Advances in Hemipterology

Edited by
Alexi Popov, Snejana Grozeva, Nikolay Simov, Elena Tacheva

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EDITORIAL

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Sixth European Hemiptera Congress

Alexi Popov[1], Nikolay Simov[1], Snejana Grozeva[2]

[1] National Museum of Natural History, Bulgarian Academy of Sciences, Tsar Osvoboditel Blvd 1, 1000 Sofia, Bulgaria *[2] Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Tsar Osvoboditel Blvd 1, 1000 Sofia, Bulgaria*

Corresponding author: *Alexi Popov* (alpopov@bulinfo.net)

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Since 1998, when the First European Hemiptera Congress (EHC) took place in the small seaside resort Amaliapolis, Greece, the Hemiptera congresses are regularly held every two-three years: EHC 2 in Fiesa, Slovenia (2001), EHC 3 in St. Petersburg, Russia (2004), EHC 4 in Ivrea, Italy (2007) and EHC 5 in Velence, Hungary (2009).

The nomination to host and organize the Sixth European Hemiptera Congress in Bulgaria, erected during the Fifth Congress in Hungary, had been a surprise and an honour for the Bulgarian hemipterists, and, of course, it is a recognition for the work of Prof. Michail Josifov, renowned taxonomist of Palaearctic Heteroptera, and a tribute to his memory. The geography of the European meetings on Hemiptera shows an interesting trend: five of all six congresses are held on the Balkan Peninsula and the neighbouring countries in south-eastern Europe, Hungary and Italy. The explanation of this fact should be the rich fauna of this region, very suitable for congress trips, more than in many other countries.

Later, the entomologist Alexi Popov, Director of the National Museum of Natural History in Sofia, kindly accepted to be Chairman of the Congress. He is not a hemipterist, but knowing personally some of the remarkable taxonomists in this field, was happy when agree to lead the Organizing Committee and to help the preparation and realizing the Congress.

The institutional co-organizers of the Congress become National Museum of Natural History (Bulgarian Academy of Sciences), Institute of Biodiversity and Ecosystem Research (Bulgarian Academy of Sciences) and St. Kliment Ohridski University of Sofia.

An international recognition of the Congress is the patronage of Director-General of UNESCO Ms Irina Bokova and the promise for financial and other support.

As venue of the Congress, we chose Scaptopara Campus of the American University in Bulgaria, Blagoevgrad. This town, situated 100 km south of Sofia, has a remarkable location. It is situated at the foot of Rila Mts., the highest mountain on the Balkan Peninsula, and is only 30 km from Kresna Gorge in Struma Valley. These are areas with most cold-resistant and most thermophilic fauna in Bulgaria, where many new species of Hemiptera were described from.

The website of the Congress, arranged by the Organizing Committee members and maintained by Ilia Gjonov, comprises the whole information of interest to the participants, including as well the history of the previous congresses. The Organizing Committee published for the participants a booklet by Victor Fet, a well-known taxonomist on scorpions. Prof. Fet (Marshall University, Huntington, West Virginia, USA) for many years combined his biology with literary work involving themes of modern natural science and their philosophy. The booklet consists of three literary pieces: The tale of Prime Minister and a Golden Bedbug (a fairytale on free government elections), The Kirkaldy connection (the generic names used in a novel of Vladimir Nabokov are the generic Hemiptera names of George Willis Kirkaldy) and Zoological label as literary form (also devoted to V. Nabokov).

The Sixth European Hemiptera Congress held from 25 to 29 June 2012 with 100 participants from 26 countries in four continents, including 6 from Bulgaria (Fig. 1). For comparison, the number of participants in each of the previous congresses without these from the host-country is between 30 and 60. More than twice increased number of participants indicates the deep interest to this congress. The significant extension of the geography of European Hemiptera congresses is also impressive. Several countries are presented for the first time in these congresses, among them a large group of hemipterists from countries beyond the border of Europe (17 entomologists from 7 non-European countries or one sixth of participants and more than one fourth of the countries or 27 %). Most hemipterists took part from Poland (15), Czech Republic (9) and Germany, Austria, Hungary, Bulgaria (6 participants each).

During the four days of plenary sessions, 102 reports (45 oral presentations and 57 posters) altogether were delivered and presented, and in this respect the Congress in Bulgaria also exceeds to a large degree the previous ones. There were 11 plenary sessions (Fig. 2), one poster session (Fig. 3) and another session was devoted to the opening ceremony. The short Scratchpads Training course, included in the scientific program of the Congress, is an easy to use, social networking application which enables communities of researchers to manage, share and publish taxonomic data online. It has attracted considerable attention of many participants.

The reports presented were focused on general aspects of studies on Hemiptera treating faunistics and biogeography of the Mediterranean Basin and Europe more generally as well as on taxonomy and phylogeny of Cicadomorpha, Fulgoromorpha, Heteroptera, Aphidoidea and Psylloidea; complex application of ecological, acoustic, genetic, palaeontological and behavioural methods; applied research and pest control.

Figure 1. Participants in the Sixth European Hemiptera Congress in front of Scaptopara building, Blagoevgrad, Bulgaria, 26 June 2012. Photo: Werner Holzinger.

Figure 2. Plenary session in the congress hall, 25 June 2012.

The Congress was opened by the Chairman Assoc. Prof. Alexi Popov and welcome speeches were delivered as well by Prof. Sakis Drosopoulos, initiator of the European congresses and organizer of the First congress; Prof. Matija Gogala, Vice-president of the Slovenian Academy of Sciences and Arts; and Prof. Ernst Heiss, former President of the International Heteropterists Society (Fig. 4).

The Organizing Committee initiated an award for young researchers in memory of Michail Josifov due to the sponsorship of Asen Nikolov Foundation and Pensoft Publishers. The organizers decided to present three equal rewards for achievements in hemipterology and as support of participation in the Sixth Congress. Eleven researchers applied with their abstracts for the award. The Scientific Committee of the Congress discussed the applications and three applicants were chosen as winners by voting: Qiang Xie (China), Ondřej Balvín (Czech Republic) and Vikas Suman (India) (Fig. 5). Certificates and rewards were delivered to the winners by Milena Josifova, the daughter of Michail Josifov.

First stop of the one-day field trip was Kresna Gorge (Fig. 6). The Kresna Gorge is situated along the Struma River, which passes there between Pirin, Vlahina and Maleshevska mountains. The gorge starts at the Simitli Kettle and ends at the town of Kresna going deep into crystalline schists and granites. Typical habitats for this place are Forests of Grecian juniper (*Juniperus excelsa*); Xerothermic meadows and pastures of *Chrysopogon gryllus*, *Bothriochloa ischaemum* and *Festuca valesiaca*; Sub-Mediterranean pseudo-steppes with annual herbs; Balkan pseudomaquis; Prickly juniper (*Juniperus*

Figure 3. Poster session, 28 June 2012.

Figure 4. Opening ceremony of the Congress, 25 June 2012, from left to right: Alexi Popov, Matija Gogala, Ernst Heiss, Sakis Drosopoulos.

