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How Big Is Our Knowledge Gap in Taxonomy and Systematics? A Decade Long Aphidiinae Story †

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Abstract: Knowledge gaps in taxonomy and systematics are present in all insect groups, differing just in size. Generally, size of the gap is negatively correlated with body size and positively with number of species within the group. As an example, we present the size of the knowledge gap within the subfamily Aphidiinae (Hymenoptera: Braconidae). As solitary koinobiont endoparasitoids of aphids, Aphidiinae are widely used as biocontrol agents and consequently one of the best studied parasitoid groups. In the last decade, taxonomical studies on Aphidiinae have been focused on an integrative approach which resulted in numerous new findings: description of new species, detection of alien species, resolving the taxonomical status of genera and species groups, proposition of new classification schemes, etc. All those findings are critically summarized. Availability of different types of data is discussed and propositions for future studies and optimal research practices are given.

Keywords: taxonomic impediment; biodiversity crisis; Aphidiinae; parasitoids

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1. Prologue (Introduction)

The biodiversity crisis has been known for decades, but it just recently started getting the public attention it deserves [1]. There is an urgent need to mitigate the crisis by exploring, managing and conserving biodiversity. The very first step is to overcome the ignorance and realize that the most important unfinished job in biology is discovering and describing biodiversity [2, 3]. This brings us to the vital role of taxonomy in today's biology. As a biological discipline with the task to identify, name and describe organisms [4], taxonomy represents a bridge between morphology and systematics. Unfortunately, at this moment, taxonomy is not a highway bridge that we need. It is more like an old, decrepit bridge which is still standing on a good foundation, but full of gaps, holes, and obstacles. These difficulties associated with taxonomy are: gaps in taxonomic knowledge, lack of taxonomic infrastructure and an insufficient number of taxonomic experts; and are called "taxonomic impediment". With more than 1 million described species, insects comprise more than half of all known species [5], and with an estimate of 5.5 million living species [6] they represent the biggest proportion of the taxonomic impediment.

Knowledge gaps in taxonomy and consequently in systematics are present in all insect groups, differing just in size. Generally, size of the gap is negatively correlated with body size and positively with number of species within the group. Families of small Diptera and parasitoid wasps (Hymenoptera) are recognized as groups with highest proportions of dark taxa (little-known and unknown species).

In order to present the size of the knowledge gap in taxonomy and systematics I chose the subfamily Aphidiinae (Hymenoptera: Braconidae) as an example.

Aphidiinae are solitary koinobiont endoparasitoids of aphids and as such, a single specimen completes its development inside the living aphid host, which continues to feed and grow [7]. Among Aphidiinae there are several species which are widely used as biocontrol agents. Primarily because of their economic importance, Aphidiinae are one of the best studied parasitoid groups. Taxonomy and systematics of Aphidiinae is especially well studied in Europe, with over 70 years of continuous research [8]. History of Aphidiinae taxonomy goes back to the dawn of nomenclature and taxonomy, with the first species described in the 10th edition of Systema Naturae (*Aphidius rosae* Haliday, 1834 described as *Ichneumon aphidum* L. 1758) [9]. In the last 263 years, many notable entomologists have contributed to Aphidiinae taxonomy (e.g. Christian Gottfried Daniel Nees von Esenbeck, Alexander Henry Haliday, Thomas Ansell Marshall, William Harris Ashmead and many others), but the real pioneers are our contemporaries: professor Manfred Mackauer and Dr. Petr Starý. More than six decades ago they started their research on Aphidiinae, and since then published numerous papers concerning taxonomy, systematics and all other aspects of Aphidiinae biology. Dr. Petr Starý, with more than 500 published papers dealing with Aphidiinae, can undoubtedly be labeled as a man who made a difference. One may ask where that knowledge gap is if one man performed so much research. Well, the answer would be that taxonomy is a never ending story, so here we present taxonomical studies on Aphidiinae conducted in the period 01.01.2010–01.06.2020. as a proxy of knowledge gap size.

2. Chapters that have been told in the last decade

The first problem that emerges when someone starts reading about the subfamily Aphidiinae is the number of described species and genera. Those numbers differ as much as 33% in various sources, starting with 400 species in 50 genera in Boivin et al. [8], then 505 species in 38 genera according to Žikić et al. [10], up to more than 600 species in 65 genera according to Tian et al. [11]. There are two reasons for this discrepancy: 1) lack of an updated world checklist of Aphidiinae (last comprehensive list was published in late 1960s [8, 12]) and 2) uncritical use of World Ichneumonoidea database in Taxapad [13]. Determination of the exact number of Aphidiinae species is beyond the subject of this paper but according to available data our best estimate is that there were about 500 living species classified in 52 genera prior to year 2010.

