberg, 2014).

Subfamily Microgastrinae

Sathon falcatus (Nees, 1834)

Material examined: 1♀, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 01-02.VII.2022, leg. ŽT (sweeping).

Remarks: This species has been reared from lepidopteran larvae of *Eupithecia succenturiata* (L.) (Geometridae), *Hellinsia osteodactylus* (Zeller) (Pterophoridae), *Apamea lateritia* (Hufnagel), *A. monoglypha* (Hufnagel), *Noctua* (L.) (Noctuidae), *Synanthedon tipuliformis* (Clerck) (Sesiidae) (Williams, 1988).

Distribution: Palaearctic, Oriental (van Achterberg, 2014).

Glyptapanteles fulvipes (Haliday, 1834)

Material examined: 2♂, Cugn Peak (Lepontine Alps, Como, Lombardy, Italy), 2194 m, 01-02.VII.2022, leg. ŽT (sweeping).

Remarks: Very important natural enemy of the gypsy moth, *Lymantria dispar* (L.) and the yellow tail, *Euproctis similis* (Füssli) (Erebidae) pests in orchards and forests. This parasitoid is also recorded from more than 30 noctuids (Yu, 2019).

Distribution: Holarctic (van Achterberg, 2014).

DISCUSSION

We conducted our sample quite early in the season, which can be a critical moment for possible climate change-driven mismatches in biotic interactions (Kudo and Cooper, 2019; Ettinger *et al.*, 2021), we found 18 species of braconid parasitoids from 6 subfamilies (Aphidiinae (12), Alysiinae (1), Braconinae (1), Cheloninae (1), Euphorinae (1), Microgastrinae (2).

With respect to Aphidiinae, *Lysiphlebus testaceipes* was introduced from Cuba to Mediterranean France in 1973, to control citrus aphids (Starý *et al*., 1988a). In a relatively short period, *L. testaceipes* spread in the coastal area of the Mediterranean, including North Africa (Starý *et al.*, 1988a; Suay Cano and Michelena Saval, 1997; Kavallieratos *et al.*, 2004; Havelka *et al.*, 2011). It has been detected in many localities in southern and central Italy in citrus plantations (Tremblay *et al.*, 1978). *L. testaceipes* also started to invade the interior of the Iberian Peninsula and the Pyrenees (Pons *et al.*, 2004; Starý *et al.*, 2004), and later in South-eastern Europe (Serbia) along the river valleys (Nišava and Južna Morava) (Žikić *et al.*, 2015) adapting to new aphid hosts. After its introduction in Europe, *L. testaceipes* has acquired over 30 aphid hosts (Starý *et al.*, 1988b; Kavallieratos *et al.*, 2004; Tomanović *et al.*, 2009). Due to the spread and adoption of new aphid hosts and competition with native parasitoids, despite the effectiveness of this species as biocontrol agent, the EPPO excluded it from the positive list of biological control agents (EPPO, 2009; EPPO, 2021). Here, to the best of our knowledge, we detect this species for the first time in the Alps, and this is the first record of *L. testaceipes* over 2000 m asl in Europe (Starý *et al.*, 2004; Mitrović *et al.*, 2013; Žikić *et al.*, 2015), providing new insights on the possible invasiveness of this species. In our samples, *L. testaceipes* dominates in the host range pattern of *B. cardui* aphids on *Carduus* and *Cirsium* plants in some samples over native *Lysiphlebus* parasitoids (*L. confusus* and *L. fabarum*). The spreading of *L. testaceipes* over fragile Alpine ecosystems could lead to a negative impact on the structure of native parasitoid complexes and consequently change ecosystems' functioning.

Regarding *L. confusus*, it is interesting to note that it consists predominantly of asexual populations throughout Europe, except for a few sexual populations in southeastern Europe (Greece) and northern Europe (Finland). We have detected additional sexual populations from the association of *B. cardui*/*Cirsium spinosissimum* in the Lepontine Alps. *L. fabarum* consists of asexual and sexual populations throughout the Palaearctic (Tomanović *et al.*, 2018). In the Lepontine Alps, we also detected a sexual population of *L. fabarum* dominated by females. These findings may be helpful for future studies to evaluate the factors involved in determining the drivers of geographic parthenogenesis and sex determination process.