Figure 5. Rewarding ceremony of the winners of Michail Josifov awards, 26 June 2012, from left to right: Ondřej Balvín, Qiang Xie, Vikas Suman (the winners in the competition), Alexi Popov, Milena Josifova, Nikolay Simov. Portrait of Michail Josifov on the wall. Photo: Ilia Gjonov.

oxycedrus) scrub. Part of the territory of the gorge is under the protection of Tisata Reserve and its buffer zone. According to the Bern Convention, it is declared as a CORINE site and will be part of the European Union NATURA 2000 Network. The gorge is of worldwide importance for the conservation of the habitats of the Grecian juniper and the Oriental plane forests. It is also a biological corridor for the migration of large mammals between the surrounding mountain ranges as well as a very important bird migration route (Via Aristotelis). Only among Heteroptera, 419 species are reported from the gorge. Twelve of them are endemic taxa and for nine other the gorge is the type locality. The second collecting place was the area between the Rozhen Monastery and Melnik. The habitats are similar but with forests of *Platanus orientalis* instead of *Juniperus excelsa*, xerothermic meadows and pastures, and sub-Mediterranean pseudo-steppes. Impressive is the picturesque historic town of Melnik. The region comprises the landmark of Melnishki Piramidi, declared as a protected area in 1978 for the purpose of preserving the uniqueness of these earth formations in sand-clay rocks. Because of its European importance for the preservation of rare and threatened habitats, plants and animals, Melnishki Piramidi was declared as a CORINE site in 1998.

Ten participants in the Congress from United Kingdom, the Netherlands, Germany, Austria, Italy, Slovenia and Bulgaria, guided by Ilia Gjonov, took part in an

Figure 6. Field trip in Kresna Gorge, 27 June 2012. Photo: Vikas Suman.

eight-day collecting trip. Localities were visited in Rila Mts. (Rila Monastery), Vlahina Mts., Struma Valley (the hot spring Rupite, the volcanic hill Kozhuh), Pirin Mts. (Popovi Livadi site at 1400 m asl), Western Rhodope Mts. (Shiroka Laka, vicinities of Smolyan, Smolyan Lakes, Snezhanka Peak at 1625 m asl, Sokolovtsi, Popovitsa, Besapara Hills), Eastern Rhodope Mts. (many localities in the vicinities of Momchilgrad, Krumovgrad and Ivailovgrad and along the Byala Reka River) and Sredna Gora Range (Vakarel). The rich collected material of Hemiptera will serve for future investigation of Bulgarian fauna. Various methods for collecting were used, namely hand sampling, sweep netting, light towers, suction samplers. Matija Gogala recorded the songs of some species of Cicadidae. Gernot Kunz photographed many living insects.

The Congress stimulated scientific debates, promoted the communication and cooperation between researchers from different countries, established new contacts and initiated further investigations. We shall keep in our memory the valuable discussions and the exchange of ideas, partly realized and born in the informal meetings during the Welcome party, Congress dinner and Farewell party.

After the congress closing some of the participants visited the National Museum of Natural History in Sofia and its rich collections, especially the valuable collection of Michail Josifov of Palaearctic Heteroptera. At that time, a photo exhibition in the Museum, dedicated to the diversity and significance of Hemiptera for the ecosystems and the people, presented to the audience this significant part of the biodiversity and its conservation. The Congress initiated median interest and public support for the Bulgarian science in these heavy times.

Unfortunately, because of the objective difficulties, UNESCO could not support financially the congress and because of different objective and subjective reasons the publication of this volume was delayed for about half a year.

Thirty-three manuscripts were submitted for the special issue *Advances in Hemipterology*. The selection was made according to the standards of the hosting journal ZooKeys following peer review recommendations and editorial decision. We wish to thank the reviewers for the valuable and creative remarks during the selection process and the improvement of the manuscripts accepted for this volume, which are the first successfully published proceedings of the European Hemiptera congresses.

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We are thankful and appreciate the support of the sponsors of EHC 6: Pensoft Publishers, the well-known publishing house, which published the Abstract book and accepted to support partly the present open access volume; Asen Nikolov Foundation, which provided the money for the established Michail Josifov award; Refan Bulgaria Ltd, a company trading with perfumery and cosmetics, which presented cosmetic presents for all participants. Contribution to the proper organization of the Congress have the team of the Conferences and Institutes Office of American University in Bulgaria as a host; the National Commission of UNESCO in Sofia, which help the participants from some countries to receive visas; our friends and colleagues, who provided a valuable logistic support. We are most grateful to Dr Werner Holzinger who accepted to organize the Seventh European Hemiptera Congress in Graz (Austria) in 2015. We wish all European hemipterists valuable new results in the years to come and Werner Holzinger every success in the works that await for him.

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RESEARCH ARTICLE

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Morphological differences among egg nests and adult individuals of *Cicadatra persica* (Hemiptera, Cicadidae), distributed in Erneh, Syria

Marah A. Dardar[1], Hamzeh MR. Belal[2]

1 *General Commission for Scientific Agricultural research, Administration of Plant Protection Research, Dep. Insects Research, Alkoatly street, Douma, Damascus, Syria* **2** *University of Damascus, Faculty of Agriculture, Dep. Plant Protection, Damascus, Syria*

Corresponding author: *Marah A. Dardar* (marah.dardar@hotmail.com)

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Abstract

The aim of this study is determining the different patterns of egg nests and the morphological differences between the specimens of *Cicadatra persica* Kirkalidy, 1909 (Hemiptera: Cicadidae) distributed in fruit orchards in Erneh located on AL-Sheikh mountain southwest of Syria. The appearance of 80 egg nests was studied, and the results showed that there were two basic patterns of egg nests laid by *C. persica*, 90% of the egg nests were of the first pattern (consists of several adjacent slits), while 10% of them were of the second pattern (consists of several divergent slits). A random sample consisting of 300 specimens (150 males and 150 females) were also studied concentrating on the differences in the color of the supra-antennal plate and in the number of spurs on the tibia of the hind legs. The results showed that there were two basic patterns of individuals based on the differences in the color of supra-antennal plate. The first pattern (individuals with yellow supra-antennal plates), constituted more than 90%, and the second one (individuals with black supra-antennal plates) constituted less than 10%. The results also showed that there were 27 different patterns based on the number of spurs on the tibia of the hind legs. One of them was a common pattern (2, 3) whose individuals have 2 spurs on the upper side of the tibia of the hind legs and 3 spurs on the lateral side of the tibia of the hind legs. The total percent of this common pattern was 76%. The other 26 patterns were different from each other, and the total percent of all these different patterns was 24%.

Keywords

Cicadidae, individuals, pattern, orchards, Erneh

Introduction

Cicadas are large insects obvious in their environment because of their mating calls. However, they receive relatively little attention because they are often difficult to catch and there are few individuals who can identify insects of the group (Sanborn 2008). Morphological studies on cicadas were restricted to identify some species. There are few studies which were conducted to distinguish between some closely species. For example, morphological and occurrence studies of species of the genus *Fidicinoides* have been carried out by Boulard and Martinelli (1996), Sanborn (2008), Sanborn et al.(2008), Santos and Martinelli (2007, 2009a, 2009b) and Santos et al. (2010). Some species of Brazilian *Fidicinoides* were also characterized morphologically, presenting illustrations of the head, thorax, abdomen, right forewing and male sternite VIII of the species of Brazilian *Fidicinoides* (Santos and Martinelli 2011).

In practice it is usually not always possible to have live specimens and thus difficulties may arise in the identification of cicadas. In many instances, like in the genus *Cicada* Linnaeus, it is difficult to separate species only on the basis of their morphology. Five species of the genus *Cicada* were analyzed to use a set of measurements of the external morphology and male genitalia to identify and quantify subtle differences among the five species (Simões and Quartau 2009). Another study was conducted to test the discrimination capabilities of numerical techniques commonly used for classificatory purposes, as well as to discover the most effective characters to distinguish between *Cicada orni* and *C. barbara* which are very similar and sometimes difficult to distinguish using external keys (Quartau 1988).