2.1. New taxa in the Old World and all other 'Worlds'

The subfamily Aphidiinae is an excellent model to emphasize the 'taxonomic impediment'. We estimate that in the last 12 years (2010–2021) about 1800 papers (2770 results in Google scholar search minus double results) which deal with Aphidiinae were published. A vast majority of studies have been done on various applied aspects of Aphidiinae biology (life history, demography, functional response, host preference, foraging behavior), and to a lesser extent on local faunas, all with the aim of using those parasitoids in biological control. To the best of our knowledge, among those papers there are less than 60 papers focusing on Aphidiinae taxonomy and systematics, and only 37 in which new Aphidiinae taxa are described [14-50]. This discrepancy between applicative and taxonomical studies (30:1) is a real proxy of the "taxonomic impediment". In total, three new genera (*Choreopraon* Mackauer, 2012; *Sergeyoxys* Davidian, 2016; and *Astigmapraon* Tian et Chen, 2017) [25, 32, 35] and 55 new species were described from around the world. Newly described taxa represent 6% and 10 % of all known Aphidiinae genera and species, respectively (Figure 1). Those numbers alone indicate that the knowledge gap in Aphidiinae taxonomy is very big, despite the long research history and economic importance. Further analysis of data about taxa described since 2010 provides us an insight to other aspects of the 'taxonomic impediment'. Two out of three genera were described from the Palaearctic (*Sergeyoxys* - Russia, *Astigmapraon* - China) while *Choreopraon* was discovered in New Zealand (Australasia).

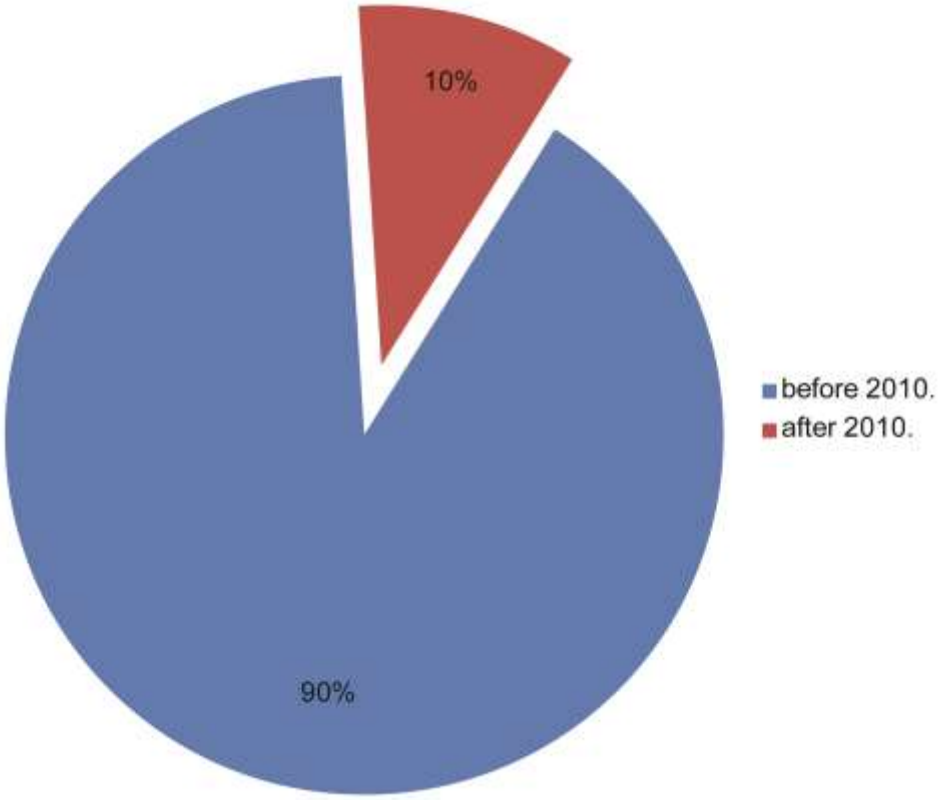

Figure 1. Percentage of described Aphidiinae species before and after year 2010.

Dominance of discoveries in Palaearctic is much more expressed on species level with 67% of them being described from this region, while none of the species were discovered in Afrotropical and Neotropical regions (Figure 2). This is a clear indicator of the fact that there is an insufficient number of taxonomic experts and that they are unevenly distributed in the world.