Additionally, we found nine other Aphidiinae species in the investigated area of Alpine ecosystems. According to Fauna Europea (van Achterberg, 2014) and the available literature, we recorded four new Aphidiinae species to Italy – *Aphidius hieraciorum*, *A. schimitscheki*, *Harkeria angustivalvus,* and *Monoctonus crepidis*. According to Starý (1970) *A. hieraciorum*, *H. angustivalvus,* and *M. crepidis* belong to the faunal complexes of European deciduous forests and represent a member of the parasitoid guilds of *Nasonovia* aphids on *Hieracium* plants. *A. schimitscheki* belongs to West – Eurasian Coniferous Forest faunistic complexes (Starý, 1970). Based on literature data, we could assert that all four species are mountain faunistic elements in the southern Europe (Kavallieratos *et al.*, 2004). It is worth noting that *A. schimitscheki* has so far been recorded in only a few European countries (van Achterberg, 2014). It is a specific parasitoid of *Elatobium abietinum* aphids on *Picea* trees. Although these parasitoid species are not directly related to pest aphids in agroecosystems, it is known that *M. crepidis* parasitizes *Nasonovia ribisnigri* on lettuce (Tomanović *et al.*, 2008). Other recorded species are widely distributed and cosmopolitan, parasitizing several aphid species in crop and non-crop habitats (e.g., *A. avenae*, *A. ervi* – cereal and legume aphids; *A. uzbekistanicus* – cereal aphids; *D. rapae* – aphids on Brassicaceae and vegetables; *L. fabarum* – aphids on various vegetables, legumes and orchards). All these parasitoid species can regulate aphid population density in agroecosystems to a greater or lesser extent (Kavallieratos *et al.*, 2004; Tomanović *et al.*, 2009).

In addition to Aphiidinae, five other species of Braconidae, known as widely distributed in Europe, were detected.

Aspilota fuscicornis (Alyisiinae) is widely distributed on the European continent and belongs to the tribe Alysiini, as well as to the group of genera called the "*Aspilota*-group" (van Achterberg, 1988; Yu, 2019). This species is associated with cyclorrhaphous dipteran hosts, parasitizing their plant-feeding larvae (Fischer, 1975; Fischer *et al*., 2014), as well as necrophagous dipterans in urban biotope (Frederickx *et al.*, 2013). *Bracon intercessor* (Braconinae), a generalist parasitoid, is one of about 80 *Bracon* species inhabiting Italy (van Achterberg, 2014). *Ascogaster varipes* is a solitary en-

doparasitoid that, like other members of the subfamily Cheloninae, parasitizes the eggs of microlepidoptera, and leaves the host when it is in the larval stage. A parasitoid of weevils, *Pygostolus falcatus* (Euphorinae) is one of the four species of this genus registered in Europe. In addition to this species, *P. multiarticulatus* (Ratzeburg) and *P. sticticus* (F.) are also known to be present in the fauna of Italy. Microgastrinae are a very diverse subfamily of braconids both in Europe and in the world. They are solitary and gregarious parasitoids of exophytophagous and mining caterpillars. Therefore, some of them, such as *Cotesia glomerata* (L.) have been investigated as natural agents for the biological control of *Pieris* (Schrank) spp. Due to its long ovipositor, *Sathon falcatus* is specialized for parasitizing concealed microlepidopteran larvae, while *Glyptapanteles fulvipes*, like other members of this diverse genus, which have a relatively short ovipositor, is adapted to oviposition in exposed hosts such as many members of Erebidae, Geometridae, Lasiocampidae or Noctuidae (Yu, 2019). All recorded braconids not trophically connected with aphids discussed here are important members of parasitoid complexes, associated with their dipteran, lepidopteran and coleopteran hosts (Yu, 2019).

The detected species likely do not reflect the diversity along the whole season present in the researched area, although there is no recent checklist of Braconidae for Italy with which to compare it and especially there is not at all a checklist for the Alps. However, apart from the relatively well-studied subfamily Aphidiinae for the territory of Italy (Starý, 1965), the other subfamilies are scarce in data. Based on old reports that have not been verified, the checklist of Italian braconids consists of 866 species (Bergamasco *et al.*, 1995), which is low, considering the geographical position of Italy and its diverse terrain.

This work contributes to the knowledge of braconid diversity in the Alps. Providing new data, especially for the poorly investigated early season, can be relevant to gain new faunistic knowledge about parasitoids which may have a main role in Alpine ecosystems. Moreover, it can provide a baseline to explore complex tritrophic interactions that may be threatened by climate change and the role of early flowering alpine plants on braconid diversity.