For the species *Cicadatra persica*, morphological studies have been restricted to describe the morphological characters of the species like in the research of Mozaffarian and Sanborn (2009). There is also another morphological study on *Cicadatra persica* in which the morphology of genital organs and maximum oviposition of capacity of female was determined in Turkey (Kartal and Zeybekoğlu 1999). *Cicadatra persica* was recorded for the first time in Syria in summer 2011 (Dardar et al. 2012). Little is known about the morphological patterns of *C. persica*. This study was undertaken with two main objectives in mind. The first was to distinguish between two basic patterns of egg nests laid by *C. persica* during summer 2011. The second objective is to distinguish among the patterns of *C. persica* based on the color of the supra-antennal plate and the number of spurs located on the tibia of the hind legs as well as the patterns of egg nests.

Material and methods

Egg nests

80 egg nests were collected from three different apple fruit orchards in the village Erneh. The samples were collected on 9th, 11th, and 17th of July. 50 twigs hold one egg nest were cut from each orchard by using a paring scissor. The collected twigs (150) were mixed well

together, then 80 twigs were chosen randomly from them one after one, then they were left in the room temperature to be dried and to prevent them from decomposition caused by humidity. The external structure of the chosen egg nests were studied in the laboratory.

Adult individuals

300 adults (150 males + 150 females) were collected from several fruit orchards in the village Erneh on 27th of June, 2011. Then they were put in a plastic container and kept in the refrigerator under 4°–6°C. The color of the supra-antennal plate and the number of spurs on the tibia of the hind legs of the collected adults were studied in the laboratory by using a Binocular microscope.

Results

Egg nests

It was observed that the female of *Cicadatra persica* lay two basic patterns of egg nests. The first pattern of egg nest consists of several adjacent slits (Fig. 1), while the second pattern of egg nest consists of several divergent slits (Fig. 2). 72 egg nests were from the first pattern which constituted 90% (Fig. 1) and 8 egg nests were from the second pattern which constituted 10% (Fig. 2).

Adult individuals

The results showed that there were two basic patterns of specimens according to the color of the supra-antennal plate (Table 1). The first pattern involved Individuals with

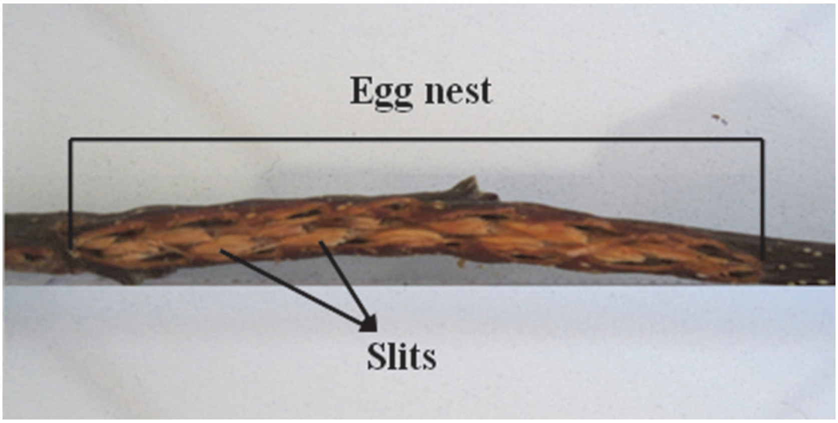

Figure 1. The first pattern of egg nests of *Cicadatra persica*

Table 1. The distribution of two basic patterns of individuals of *C. Persica*.

Gender		**No. of yellow supra-antennal plate individuals**	**No. of black supra-antennal plate individuals**
Males	Number	138	12
	Percent of total males	92%	8%
	Percent of total individuals	46%	4%
Females	Number	145	5
	Percent of total females	96.67%	3.33%
	Percent of total individuals	48.33%	1.67%
Males and females	Total number	283	17
	Total percent	94.33%	5.67%

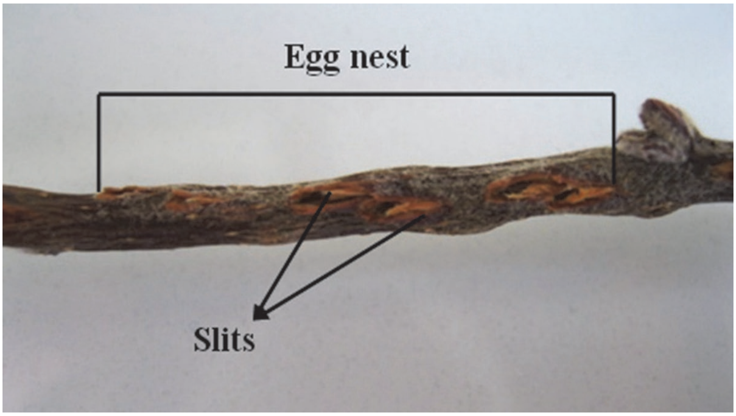

Figure 2. The second pattern of egg nests *Cicadatra persica*

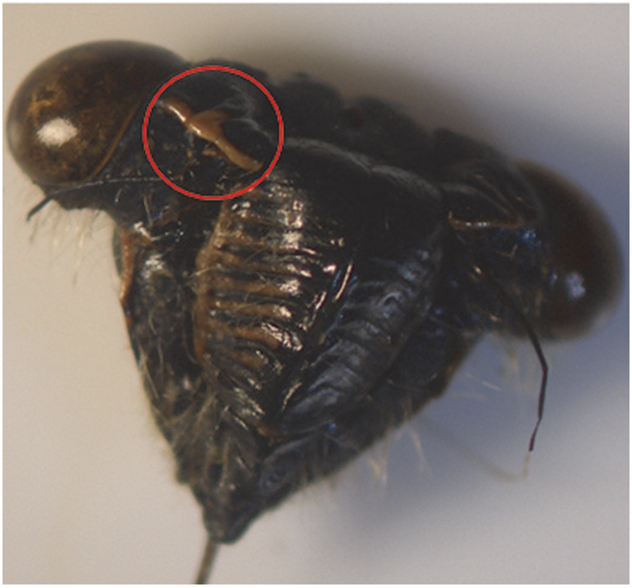

Figure 3. Pattern with yellow supra-antennal plate

Figure 4. Pattern with black supra-antennal plate

Figure 5. The common pattern (2, 3) of *Cicadatra persica*

yellow supra-antennal plates (Fig. 3), and the second pattern involved Individuals with black supra-antennal plates (Fig. 4).

The results also showed that there were several patterns of individuals according to the number of spurs on the lateral and upper sides of the hind legs. The total number of patterns was 27. There were 26 patterns which was different from each other. The percent of those different patterns in individuals with yellow supra-antennal plates was 22%, and 2% in individuals with black supra-antennal plates, and the total percent was 24%. The most common pattern was (2, 3) whose individuals have 2 spurs on the upper side of the tibia of the hind legs and 3 spurs on the lateral side (Fig. 5). The per-

Table 2. Number of yellow supra-antennal plate individuals of *C. persica* based on the number of spurs on the tibia of the hind legs.