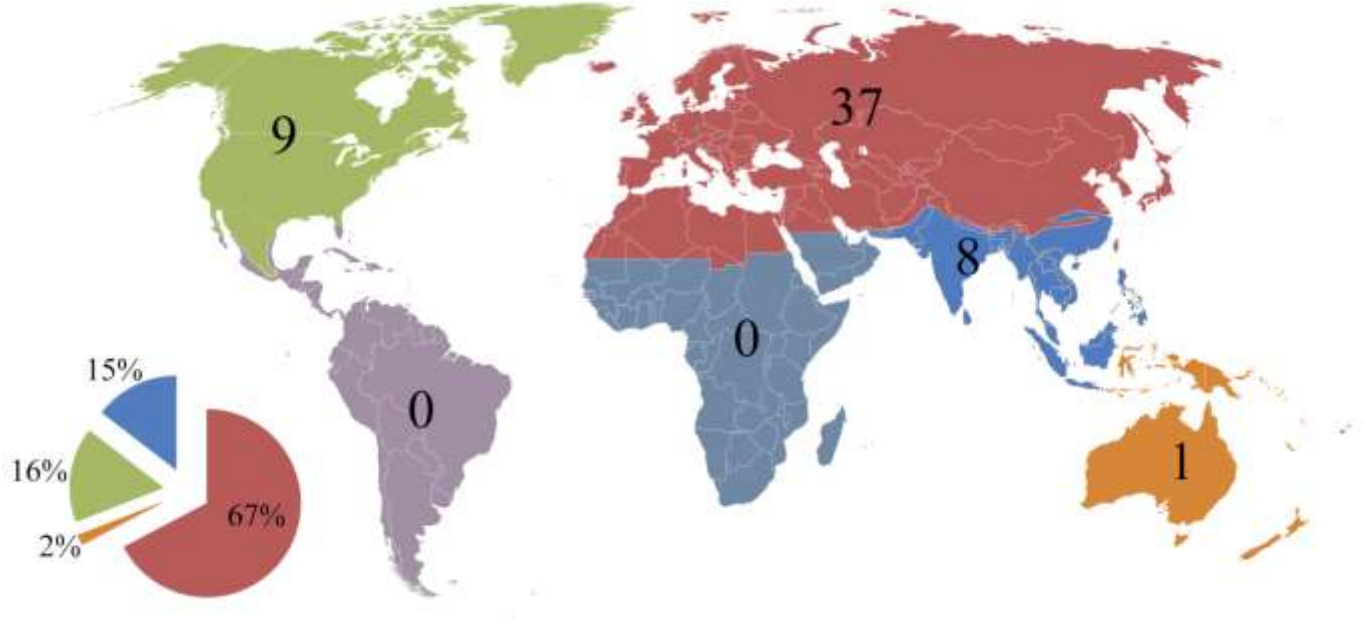

Figure 2. Number and percentage (lower left corner) of described Aphidiinae species in different ecoregions in the period 01.01.2010–01.06.2021.

Uneven distribution of experts is even more obvious when species authors were analyzed. Fifty five Aphidiinae species described between 2010 and 2021 were named by 19 researchers (up to 3 authors per species) from which four were from USA (Nearctic), one from India (Oriental), and 14 from Palaearctic (two from China, one from Iran and 11 from Europe). Only seven species were described without authors from Europe.

2.2. Foreigners in Europe (New alien species in Europe)

Species descriptions and rate of species description are often used as sole indicator of taxonomic activity, but taxonomy is much more than just naming a species, and various indicators can and should be used to assess the current state of taxonomy and systematics [51]. One such indicator, which is widely underestimated, is the crucial role of taxonomists in identification of alien species. In European Aphidiinae fauna only five species were marked as alien (*Aphidius colemani* Viereck, 1912; *Aphidius smithi* Sharma & Subba Rao, 1959; *Lysiphlebus testaceipes* (Cresson, 1880); *Pauesia cedrobii* Starý & Leclant, 1977 and *Pauesia unilachni* (Gahan, 1927)) before year 2010, and all were intentionally introduced as biocontrol agents [52-53]. Three more alien species, namely *Lysiphlebus orientalis* Starý & Rakhshani, 2010, *Aphidius ericaphidis* Pike & Starý, 2011 and *Trioxys liui* Chou & Chou, 1993 were detected in Europe in the last decade and all were accidentally introduced [54-56]. Interestingly, two species were detected in Europe soon after their descriptions. *Lysiphlebus orientalis* was described in 2010 from China and detected in samples from Serbia collected in 2010 and 2011 [54], while *Aphidius ericaphidis* was described in 2011 from USA and was detected in samples from Serbia and Scotland collected in 2014 and 2015, respectively [55]. Additional revision of collections determined that both species were present in Europe long before their formal descriptions (*L. orientalis* back in 1995, and *A. ericaphidis* in 1965). *Trioxys liui* was first collected in Spain in 2017 [55]. All three alien species were identified by an integrative taxonomic approach using molecular, morphological and ecological data, which became the standard in Aphidiinae taxonomical studies in the last decade. Using all available types of data is the only way which will lead to shrinking the knowledge gap in taxonomy and systematics.

2.3. Revising the unrevised

A single description of a species is of inestimable importance, but sometimes alpha-taxonomy can be in discrepancy with beta-taxonomy because of "superficial description taxonomic impediment" (older descriptions often can be too superficial by today's standards) [3]. In such cases revision of a whole group of organisms (species group, genus, tribe...) is necessary in order to reduce the knowledge gap [51].