ACKNOWLEDGEMENTS

The contribution of ŽT and VŽ was supported by the Ministry of Science, Technological Development and Innovations (contract numbers: 451-03-47/2023-01/200178; 451-03-47/2023-01/200124) and the Serbian Academy of Sciences and Arts (grant F131). We would like to thank Korana Kocić, Jelisaveta Čkrkić and Saša S. Stanković for their help in identifying some Braconidae specimens using DNA barcoding and for technical assistance. The authors MB and EE would like to acknowledge prof. Marco Caccianiga, prof. Morena Casartelli, prof. Luca Gianfranceschi, and Mauro Gobbi for their human and financial support; and all the bachelor and master students (Erica Ceresa, Elisa Legoratti, Alessio Minici, Irene Monti, Nora Noseda, Stefano Peri) for their help in fieldwork.

REFERENCES

Baer C.F., Tripp D.W., Bjorksten T.A., Antolin M.F., 2004 - *Phylogeography of a parasitoid wasp (*Diaeretiella rapae*): no evidence of host-associated lineages*. - Molecular Ecology, 13: 1859-1869.

Bergamasco P., Pennacchio F., Scaramozzino P.L., Tremblay E., 1995 - *Hymenoptera Braconidae*. - Checklist della Specie della Fauna Italiana, 95: 1-31. [in Italian].

Bonelli M., Eustacchio E., Avesani D., Michelsen V., Falaschi M., Caccianiga M., Gobbi M., Casartelli M., 2022 - *The early season community of flower-visiting arthropods in a high-altitude Alpine environment*. - Insects, 13: 393.

Bonelli M., Melotto A., Minici A., Eustacchio E., Gianfranceschi L., Gobbi M., Casartelli M., Caccianiga M., 2020 - *Manual sampling and video observations: an integrated approach to studying flower-visiting arthropods in high-mountain environments.* - Insects, 11: 881.

Čapek M., Hofmann C, 1997 - *The Braconidae (Hymenoptera) in the collections of the Musée cantonal de Zoologie, Lausanne*. - Litterae Zoologicae, 2: 25-162.

Das B.C., Chakrabarti S., 2023 - *Aphidiinae (Hymenoptera) parasitoids in India with examples of their biocontrol successes*. - Proceedings of the Zoological Society, 76: 355-372.

EPPO (European and mediterranean Plant Protection Organization), 2009 - 2nd Joint EPPO/IOBC panel meeting on biological control agents. Engelberg (CH), 25–27 March 2009. - [online] URL: http://www.eppo.org/MEETINGS/2009_meetings/biocontrol_ch.htm (accessed 1 August 2023)

EPPO (European and mediterranean Plant Protection Organization), 2021 - *PM 6/3 (5) Biological control agents safely used in the EPPO region*. - EPPO Bullettin, 51: 452-454.

Ernakovich J.G., Hopping K.A., Berdanier A.B., Simpson R.T., Kachergis E.J., Steltzer H., Wallenstein M.D., 2014 - *Predicted responses of arctic and alpine ecosystems to altered seasonality under climate change*. - Global Change Biology, 20: 3256-3269.

Ettinger A.K., Buonaiuto D.M., Chamberlain C.J., Morales-Castilla I., Wolkovich E.M., 2021 - *Spatial and temporal shifts in photoperiod with climate change*. - New Phytologist, 230: 462-474.

Eustacchio E., Bonelli M., Beretta M., Monti I., Gobbi M., Casartelli M., Caccianiga M., 2023 - *Pollen and floral morphology of* Androsace brevis *(Hegetschw.) Ces. (Primulaceae), a vulnerable narrow endemic plant of the Southern European Alps*. - Flora, 301: 152256.

Fischer M., 1975 - *Alysiinen-Wespen aus der Umgebung von Hüttenberg in Kärnten (Hymenoptera, Braconidae, Alysiinae)*. - Carinthia, 2: 303-342. [in German].

Fischer M., Sullivan G.T., Karaca I., Sullivan S., 2014 - *A new species of the genus* Dinotrema *Foerster (Hymenoptera, Braconidae, Alysiinae) from Turkey*. - Turkish Journal of Zoology, 38: 651-654.

Frederickx C., Dekeirsschieter J., Verheggen F.J., Haubruge E., Strand M., 2013 - *The community of Hymenoptera parasitizing necrophagous Diptera in an urban biotope.* - Journal of Insect Science, 13: 1-14.