Number of Patterns	*Number of spurs on the tibia of the hind legs		Number of males	Number of females	Total number	Total percent
	Left leg	Right leg				
1	(2, 3)	(2, 3)	103	114	217	72.33%
2	(2, 3)	(2, 4)	2	3	5	1.67%
3	(2, 4)	(2, 3)	7	4	11	3.67%
4	(2, 4)	(2, 4)	2	3	5	1.67%
5	(2, 5)	(2, 4)	0	2	2	0.67%
6	(2, 3)	(3, 3)	2	6	8	2.67%
7	(3, 3)	(3, 4)	0	1	1	0.33%
8	(2, 3)	(1, 3)	2	2	4	1.33%
9	(1, 3)	(2, 3)	1	1	2	0.67%
10	(2, 4)	(2, 5)	1	0	1	0.33%
11	(2, 3)	(2, 2)	5	2	7	2.33%
12	(3, 3)	(3, 3)	1	0	1	0.33%
13	(3, 3)	(2, 3)	2	1	3	1%
14	(2, 5)	(2, 3)	1	1	2	0.67%
15	(2, 3)	(1, 1)	2	0	2	0.7%
16	(2, 3)	(3, 4)	0	1	1	0.33%
17	(2, 6)	(2, 6)	0	1	1	0.33%
18	(3, 4)	(0, 1)	1	0	1	0.33%
19	(3, 4)	(2, 5)	1	0	1	0.33%
20	(2, 5)	(2, 5)	1	0	1	0.33%
21	(1, 6)	(3, 5)	1	0	1	0.33%
22	(4, 4)	(2, 3)	1	0	1	0.33%
23	(2, 5)	(4, 4)	1	0	1	0.33%
24	(2, 6)	(2, 5)	1	0	1	0.33%
25	(2, 5)	(3, 4)	0	1	1	0.33%
26	(2, 2)	(2, 3)	0	1	1	0.33%
27	(1, 2)	(2, 3)	0	1	1	0.33%
Total	-	-	139	145	284	94.33%

* the first number refer to the number of the spurs on the upper side of tibia of the hind leg, and the second number refer to the number of the spurs on the lateral side of tibia of the hind leg.

cent of that common pattern was 72.33% in individuals with yellow supra-antennal plates, and 3.67% in individuals with black supra-antennal plates, and the total percent was 76% (Table 2, 3). The hind leg of *Cicadatra persica* had 14 different patterns (Figs 5–18) based on the number of spurs on its tibia, and they were:

(2, 3), (2, 4), (2, 5), (3, 5), (3, 3), (3, 4), (1, 3), (2, 2), (1, 1), (1, 2), (0, 1), (2, 6), (1, 6), (4, 4).

Table 3. Number of black supra-antennal plate individuals of *C. persica* based on the number of spurs on the tibia of the hind legs.

Number of Patterns	*Number of spurs on the tibia of the hind legs		Number of males	Number of females	Total number	Total percent
	Left leg	Right leg				
1	(2, 3)	(2, 3)	8	3	11	3.67%
2	(2, 3)	(2, 4)	2	0	2	0.67%
3	(2, 4)	(2, 3)	1	2	3	1%
13	(3, 3)	(2, 3)	1	0	1	0.33%
Total	-	-	12	5	17	5.67%

Figure 6. Pattern (2, 4) of *Cicadatra persica*

Figure 7. Pattern (2, 5) of *Cicadatra persica*

Figure 8. Pattern (3, 5) of *Cicadatra persica*

Figure 9. Pattern (3, 3) of *Cicadatra persica*

Figure 10. Pattern (3, 4) of *Cicadatra persica*

Figure 11. Pattern (1, 3) of *Cicadatra persica*

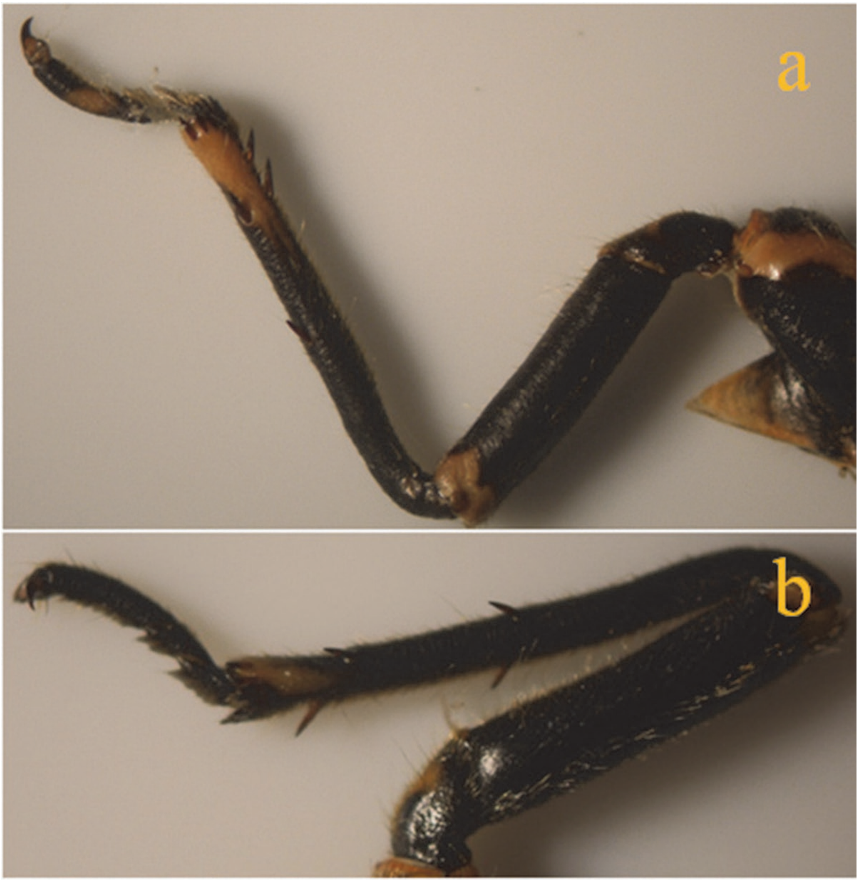

Figure 12. a, b Pattern (2, 2) of *Cicadatra persica*

Figure 13. Pattern (1, 1) of *Cicadatra persica*

Figure 14. Pattern (1, 2) of *Cicadatra persica*

Figure 15. Pattern (0, 1) of *Cicadatra persica*

Figure 16. Pattern (2, 6) of *Cicadatra persica*

Figure 17. Pattern (1, 6) of *Cicadatra persica*

Figure 18. Pattern (4, 4) of *Cicadatra persica*

Discussion

Egg nests and adults

The results showed that there could be a relation between the two basic patterns of egg nests made by females of *C. persica* and the two basic patterns of individuals based on the color of supra-antennal plate. The first pattern of egg nests which formed 90% could be laid by the first pattern of females with yellow supra- antennal plates which formed more than 90% of total individuals. The second pattern of egg nests which formed 10% could be laid by the second pattern of females with black supra- antennal plates which formed less than 10% of total individuals. But this supposition needs to be proved by separating the individuals of each pattern and monitoring the egg nests laid by each of them. This result also refer to that could be two basic strains of *C. persica* the first one with a yellow supra- antennal plate, and the second with a black supra-antennal plate, and this supposition also need to be proved by doing some microbiological studies on the DNA of this species.