The majority of Aphidiinae tribes, subtribes and genera were revised 30-50 years ago and those revisions are mainly outdated. In the last decade a lot of effort has been put into the improvement of Aphidiinae taxonomy and systematics and into clarification of species status. Revision of the world Monoctonina is the only revision on the subtribe level and it included all available species [43, 47]. Several genera with smaller number of species were also reviewed: *Monoctonia* Starý, 1962 [31], *Lipolexis* Foerster, 1862 [31], *Areopraon* Mackauer, 1959 [39], *Pseudopraon* Starý, 1975 [39], *Paralipsis* Foerster, 1862 [33, 41], *Acanthocaudus* Smith, 1944 [37], *Euaphidius* Mackauer, 1961 [57], *Remaudierea* Starý, 1973 [57]. Most of those revisions resulted in a higher nuber of species within the genus, while genera *Euaphidius* and *Remaudierea* were determined as junior synonyms of *Aphidius* [57]. European species of the genera *Adialytus* Foerster, 1862 and *Lysiphlebus* Foerster, 1862 were also revised [40, 58], and new subgeneric classification of European *Ephedrus* Haliday, 1833 species was proposed [42]. *Lysiphlebus* revision [40] can serve as a classical example of importance of revisions in taxonomy and consequently in biodiversity research. Prior to revision there were 15 *Lysiphlebus* species known from Europe. With this study the number of European *Lysiphlebus* species is reduced to 13; four species were synonymized and two new species were described. Although this quantitative

taxonomic information is very important, even more important is the quality of taxonomic information [51]. Within this study Tomanović et al. determined that only two descriptions of *Lysiphlebus* species match today's standards in Aphidiinae taxonomy and redescribed all other species [40]. In addition, remarks about species biology and distribution were also provided.

There are several published studies dealing with taxonomic status of Aphidiinae species groups [26, 29, 30, 53, 59-62] among which the most important are those about taxonomy of biocontrol agents belonging to *Aphidius colemani* and *A. eadyi* species groups [53, 61]. It was determined that *Aphidius colemani* species group is consisted of three species - *A. colemani*, *A. transcaspicus* Telenga, 1958 and almost forgotten *A. platensis* Brethes, 1913 [61]. At the time when this study was conducted, parasitoids within global commercially distributed materials were a mixture of all three species [61], and most likely the situation is the same at this moment. Interestingly, similar results were obtained within the *A. eadyi* species group [53]. Three species of biocontrol agents against *Acyrthosiphon pisum* (Harris) were identified (*A. smithi*, *A. eadyi* Stary, Gonzalez & Hall, 1980 and *A. banksae* Kittel, 2016). *Aphidius banksae*, which was previously known only from Israel and Turkey, was identified as a widely distributed species with a range that covers most of the western Palaearctic [53]. Such huge knowledge gaps in taxonomy of economically very important biocontrol agents raise numerous questions about the taxonomic status of many other Aphdiinae species, especially those which parasitize aphids on nonagricultural plants.

3. Epilogue

The bridge from the beginning of the story looks a bit different after a decade of research. Some holes are filled and some obstacles are removed. Now we can see further. We can see some new holes, obstacles and gaps that need to be fixed.

Even with the tremendous work that has been done so far, the knowledge gap in Aphidiinae taxonomy is still very big and all aspects of the taxonomic impediment are more than obvious.

Although there is no meaningful research in biology without reliable taxonomy [53], its importance in the modern world is far from being fully acknowledged [63]. Recently Swiss Re concluded that 55% of global GDP is dependent on biodiversity and ecosystem service [64], but we are still lacking large research grants (and even small ones) for taxonomy which is considered only as a cost [63]. Until institutions, governments and the world realize the importance of this kind of research, taxonomists need to be more clever and utilize data from all available resources such as museum collections, as well as cybertaxonomy and molecular data. In the last two years 10 Aphidiinae species were described thanks to cooperation between taxonomists and the Barcode of life initiative [43, 45, 47].

The one who would like to take this interesting walk over the bridge called taxonomy should be aware that in Aphidiinae taxonomy barcodes are not enough, and must be used only as a part of integrative taxonomy. Similar situation is in most other taxa, and using just one type of information can make our knowledge gaps even bigger.

It seems appropriate to finish with a citation of a song by Jonathan Coulton adapted for taxonomy:

"We've experiments to run

There is research to be done

On the species who are

Still alive."