Frost S.W.,1924 - *A study of the leaf-mining Diptera of North America.* - Cornell University, Ithaca, New York, USA.

Godfray H.C.J., 1994 - *Parasitoids: behavioral and evolutionary ecology*. - Princeton University Press, Princeton, New Jersey, USA.

Halme J., 1992 - Ephedrus (Ephedrus) koponeni *sp. n. from Finland (Hymenoptera, Braconidae, Aphidiinae)*. - Entomologica Fennica, 3: 113-116.

Havelka J., Shukshuk A.H., Ghaliow M.E., Lamari M., Kavallieratos N.G., Tomanović Ž., Rakhshani E., Pons X., Starý P., 2011 - *Review of invasive grapevine aphid,* Aphis illinoisensis *Shimer, and native parasitoids in the Mediterranean (Hemiptera, Aphididae; Hymenoptera, Braconidae, Aphidiinae)*. - Archives of Biological Sciences, 63: 269-274.

Havelka J., Tomanović Ž., Kos K., Kavalleratos N.G., Janeček J., Pons X., Rakhshani E., Starý P., 2014 - *Mountain aphid and parasitoid guilds on* Aconitum *spp. in Europe*. - Bulletin of Insectology, 67: 57-61.

Jamhour A., Mitrović M., Petrović A., Starý P., Tomanović Ž., 2016 - *Re-visiting the* Aphidius urticae *s. str. group: re-description of* Aphidius rubi *Starý and* A. silvaticus *Starý (Hymenoptera: Braconidae: Aphidiinae)*. - Zootaxa, 4178: 278-288.

Kavallieratos N.G., Tomanović Ž, Starý P., Athanassiou C.G., Sarlis G.P., Petrović O., Niketić M., Veroniki M.A., 2004 - *A survey of aphid parasitoids (Hymenoptera: Braconidae: Aphidiinae) of Southeastern Europe and their aphid - plant associations*. - Applied Entomology and Zoology, 39: 527-563.

Kenis M., Herz K., West R.J., Shaw M.R., 2005 - *Parasitoid assemblages reared from geometrid defoliators (Lepidoptera: Geometridae) of larch and fir in the Alps*. - Agricultural and Forest Entomology, 7: 307-318.

Körner C., 2001 - *Alpine ecosystems*. In: Encyclopedia of Biodiversity, (Levin, S.A., Eds).- Academic Press, San Diego, California, USA, pp. 133-144.

Kos K., Petrović A., Starý P., Kavallieratos N.G., Ivanović A., Toševski I., Jakše J., Trdan, S., Tomanović Ž., 2011 - *On the identity of cereal aphid parasitoid wasps* Aphidius uzbekistanicus*,* Aphidius rhopalosiphi*, and* Aphidius avenaphis *(Hymenoptera: Braconidae: Aphidiinae) by examination of COI mitochondrial gene, geometric morphometrics, and morphology.* - Annales of Entomological Society of America, 104: 1221-1232.

Kudo G., Cooper E.J., 2019 - *When spring ephemerals fail to meet pollinators: mechanism of phenological mismatch and its impact on plant reproduction*. - Proceedings of the Royal Society B, 286: 20190573.

Loan C., Holdaway F.G., 1961 - Pygostolus falcatus *(Nees) (Hymenoptera, Braconidae), a parasite of* Sitona *species (Coleoptera, Curculionidae)*. - Bulletin of Entomological Research, 52: 473-488.

Lozan A., Belokobylskij S., Achterberg C., Van Monaghan M.T., 2010 - *Diversity and distribution of Braconidae, a family of parasitoid wasps in the Central European peatbogs of South Bohemia, Czech Republic.* - Journal of Insect Science*,* 10: 1-21.

Menchetti M., Talavera G., Cini A., Salvati V., Dincă V., Platania L., Bonelli S., Balletto E., Vila R., Dapporto L., 2021 - *Two ways to be endemic. Alps and Apennines are different functional refugia during climatic cycles.* - Molecular Ecology, 30: 1297-1310.

Mitrović M., Petrović A., Kavallieratos N.G., Starý P., Petrović-Obradović O., Tomanović Ž., Vorburger C., 2013 - *Geographic structure with no evidence for host-associated lineages in European populations of* Lysiphlebus testaceipes*, an introduced biological control agent.* - Biological Control, 66: 150-158.

Parisod C., 2022 - *Plant speciation in the face of recurrent climate changes in the Alps.* - Alpine Botany*,* 132: 21-28.