Adults and host plants

The results showed that there was a common pattern (2, 3) of individuals based on the number of spurs on the tibia of the hind legs whose individuals have 2 spurs on the upper side of the tibia and 3 spurs on the lateral side of the tibia. The total percent of that pattern was 76% and this percent correspond with the percent of apple fruit orchards in Erneh which is about 75%. The total percent of other patterns was 24% and this corresponds with the percent of other different fruit orchards in Erneh which is about 25%. The morphological differences among the individuals of *C. persica* in the number of spurs on the tibia of the hind legs may be related to the host plant which the individual feed on its sap during the juvenile stage underground.

Conclusion

This research showed that there are different patterns of egg nests and morphological differences of *Cicadatra persica*, distributed in fruit orchards in Erneh. The result lead to do further investigations on the morphological differences and studying other morphological characters of this species and also to study the DNA of those different patterns of *C. persica* to prove if these differences in the morphological characters related to the genetic differences or other ecological factors.

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RESEARCH ARTICLE

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Thorax morphology of selected species of the genus *Cacopsylla* (Hemiptera, Psylloidea)

Jowita Drohojowska[1], Małgorzata Kalandyk-Kołodziejczyk[1], Ewa Simon[1]

[1] *Department of Zoology, University of Silesia, Bankowa 9, 40-036 Katowice, Poland*

Corresponding author: *Jowita Drohojowska* (jowita.drohojowska@us.edu.pl)

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Abstract

The paper concerns with characteristics of a thorax morphological structure *Cacopsylla* Ossiannilsson, 1970 species, referring to an analysis of five species classified in the past in three subgenera. The structure of the sternites, tergites and pleurites of all the parts of the thorax was studied by a scanning microscope. Descriptions of particular elements building up thorax plates, their shape, size and links as well as a course of all the clefts and sulcus are provided. The study of thorax morphology of *Cacopsylla* species suggests that the thorax morphology is relatively homogenous within a genus.

Keywords

Psylloidea, *Cacopsylla*, morphology, thorax

Introduction

Jumping plant-lice or psyllids (Psylloidea) constitute a superfamily of Sternorrhyncha comprising over 3800 described species of small plant-sap feeding insects (Li 2011).

Studies of the adult morphology have concentrated mainly on the head, fore and hindwings as well as the terminalia (Klimaszewki 1975, Hodkinson and White 1979, Ossiannilsson 1992). Despite the fact that the thorax of adult psyllids is relatively large compared to the total body length, there is surprisingly little information available on its detailed morphology (Stough 1910, Crawford 1914, Taylor 1918, Weber 1929, Tremblay 1965, Ouvrard et al. 2002, 2008). This is mainly because most morphological data relate to diagnostic features of which few have been found on the thorax. Heslop-Harrison (1951) sought taxonomically useful characters in the prothorax (shape of propleurites and propleural sulcus) to separate his subfamilies Liviinae and Aphalarinae. Loginova (1978) used the relative lengths of the pronotum, mesopraescutum and mesoscutum to separate *Thamnopsylla* from the other subgenera of *Cacopsylla*. This character was also used by Burckhardt (2010). Klimaszewski (1975) used the shape of propleural sulcus to separate Arytaininae from Psyllinae.

The genus *Cacopsylla* Ossiannilsson, 1970 belongs to the subfamily Psyllinae (Psyllidae) and consists of approximately 170 described species associated with woody dicotyledonous plants as does the majority of species of this family and psyllids in general. The genus has a predominantly Holarctic distribution with a few species occurring in the Afrotropical, Oriental and Australian biogeographical regions (Hollis 2004, Burckhardt pers. comm.). This large genus has been divided into the taxa *Cacopsylla* s.str. Ossiannilsson, 1970, *Hepatopsylla* Ossiannilsson, 1970, *Osmopsylla* Loginova, 1978 and *Thamnopsylla* Loginova, 1978. Recently Burckhardt and Ouvrard (2012) synonymised all subgenera with *Cacopsylla*.

Material and methods

Adult psyllids were collected with an entomological sweep-net and killed in vapours of potassium cyanide. After air drying and removing the wings and legs, the specimens were cleaned with 10% alcohol and then mounted on a stub for the analysis in a low vacuum electron scanning microscope S-3400N. The specimens were not gold coated. The following species were analysed: *Cacopsylla peregrina* (Foerster, 1848), syn. *C.* (*Cacopsylla*) *peregrina* (Foerster, 1848); *Cacopsylla sorbi* (Linnaeus, 1767), syn. *C* (*Cacopsylla*) *sorbi* (Linnaeus, 1767); *Cacopsylla ambigua* (Foerster, 1848), syn. *C.*(*Hepatopsylla*) *ambigua* (Foerster, 1848); *Cacopsylla crataegi* (Schrank, 1801), syn. *C.* (*Thamnopsylla*) *crataegi* (Schrank, 1801); *Cacopsylla melanoneura* (Foerster, 1848), syn. *C.* (*Thamnopsylla*) *melanoneura* (Foerster, 1848). Additional 24 *Cacopsylla* species deposited in the Department of Zoology, University of Silesia (Poland) were analysed using Nikon MZ1500 stereoscopic microscope.

Morphological terminology and the list of abbreviations used to describe the photographs is after Ouvrard et al. (2002, 2008): aas- anterior accessory sclerite, acl2- anapleural cleft, apwp- anterior pleural wing process, axc2- axillary cord, cx1- procoxa, cx2- mesocoxa, cx3- metacoxa, epm1- proepimeron, epm2- mesepimeron, epm3- metepimeron, eps1- proepisternum, eps2- mesepisternum, eps3- metepisternum, fpa2- fossa of the pleural apophysis, ftna2- fossa of the trochantinal apodeme on mesothorax, ftna3- fossa of the trochantinal apodeme on metathorax, kes2- katepisternum, mcs- meracanthus, nt1- pronotum, pas- posterior accessory sclerite, pls1- propleural sulcus, pls2- mesopleural sulcus, pls3- metapleural sulcus, pnt2- mesopostnotum, pnt3- metapostnotum, ppt- parapterum, psc2- mesopraescutum, ptm2- mesothorax peritreme, ptm3- metathorax peritreme, s2- mesosternum, sc2- mesoscutum, sc3- metascutum, scl2- mesoscutellum, scl3- metascutellum, tg-tegula, trn2- mesothorax trochantin, trn3- metathorax trochantin.

Results

In all *Cacopsylla* species the head is strongly inclined from longitudinal body axis resulting in an arched dorsal outline of the thorax. The prothorax is the smallest thorax segment and undergoes strong modifications because the mouth parts are displaced posteriad. Mesothorax is the biggest part of the thorax related to a functional dominaton of forewings, which is further connected with the development of muscles that move them.