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References

1. World Economic Forum, 2020. The Global Risks Report. Available online: https://www.weforum.org/reports/the-global-risks-report-2020 (accessed on 10.06.2021).
2. May, R.M. Why Worry about How Many Species and Their Loss? *PLoS Biol* **2011**, 9(8): e1001130. doi:10.1371/journal.pbio.1001130
3. Meier, R.; Blaimer, B.; Buenaventura, E.; Hartop, E.; von Thomas, R.; Srivathsan, A.; Yeo, D. A re-analysis of the data in Sharkey et al.,'s (2021) minimalist revision reveals that BINs do not deserve names, but BOLD Systems needs a stronger commitment to open science. *bioRxiv* **2021**. doi:10.1101/2021.04.28.441626
4. Michener, C.D.; Corliss, J.O.; Cowan, R.S.; Raven, P.H.; Sabrosky, C.W.; Squires, D.S.; Wharton, G.W. *Systematics in support of biological research*. Division of Biology and Agriculture, National Research Council, Washington, D.C., USA, 1970. pp. 1–25.
5. Chapman, A. *Numbers of Living Species in Australia and the World.* Australian Biological Resources Study, Canberra, Australia, 2009. pp 1–80.
6. Stork, N. How many species of insects and other terrestrial arthropods are there on Earth? *Annu. Rev. Entomol* **2018**, 63: 31–45.
7. Boivin, G.; Hance, T., Brodeur, J. Aphid parasitoids in biological control. *Can. J. Plant Sci.* **2012**, 92, 1–12.
8. Mackauer, M.; Starý, P. *World Aphidiidae (Hym. Ichneumonoidea)*. Index of Entomophagous Insects. Le Francois, Paris, France, 1967. pp 1–195.
9. Linnæus, C. *Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I. Editio decima, reformata*, 1758. pp. [1–4], 1–824. Holmiæ. (Salvius).
10. Žikić, V.; Lazarević, M.; Milošević, D. Host range patterning of parasitoid wasps Aphidiinae (Hymenoptera: Braconidae). *Zool. Anz.* **2017**, 268: 75–83. doi:10.1016/j.jcz.2016.10.001
11. Tian, H.W.; Achterberg, K.V.; Chen, X.X. A new genus of the tribe Praini Mackauer (Hymenoptera: Braconidae: Aphidiinae) from China. *Zootaxa* **2017**, 4362(1): 131–134. doi:10.11646/zootaxa.4362.1.7.
12. Mackauer, M. Pars 3. Aphidiidae. In: *Hymenopterorum Catalogus (nova edito)*; Ferriere, C.; van der Vecht, J. (Eds.); Dr. W. Junk: The Hague, Netherlands, 1968, pp. 1–103.
13. Yu, D.S.; van Achterberg, K.; Horstmann, K. Taxapad 2012. Ichneumonoidea 2011 – Database on flash–drive. Ottawa, Ontario, Canada, 2012.
14. Starý, P.; Rakhshani, E.; Tomanović, Ž.; Hoelmer, K.; Kavallieratos, N.G.; Yu, J.; Wang, M.; Heimpel, G.E. (2010) A new species of *Lysiphlebus* Förster 1862 (Hymenoptera: Braconidae: Aphidiinae) attacking soybean aphid, *Aphis glycines* Matsumura (Hemiptera: Aphididae) from China. *J. Hymenop. Res.* **2010**, 19, 179–186.
15. Davidian, E.M.; Gavrilyuk, A.V. A new species of the genus *Areopraon* Mackauer, 1959 (Hymenoptera: Aphidiidae) from Western Siberia. *Russ. Entomol. J.* **2011**, 20(3): 247–249.
16. Starý, P.; Rakhshani, E.; Tomanović, Ž.; Kavallieratos, N.G.; Sharkey, M. Review and key to the world parasitoids (Hymenoptera: Braconidae: Aphidiinae) of Greenideinae aphids. *Ann. Entomol. Soc. Am.* **2010**, 103, 307–321.
17. Akhtar, M. S.; Khan, F.R.; Ramamurthy, V.V. Description of a new species of the genus *Ephedrus* (Hymenoptera: Braconidae: Aphidiinae) from India with an up to date checklist. *Pan-Pac. Entomol.* **2011**, 87(2), 98–105.
18. Rakhshani, E.; Tomanović, Ž.; Starý, P.; Kavalieratos, N.G.; Ilić, M.; Stanković, S.S.; R.-Mazhar, N. Aphidiinae parasitoids (Hymenoptera: Braconidae) of *Macrosiphoniella* aphids (Hemiptera: Aphididae) in the western Palaearctic region. *J. Nat.Hist.* **2011**, 45, 2559–2575.
19. Petrović, A.; Žikić, V.; Petrović-Obradović, O.; Mitrovski Bogdanović, A.; Kavallieratos, N. G.; Starý, P.; Tomanović, Ž. Two new species of aphid parasitoids (Hymenoptera, Braconidae, Aphidiinae) from the Balkan Peninsula. *Zootaxa* **2011**, 2895, 58–64.
20. Pike, K.S.; Starý, P.; Graf, G.; Raworth, D.A.; Mathur, S.; Tanigoshi, L.K.; Murray, T. A new *Aphidius* Nees (Hymenoptera, Braconidae, Aphidiinae) of *Ericaphis fimbriata* (Richards) (Hemiptera, Aphididae) and key to parasitoids of blueberry aphid in the Pacific Northwest. *Zootaxa* **2011**, 2802, 58–62.
21. Rakhshani, E.; Kazemzadeh, S.; Starý, P.; Barahoei, H.; Kavallieratos, N. G.; Ćetković, A.; Popović, A.; Bodlah, I.; Tomanović Ž. Parasitoids (Hymenoptera: Braconidae: Aphidiinae) of northeastern Iran: Aphidiinae-aphid-plant associations, key and description of a new species. *J. Insect Sci.* **2012**, 12, 143, 1–26.