Peñalver-Cruz A., Ortiz-Martinez S., Villegas C., Tomanović Ž., Zepeda-Paulo F., Žikić V., Lavandero B., 2017 - *Abundancia y prevalencia de* Aphidius avenae *(Hymenoptera: Braconidae: Aphidiinae) en Chile.* - Ciencia e investigación agraria, 44: 207-214. [in Spanish].

Pennacchio F., Tremblay E., 1988 - *A new species of* Aphidius *from Italy.* - Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri, 45: 167-169.

Pike K.S., Starý P., Miller T., Allison D., Graf G., Boydston L., Miller R., Gillespie R., 1999 - *Host range and habitats of the aphid parasitoid* Diaeretiella rapae *(Hymenoptera: Aphidiidae) in Washington State.* - Environmental Entomology*,* 28: 61-71.

Pons X., Lumbierres B., Starý P., 2004 - *Expansión de* Lysiphlebus testaceipes *(Cresson) (Hymenoptera: Braconidae: Aphidiinae) en el noreste de la Península Ibérica*. - Boletín Sanidad Vegetal Plagas, 30: 547-552. [in Spanish].

Starý P., 1965 - *The Aphidiidae of Italy: (Hymenoptera: Ichneumonoidea).* - Bollettino dell'Istituto di Entomologia della Università degli Studi di Bologna, 28: 65-139.

Starý P., 1970 - *Biology of aphid parasites (Hymenoptera: Aphidiidae) with respect to integrated control*.- Springer, Dordrecht, Germany.

Starý P., 1973 - *A review of the* Aphidius *species (Hymenoptera: Aphidiidae) of Europe*. - Annotationes Zoologicae et Botanicae, 85: 1-85.

Starý P., 1993 - *The fate of released parasitoids (Hymenoptera: Braconidae, Aphidiinae) for biological control of aphids in Chile*. - Bulletin Entomological Research, 83: 633-639.

Starý P., Lumbierres B., Pons X., 2004 - *Opportunistic changes in the host range of* Lysiphlebus testaceipes *(Cr.), an exotic aphid parasitoid expanding in the Iberian Peninsula*. - Journal of Pest Science, 77: 139-144.

Starý P., Lyon J. P., Leclant F., 1988a - *Biocontrol of aphids by the introduced* Lysiphlebus testaceipes *(Cress.) (Hym., Aphidiidae) in Mediterranean France*. - Journal of Applied Entomology, 105: 74-87.

Starý P., Lyon J.P., Leclant F., 1988b - *Post-colonisation host range of* Lysiphlebus testaceipes *in the Mediterranean area (Hymenoptera, Aphididae*). - Acta Entomologica Bohemoslovaca, 85: 1-11.

Starý P., Remaudière G., Leclant F., 1971 - *Les Aphidiidae (Hym.) de France et leurs Hôtes (Hom. Aphididae): description d'espèces nouvelles écologie lutte biologique*. - Entomophaga, Mémoire Hors-Série, 5: 6. [in French].

Starý P., Tomanović Ž., Petrović O., 1998 - *A new parasitoid of root-feeding aphids from the Balkan mountains (Hymenoptera, Braconidae, Aphidiinae).* - Deutsche Entomologische Zeitschrift, 45: 175-179.

Suay Cano V. A., Michelena Saval J.M., 1997 - *Dispersión de* Lysiphlebus testaceipes *(Cresson, 1880) (Hymenoptera, Braconidae, Aphidiinae) y rango de hospedadores en Valencia*. - Zoologica Baetica, 8: 111-121. [in Spanish].

Tobias V.I., 1976 - *Braconids of the Caucasus (Hymenoptera, Braconidae).* - Nauka Press, Leningrad, Russia. [in Russian].

Tobias V.I., Belokobylskij S.A., Kotenko A.G., 1986 - *The Family Braconidae*, In*:* A Key to the Insects of the European Part of the USSR. Vol. 3. Hymenoptera. Part. 4, (Medvedev, G.S., Eds). - Nauka Press, Leningrad, Russia. [in Russian].

Tomanović Ž., Kavallieratos N.G., 2002 - *Two new aphidiine wasps (Insecta: Hymenoptera: Braconidae: Aphidiinae) from the southeastern Europe*. - Reichenbachia, 34: 341-345.