Dorsum (Fig. 1A, B, C). The dorsum of the prothorax consists of one sclerite, the pronotum (nt 1), which is narrow and arcuate medially. Anterior and posterior margins of pronotum are distinct. The pronotum is narrower than the head including eyes but wider than vertex. Laterally the pronotum is as long as the pronotum along midline. The dorsum of the mesothorax is divided into the large mesonotum and the small, transverse, weakly raised mesopostnotum. The mesonotum is divided into three sclerites: mesopraescutum (psc2), mesoscutum (sc2) and mesoscutellum (scl2), which are separated from each other by a distinct sulcus. The mesopraescutum (psc2) is a medium sized sclerite, it's fore margin is slightly arched and covered by the hind margin of the pronotum. The hind margin of the mesopraescutum is vaguely semicircular. The mesopraescutum and mesoscutum are linked together because the sulcus which separates them is not complete. In the middle there are two symmetrical joints except for *C. ambiqua*. The mesoscuctum (sc2), the biggest sclerite of the mesonotum, is U-shaped with elongated processes reaching the parapteron. The mesoscutellum (scl2) is

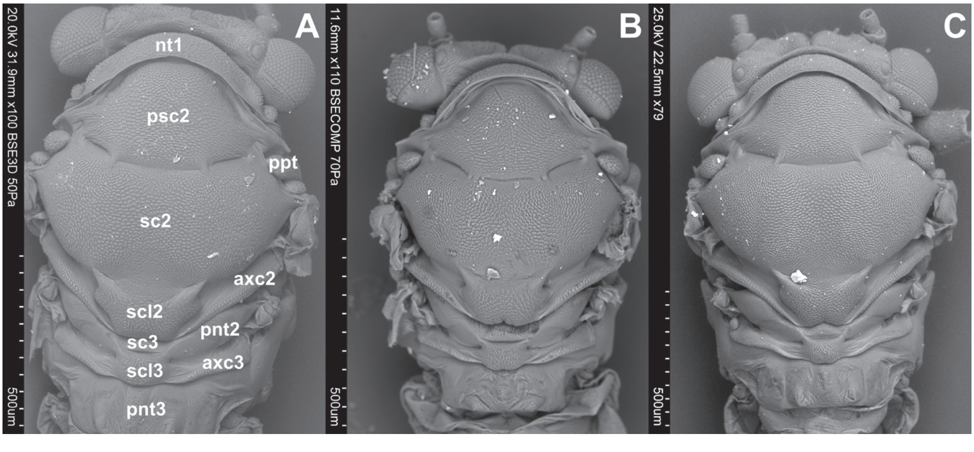

Figure 1. Dorsal side. **A** *Cacopsylla peregrina* **B** *C. crataegi* **C** *C. ambigua*

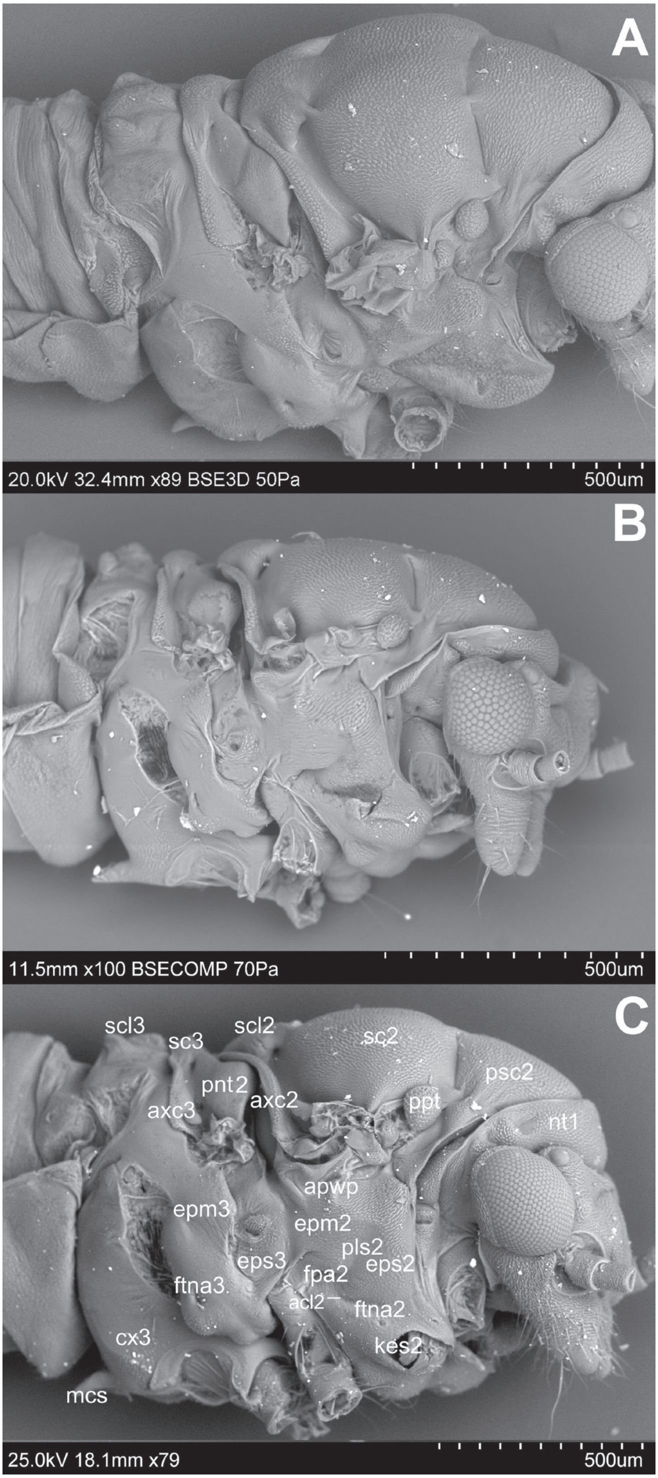

Figure 2. Lateral side **A** *Cacopsylla peregrina* **B** *C. crataegi* **C** *C. ambigua*

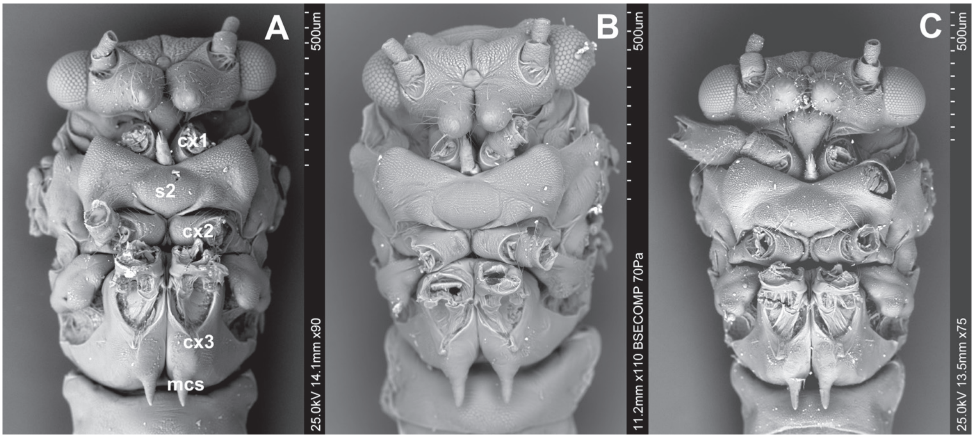

Figure 3. Ventral side **A** *Cacopsylla peregrina* **B** *C. crataegi* **C** *C. ambigua*.

small and trapezoidal. The hind part of the mesoscutellum is strongly incised in the middle in *Hepatopsylla* and some *Thamnopsylla* species. The mesopostnotum, situated behind mesonotum, is not visible dorsally as it is covered by the mesoscutellum (scl2), laterally it forms a narrow ridge running diagonally towards the mesoepimeral sclerite. The metathorax consists dorsally of the metanotum and metapostnotum. The metanotum consists of two plates, the metascutum (sc3) and the metascutellum (scl3). The metascutum (sc3) is a small sclerite, while the metascutellum (scl3) is bigger and clearly raised in relation to the metascutum. The metapostnotum (pnt3) is relatively large and trapezoidal. The metapostnotum is completely fused with the first abdominal tergite.