22. Rakhshani, E.; Barahoei, H.; Ahmed, Z;, Tomanović, Ž., Janković, M.; Petrović, A.; Starý, P. New species and additional evidence of aphid parasitoids (Hymenoptera: Braconidae: Aphidiinae) from India. *Zootaxa* **2012**, 3397, 45–54.
23. Kos, K.; Trdan, S.; Petrović, A.; Starý, P.; Kavallieratos, N. G.; Petrović-Obradović, O.; Tomanović, Ž. Aphidiinae (Hymenoptera, Braconidae, Aphidiinae) from Slovenia, with description of a new *Aphidius* species. *Zootaxa* **2012**, 3456, 36–50.
24. Hollingbery, E.N.; Pike, K.S.; Graf, G.; Graf, D. Parasitoids (Hymenoptera: Braconidae: Aphidiinae) of rabbitbrush aphids and linkage with agriculturally important pest aphids in Washington State, United States of America. *Can. Entomol.* **2012**, 144(5), 621–634.
25. Mackauer, M.; Finlayson, T. *Choreopraon totarae* (Hymenoptera, Braconidae, Aphidiinae), a new parasitoid of *Neophyllaphis totarae* (Hemiptera, Aphidoidea, Drepanosiphidae) in New Zealand. *N. Z. J. Zool.* **2012**, 39(1), 77–84.
26. Mitrovski Bogdanović, A.; Petrović, A.; Mitrović, M.; Ivanović, A.; Žikić, V.; Starý, P.; Vorburger, C.; Tomanović, Ž. Identification of two cryptic species within the *Praon abjectum* group (Hymenoptera: Braconidae: Aphidiinae) using molecular markers and geometric morphometrics. *Ann. Entomol. Soc. Am.* **2013**, 106(2), 170–180.
27. Chaubet, B.; Derocles, S.A.P.; Hullé, M.; Le Ralec, A.; Outreman, Y.; Simon, J-C.; Tomanović, Ž. Two new species of aphid parasitoids (Hymenoptera, Braconidae, Aphidiinae) from the high arctic (Spitsbergen, Svalbard). *Zool. Anz.* **2013**, 252, 34–40.
28. Davidian, E.M. A new species of the genus *Trioxys* Mackauer (Hymenoptera: Aphidiidae) from Sverdlovsk Province of Russia. *Proceedings of the Russian Entomological Society* **2014**., **85**(1), 157–159. [In Russian].
29. Mitrovski Bogdanović, A.; Tomanović, Ž.; Mitrović, M.; Petrović, A.; Ivanović, A.; Žikić, V.; Starý, P.; Vorburger, C. The *Praon dorsale-yomenae* complex *s. str.* (Hymenoptera, Braconidae, Aphidiinae): species discrimination using geometric morphometrics and molecular markers with description of a new species. *Zool. Anz.* **2014**, 253(4), 270–282.
30. Davidian, E.M. Parasitoid wasps of the subgenus *Pauesia* Quilis s. str. (Hymenoptera, Aphidiidae) from Russia and neighboring countries. *Entomol. Obozr.* **2015**, 94(2), 440–445. [In Russian].
31. Rakhshani, E.; Starý, P.; Perez Hidalgo, N.; Čkrkić, J.; Tomanović, S.; Petrović, A.; Tomanović, Ž. Revision of the world *Monoctonia* Starý, parasitoids of gall aphids: taxonomy, distribution, host range, and phylogeny (Hymenoptera, Braconidae: Aphidiinae). *Zootaxa* **2015**, 3905 (4), 474–488.
32. Davidian, E.M. A new genus and new species of subfamily Trioxinae (Hymenoptera: Aphidiidae) from the Russian Far East. *Zootaxa* **2016**, 4205(5), 475–479.
33. van Achterberg, C.; Ortiz de Zugasti Carrón, N.F. Revision of the genus *Paralipsis* Foerster, 1863 (Hymenoptera, Braconidae), with the description of two new species. *ZooKeys* **2016**, 606: 25.