Tomanović Ž., Kavallieratos N.G., Athanassiou C., Petrović O., Stanisavljević L.Z., 2004 - *A new* Aphidius *species (Hymenoptera: Braconidae: Aphidiinae) from high-montane areas of southeastern Europe.* - Phytoparasitica, 32: 221-225.

Tomanović Ž., Kavallieratos N.G., Starý P., Stanisavljević L., Ćetković A., Stamenković S., Jovanović S., Athanassiou C.G., 2009 - *Regional tritrophic relationship patterns of five aphid parasitoid species (Hymenoptera: Braconidae: Aphidiinae) in agroecosystem-dominated landscapes of southeastern Europe*. - Journal of Economic Entomology, 102: 836-854.

Tomanović Ž., Kavallieratos N., Starý P., Žikić V., Tomić V., Lučić L., 2007 - *Redescription of two species of Aphidiinae (Hymenoptera: Braconidae) from high mountain areas of south-eastern Europe, with biological and biogeographical notes on co-occurring guild members*. - Entomologica Fennica, 18: 36-45.

Tomanović Ž., Mitrović M., Petrović A., Kavallieratos N.G., Žikić V., Ivanović A., Rakhshani, E., Starý P., Vorburger C., 2018 - *Revision of the European* Lysiphlebus *species (Hymenoptera: Braconidae: Aphidiinae) on the basis of COI and 28SD2 molecular markers and morphology.* - Arthropod Systematics & Phylogeny, 76: 179-213.

Tomanović Ž., Starý P., Petrović O., 2002 - Monoctonus leclanti *sp. n. (Hymenoptera: Braconidae: Aphidiinae) from high-montane areas of the southeastern Europe and key to related species*. - Entomologica Fennica, 13: 159-162.

Tomanović Ž., Starý P., Kavallieratos N.G., Petrović A., Niketić M., Vučetić A., 2008 - Hieracium-*associated aphid parasitoid guilds (Hymenoptera: Braconidae: Aphidiinae) in Europe*. - Zootaxa, 1781: 20-30.

Tomanović Ž., Žikić V., Petrović A., 2021 - *Fauna of parasitoid wasps (Hymenoptera, Braconidae, Aphidiinae) of Serbia*. - Serbian Academy of Sciences and Arts, Belgrade, Serbia. [in Serbian].

Tremblay E., Barbagallo S., Biase L., Monaco R., Ortu S., 1978 - *On the presence in Italy of* Lysiphlebus testaceipes *(Cr.), a natural enemy of aphids injurious to citrus (Hymenoptera Ichneumonoidea, Homoptera Aphidoidea)*. - Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri*,* 35: 169-179.

van Achterberg C., 1988 - *The genera of the* Aspilota*-group and some descriptions of* Fungicolous alysiini *from the Netherlands (Hymenoptera, Braconidae, Alysiinae).* - Zoologische Verhandelingen*,* 247: 1-88.

van Achterberg C., 2014 - *Fauna Europaea: Braconidae*. In: Fauna Europaea: Hymenoptera: Symphyta + Ichneumonoidea. Fauna Europaea Version 1.1. - [online] URL: https://www.fauna-eu.org (accessed 1 August 2023)

Williams D.J.M., 1988 - *Classification, phylogeny and zoogeographic studies of species of* Sathon *Mason (Hymenoptera: Braconidae).* - Quaestiones Entomologicae*,* 24: 529-639.

Yu D.S.K., 2019 - *Taxapad Ichneumonoidea* (version May 2009). In: Species 2000 & ITIS Catalogue of Life (Roskov, Y., Ower, G., Orrell, T., Nicolson, D., Bailly, N., Kirk, P. M., Bourgoin, T., Dewalt, R. E., Decock, W., Nieukerken, E. Van, Zarucchi, J., Penev, L., Eds). - Species 2000: Naturalis, Leiden, the Netherlands. - [online] URL: https:// www.catalogueoflife.org/annual-checklist/2019.

Žikić V., Lazarević M., Milošević D., 2017 - *Host range patterning of parasitoid wasps Aphidiinae (Hymenoptera: Braconidae).* - Zoologischer Anzeiger, 268: 75-83.

Žikić V., Stanković S.S., Ilić Milošević M., Petrović-Obradović O., Petrović A., Starý P., Tomanović Ž., 2015 - *First detection of* Lysiphlebus testaceipes *(Cresson) (Hymenoptera: Aphidiinae) in Serbia: an introduced species invading Europe?* - North-Western Journal of Zoology, 11: 97-101.