Pleura (Figs 2A, B, C). Laterally the pronotum is constituted by two easily visible pleurites (Fig. 4), the proepisternum (eps1) in front and the proepimeron (epm1) at the rear. Proepisternum and proepimeron are of the same size. They are always clearly separated from each other by the propleural sulcus, while their border with prothorax is not always visible. The propleural sulcus (pls1) runs from the basal coxal appendix up to the hind corner of the pronotum. The sulcus is straight without any curves. Between the pleurites of pro- and mesothorax, there are three tiny, well visible sclerites of arguable origin, which are called frontal and hind additional sclerites (aas and pas), and peritrema (ptm2) which surrounds the mesothoracic spiracle (Fig. 4). The mesothoracic pleurae consist of two large sclerites (Fig. 2), the anterior mesepisternum (eps2) and posterior mesepimeron (epm2). The shape of the mesepisternum (eps2) depends on the position of the pleural sulcus (pls2) and anapleural cleft (acl2). The mesothoracic pleural sulcus (pls2) is well visible and runs from the coxal condyle and approaches the middle of pleuron but does not reach the wing base. Shape and position of the mesopleural sulcus are variable within *Cacopsylla*. It is relatively straight in *C. peregrina*, slighty curved in the distal part in *C. melanoneura* or S-shaped and strongly curved in *C. crataegi* and *C. ambigua*. It forms a shallow furrow pleural with small, shallow fossa (ftna2) in *C. melanoneura* or a distinct furrow with deep fossa in *C. ambigua*. It is very long, reaching the end of the mesepisternum in *C. crataegi* but considerably shorter in the other

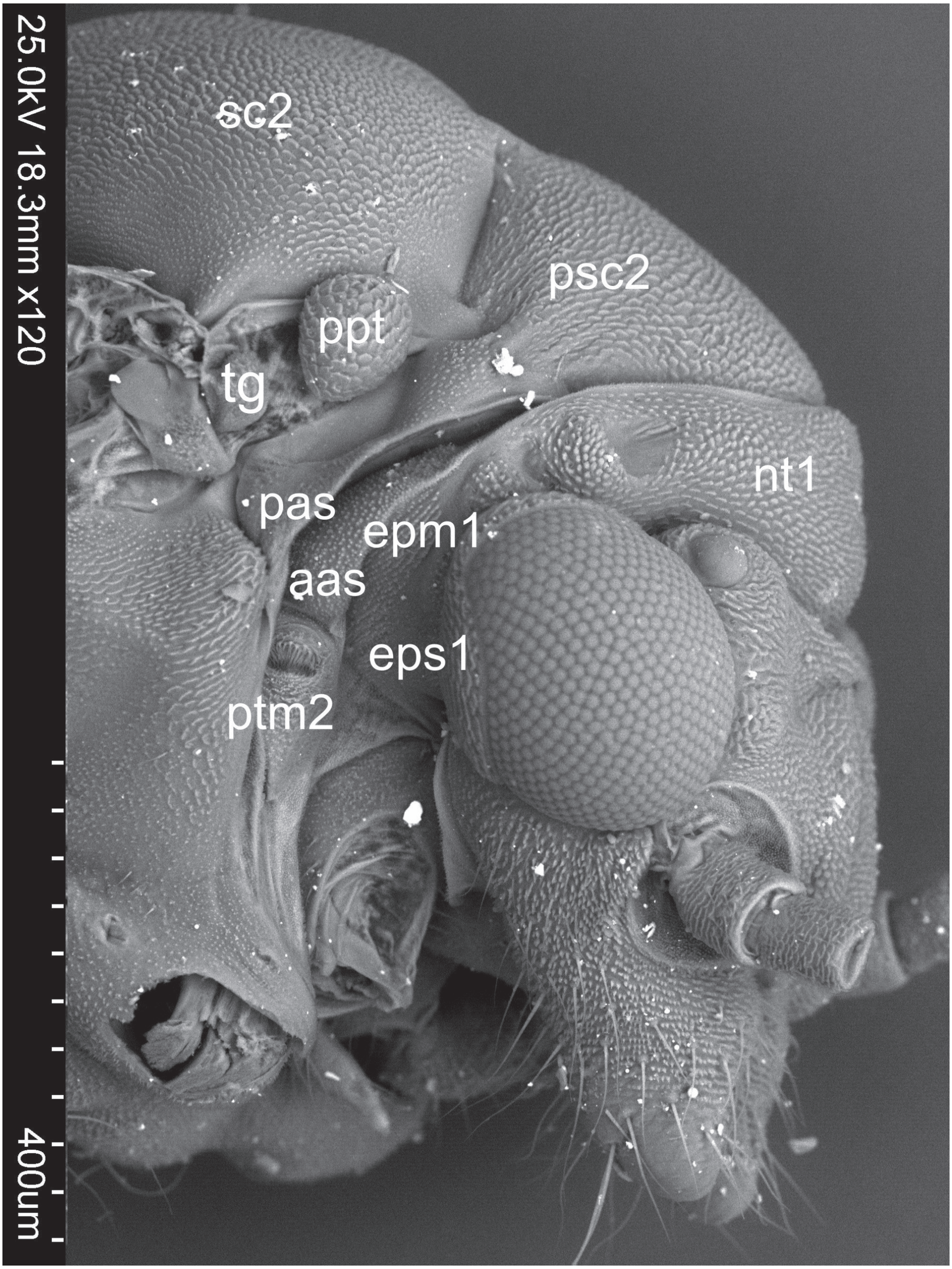

Figure 4. Sclerites between pleurites of pro- and mesothorax of *Cacopsylla crataegi*

species. The anapleural cleft (acl2) is straight and almost horizontal, the transepimeral sulcus is very short and distinct, it is never straight. The anterior pleural wing process (apwp) is thin and elastic. Parapteron (ppt) and tegula (tg) have the same oval shape and the katepisternal complex (kes2) is rounded and subtle striped. The metapleurites are well developed. The metapleural sulcus (pls3) is visible and reduced at a short distance ventrad. This sulcus does not separate metaepimeron and metaepisternum entirely. The metapleuron is strongly modified by a vertical prolongation of the coxal meron. The latter enforces on metaepimeron and metaepisternum a development into a long, thickened arch stretching above the metacoxa. The metathoracic stigma (stg3), trochantin (trn3) and external fossa of the trochantinal apodeme (ftna3) are well visible.

Venter (Figs 3A, B, C). The prothoracic sternum of psyllids is significantly reduced and covered by the rostrum. The mesothoracic venter is constituted by a well-developed sclerite, the mesosternum (s2), connected with mesocoxa. The metathoracic venter is narrow, in front it takes the form of a thickened plate, surrounding metacoxae (cx3) (Figs 3A, B).