34. Petrović, A.; Kocić, K.; Kos, K.; Plećaš, M.; Žikić, V.; Kavallieratos, N.G.; Tomanović, Ž. High genetic diversity and a new cryptic species within the *Ephedrus persicae* species group (Hymenoptera, Braconidae). *Biologia* **2016**, 71 (12), 1386–1394. DOI:10.1515/biolog-2016-0165
35. Tian, H.W.; Achterberg, K.V.; Chen, X.X. A new genus of the tribe Praini Mackauer (Hymenoptera: Braconidae: Aphidiinae) from China. *Zootaxa* **2017**, 4362(1),131–134.
36. Rakhshani, E.; Pons, X.; Lumbierres, B.; Havelka, J.; Pérez Hidalgo, N.; Tomanović, Ž.; Starý, P. A new parasitoid (Hymenoptera, Braconidae, Aphidiinae) of the invasive bamboo aphids *Takecallis* spp. (Hemiptera, Aphididae) from Western Europe. *Journal of Natural History* **2017**, 51, 1237–1248. https://doi.org/10.1080/00222933.2017.1327622
37. Kula, R.R.; Johnson, P.J.; Heidel-Baker, T.T.; Boe, A. A new species of *Acanthocaudus* Smith (Braconidae: Aphidiinae), with a key to species and new host and distribution records for aphidiines associated with *Silphium perfoliatum* L. (Asterales: Asteraceae). Zootaxa 2017, 4236(3), 543–552.
38. Davidian, E.M. A new species of the aphidiid wasp genus *Dyscritulus* Hincks, 1943 (Hymenoptera, Aphidiidae) from the Caucasus. *Entomol. Obozr* **2018**, 97(3), 518–524. [In Russian].
39. Tian, H-W.; van Achterberg, C.; Chen, X-X. The genera *Areopraon* Mackauer, 1959 and *Pseudopraon* Starý, 1975 (Hymenoptera, Braconidae, Aphidiinae) from China, with keys to species. *ZooKeys* **2018**, 780, 61–70.
40. Tomanović, Ž.; Mitrović, M.; Petrović, A.; Kavallieratos, N. G.; Žikić, V.; Ivanović, A.; Rakhshani, E.; Starý, P.; Vorburger, C. Revision of the European *Lysiphlebus* species (Hymenoptera: Braconidae: Aphidiinae) on the basis of COI and 28SD2 molecular markers and morphology. *Arthropod Syst. Phylogeny* **2018**, 76, 179–213.
41. Mitrović, M.; Starý, P.; Jakovljević, M.; Petrović, A.; Žikić, V.; Pérez Hidalgo, N.; Tomanović, Ž. Integrative taxonomy of root aphid parasitoids from the genus *Paralipsis* (Hymenoptera, Braconidae, Aphidiinae) with description of new species. *ZooKeys* **2019**, 831, 49–69.
42. Kocić, K.; Petrović, A.; Čkrkić, J.; Mitrović, M.; Tomanović, Ž. Phylogenetic relationships and subgeneric classification of European *Ephedrus* species (Hymenoptera, Braconidae, Aphidiinae). *ZooKeys* **2019**, 878, 1–22.
43. Čkrkić, J.; Petrović, A.; Kocić, K.; Kavallieratos, N. G.; Hebert, P.D.N.; Tomanović, Ž. Review of the world Monoctonina Mackauer 1961 (Hymenoptera, Braconidae, Aphidiinae): Key for identification with a description of five new species. *Zootaxa* **2019**, 4691 (4), 359–385.
44. Davidian, E.M. A New Species of the Aphidiid Wasp Genus *Trioxys* Haliday (Hymenoptera, Aphidiidae) from Orenburg Province of Russia. *Entomol. Rev.* **2020**, 100, 1029–1032.
45. Kocić, K.; Petrović, A.; Čkrkić, J.; Kavallieratos, N. G.; Rakhshani, E.; Arnó, J.; Aparicio, Y.; Hebert, P.D.N.; Tomanović, Ž. Resolving the taxonomic status of potential biocontrol agents belonging to the neglected genus *Lipolexis* Förster (Hymenoptera, Braconidae, Aphidiinae) with descriptions of six new species. *Insects* **2020**, 11, 667. doi: 10.3390/insects11100667

46. Tomanović, Ž.; Petrović, A.; Kocić, K.; Čkrkić, J.; Žikić, V. Two new morphologically interesting species of the genus *Ephedrus* Haliday (Hymenoptera, Braconidae, Aphidiinae). *J. Hymenopt. Res.* **2020**, 77, 167–174.
47. Čkrkić, J.; Petrović, A.; Kocić, K.; Mitrović, M.; Kavallieratos, N. G.; van Acheterberg, C.; Hebert, P.D.N.; Tomanović, Ž. Phylogeny of the Subtribe Monoctonina (Hymenoptera, Braconidae, Aphidiinae). *Insects* **2020**, 11(3), 160, doi:10.3390/insects11030160.
48. Čkrkić, J.; Petrović, A.; Kocić, K.; Tomanović, Ž. *Trioxys ulmi* sp. n., a new parasitoid (Hymenoptera: Braconidae: Aphidiinae) of the Japanese elm aphid, *Tinocallis takachihoensis* (Hemiptera: Aphidoidea: Aphididae) on elm hybrids. *Zoosystema* **2021**, 43: 145–154.
49. Petrović, A.; Pérez Hidalgo, N.; Michelena Saval, J.; Tomanović, Ž. A new *Aphidius* Nees species (Hymenoptera, Braconidae), a parasitoid of *Acyrthosiphon malvae* (Mosley, 1841) in Europe. *Phytoparasitica* **2021**, 49, 93–101. DOI: doi.org/10.1007/s12600-020-00860-1
50. Petrović, A.; Kocić, K.; Čkrkić, J.; Tomanović, Ž. Additional data on Aphidiinae (Hymenoptera, Braconidae) fauna of Kyrgyzstan, with description of a new species. *J. Hymenopt. Res.* **2021**, 82, 221–235.
51. Tancoigne, E.; Ollivier, G. Evaluating the progress and needs of taxonomy since the Convention on Biological Diversity: going beyond the rate of species description. *Aust. Syst. Bot.* **2017**, 30 (4), 326–336.
52. Roy, H.E.; Roy, D.B.; Roques, A. Inventory of terrestrial alien arthropod predators and parasites established in Europe. *BioControl* 2011, 56, 477–504.
53. Petrović, A.; Mitrović, M.; Ghailow, M.; Ivanović, A.; Kavallieratos, N. G.; Starý, P.; Tomanović, Ž. Resolving the taxonomic status of biocontrol agents belonging to the *Aphidius eadyi* species group (Hymenoptera: Braconidae: Aphidiinae): an integrative approach. *Bull. Entomol. Res.* **2019**, 109, 342–355.
54. Petrović, A.; Mitrović, M.; Starý, P.; Petrović-Obradović, O.; Tomanović, Ž.; Žikić, V.; Vorburger, C. *Lysiphlebus orientalis*, a new invasive parasitoid in Europe – evidence from molecular markers. *Bull. Entomol. Res.* **2013**, 103, 451–457.
55. Petrović, A.; Čkrkić J.; Jamhour, A.; Petrović-Obradović, O.; Mitrović, M.; Starý, P.; Nedstam, B.; Tomanović, Ž. First record of *Aphidius ericaphidis* (Hymenoptera, Braconidae) in Europe: North American hitchhiker or overlooked Holarctic citizen? *J. Hymenopt. Res.* **2017**, 57, 143–153.
56. Rakhshani, E.; Saval, J.M.; Pérez Hidalgo, N.; Pons, X.; Kavallieratos, N.G., Starý, P. *Trioxys liui* Chou & Chou, 1993 (Hymenoptera, Braconidae, Aphidiinae): an invasive aphid parasitoid attacking invasive *Takecallis* species (Hemiptera, Aphididae) in the Iberian Peninsula. *ZooKeys* **2020**, 944, 99–114.
57. Milošević, M.; Petrović, A; Stanković, S. S.; Čkrkić, J.; Starý, P.; Žikić, V.; Tomanović, Ž. Taxonomic position and phylogenetic relationships of the genera *Euaphidius* and *Remaudierea* (Hymenoptera: Braconidae: Aphidiinae) analyzed using molecular markers and geometric morphometrics. *Ann. Entomol. Soc. Am.* **2015**, 108(3), 435–445.
58. Stanković, S. S.; Petrović, A.; Ilić Milošević, M.; Starý, P.; Kavallieratos, N. G.; Žikić, V.; Tomanović, Ž. Morphological and molecular characterization of common European species of *Adialytus* (Hymenoptera: Braconidae: Aphidiinae) based on the mtCOI barcoding gene and geometric morphometrics of the forewings. *Eur. J. Entomol.* **2015**, 112, 165–174.
59. Kos, K.; Petrović, A.; Starý, P.; Kavallieratos, N.G.; Ivanović, A.; Toševski, I.; Jakše, J.; Trdan, S.; Tomanović, Ž.. 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. *Ann.s Entomol. Soc. Am.* **2011**, 104 (6): 1221–1232.
60. Jamhour, A.; Mitrović, M.; Petrović A.; Starý, P.; Tomanović, Ž. Re-visiting the *Aphidius urticae* s. str. group: re-description of *Aphidius rubi* Starý and *A. silvaticus* Starý (Hymenoptera: Braconidae: Aphidiinae). *Zootaxa* **2016**, 4178(2), 278–288.
61. Tomanović, Ž.; Petrović, A.; Mitrović, M.; Kavallieratos, N.G.; Starý, P.; Rakhshani, E.; Rakhshanipour, M.; Popović, A.; Shukshuk, A.H.; Ivanović, A. Molecular and morphological variability within the *Aphidius colemani* group with redescription of *Aphidius platensis* Brethes (Hymenoptera: Braconidae: Aphidiinae). *Bull. Entomol. Res.* **2014**, 104, 552 –565.
62. Rakhshani, E.; Starý, P; Davidian, E. A taxonomic review of the subgenus *Pauesiella* Sedlag & Starý, 1980 (Hym.: Braconidae: Aphidiinae). *Plant Pest Research* (Guilan University) **2017**, 7, 53–66.
63. Saunders, T.E. Taxonomy at a crossroads: Communicating value, building capability, and seizing opportunities for the future. *Megataxa* **2020**, 1, 063–066.
64. Swiss Re Institute. *Biodiversity and Ecosystem Services: A business case for re/insurance*. Swiss Re Management Ltd, Zurich, Switzerland, 2020. pp. 1–60.