Discussion

The analysis of the thorax morphology of selected *Cacopsylla* species did not indicate any characters defining the subgenera described by Ossiannilsson (1970) and Loginova (1978). However, characters which are common for all *Cacopsylla* species are described. In the analysed species the pronotum is narrow, arcuate medially and well-defined laterally. The pronotum is narrower than the head including eyes, but wider than vertex; in all species it is laterally as long as it is along the midline. The pronotal shape is homogenous within this genus but differs from some other psyllid genera (Ouvrard et al. 2002, Drohojowska 2009a). Detailed studies on the thorax morphology were made by the senior author and the results will be published soon. Generally, a massive, wide and straight pronotum is observed in the Lividae family, narrower than the width of the head and slightly bended is observed in the Aphalaridae, Homotomidae and Phacopteronidae families. In the representatives of the Triozidae family one can observe a narrowing and bending of pronotum which modify it to become a thin, hardly visible batten. In the species of Carsidaridae the pronotum is wide, slightly bended, whereas in the case of Calyophyidae the pronotum is much bended and narrowing to a different extent in the middle part. In the species of the Psyllidae family the pronotum has a diversified shape (Drohojowska 2009a, Drohojowska unpublished data).

An additional feature common for all *Cacopsylla* species is the straight rather than undulating propleural sulcus stretching from the basal coxal appendix to hind corner of the pronotum, and not in the middle, like for example in *Craspedolepta* species or the fore corner of pronotum like in *Livia* species (Drohojowska 2009a, b). Three additional sclerites (aas, pas and peritrema) are well visible in all examined species. The shape of mesothoracic sclerites and sulcus is the same in all *Cacopsylla* species. Loginova (1978) suggested that the mesoscutum is distinctly longer than the mesopraescutum along the median longitudinal body axis and the mesopraescutum is about twice as long as the pronotum in *Thamnopsylla* species,whereas in the other subgenera the mesoscutum is as long as or slightly longer than the mesopraescutum and both are more than twice as long as the pronotum. We could not confirm this suggestion. An additional character common to all species is the shape of anapleural cleft. The position of the anapleural cleft (acl2) varies in psyllids ranging from diagonal to almost horizontal (Drohojowska 2009a) but in all *Cacopsylla* species it is straight and almost horizontal. The parapteron (ppt) and tegula (tg) have the same oval shape, the anterior pleural wing process (apwp) is thin and elastic, the metathorax stigma (stg3), trochantin on metathorax (trn3) and the external fossa of the trochantinal apodeme (ftna3) are well visible and the katepisternal complex (kes2) is rounded and striped in all *Cacopsylla* species. The connecting points of the mesopraescutum with the mesoscutum are symmetrical and onefolded for every species. Only in *C. ambiqua* the points are double (Fig. 1B). It seems that it is a character specific to this species because this type of connection does not occur in other *Hepatopsylla* species and in other examined *Cacopsylla* species.

This and earlier studies (Journet and Vickery 1978, Drohojowska 2009b) suggest that the thorax morphology is relatively homogenous within a genus.

The study of thorax morphology of *Cacopsylla* species shows that the only difference between the male and the female is in the size of the latter. Shapes and proportions between particular elements of the thorax are the same in the representatives of both sexes. The results confirm those of previous studies (Drohojowska 2009b).

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The genus *Cahara* Ghauri, 1978 of China (Hemiptera, Heteroptera, Pentatomidae, Halyini) with descriptions of two new species

Zhong-hua Fan[1,†], Guo-qing Liu[1,‡]

[1] *Institute of Entomology, Nankai University, No. 94 Weijin Road, Nankai District, Tianjin 300071, China*

† *urn:lsid:zoobank.org:author:6DDE19AC-686E-43C3-95DF-C0F26D49D291*
‡ *urn:lsid:zoobank.org:author:F7CFE026-14B3-4209-A5A0-6FA52FD9D266*

Corresponding author: *Zhong-hua Fan* (zhfan@nankai.edu.cn)

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Abstract

Cahara Ghauri from China with three species is reviewed here. Two of them, *C. incisura* **sp. n.** and *C. nodula* **sp. n.** are described here. Key to the three Chinese species, habitus photographs and illustrations of genitalia are also provided. All examined materials including the types of three species mentioned are deposited in the Institute of Entomology, Nankai University, Tianjin, China (NKUM).

Keywords

Hemiptera, Heteroptera, Pentatomidae, *Cahara*, China, new species

Introduction

Ghauri (1978) erected a new genus *Cahara* of Halyini to accommodate three species formerly belonged to genus *Dalpada* Amyot & Serville, 1843, and the other six new species. Later in 1986, Zheng and Liu (1986) reported one new species *C. tibetana* found in China.

Xu and Zheng (1993) discussed the phylogenetic relationships of the nine genera of *Dalpada*-group including *Cahara* based on 18 morphological characters. Hasan and

Kitching (1993) make a cladistic analysis of 21 tribes in Pentatomidae, and suggest a monophyletic clade as "megarrhamphine tribal-group" to accommodate Halyini, Megarrhamphini, Tetrodini and Phyllocephalini. Wall (2004) also states that the Halyini is not monophyletic. Memon et al. (2011) make a phylogenetic analysis using 61 morphological characters from 31 genera of south Asian Halyini, and the single most parsimonious tree shows that *Ameridalpa* Ghauri, 1982 is the sister group to *Cahara*, while the bootstrap support value is under 50%. Later Barão et al. (2012) point out that the analysis of Memon et al. (2011) has some under-developed aspects.

Here we do not discuss the status of *Cahara* in Halyini, since both the monophyly and definition of Halyini are doubted. Memon et al. (2011) only define the south Asian Halyini, and indicate that the inclusions in the Halyini of many genera from other parts of the world is under discussion, but *Cahara* has always been placed in Halyini (Ghauri 1978, Zheng and Liu 1986, Xu and Zheng 1993, Memon 2002, Rider 2006, Memon et al. 2011). In this paper two new species from China are described. So far totally twelve species of *Cahara* are recorded.

Materials and methods

Male genitalia were illustrated after treatment with warm 2% NaOH solution for about 30–50 min, while female genitalia were illustrated directly. Photographs of both dorsal and ventral habitus were made using a Nikon SMZ1000. All measurements are in millimeters. All the studied specimens including the examined types are deposited in the Institute of Entomology, Nankai University, Tianjin, China (NKUM). The terminology of aedeagus follows Konstantinov and Gapon (2005), pygophore follows Schaefer (1977), female genitalia follows Schaefer (1967)

Taxonomic part

Cahara Ghauri, 1978

http://species-id.net/wiki/Cahara

Cahara Ghauri 1978: 163; Rider 2006: 305; Xu and Zheng 1993: 18; Memon 2002: 117; Memon et al. 2011: 1049.

Type species. *Dalpada brevivitta* Walker, 1867 by original designation.

Key to Chinese species of *Cahara*

1 Lateral margin of each mandibular plate with an angular process before eye (Figs 3a–b); ventral margin of male pygophore with two mesial processes originating from one stem (Fig. 29) .... ***C. tibetana* Zheng & Liu, 1986**

– Lateral margin of each mandibular plate without any angular process before eye (Figs 1a–b, 2a–c); ventral margin of male pygophore without above processes 2

2 Apex of clypeus broad, mandibular plates not convergent at the apex (Figs 2a–c); humeral angles distinctly elevated (Fig. 5); rostrum passing beyond the middle of the 4th sternum; ventral margin of male pygophore without process (Fig. 21).. ***C. nodula* sp. n.**

– Apex of clypeus narrow, mandibular plates convergent at the apex (Figs 1a–b); humeral angles not elevated (Fig. 4); rostrum reaching the middle of 3rd sternum; ventral margin of male pygophore with two lateral separated processes (Fig. 13) .... ***C. incisura* sp. n.**

***Cahara incisura* Fan & Liu, sp. n.**

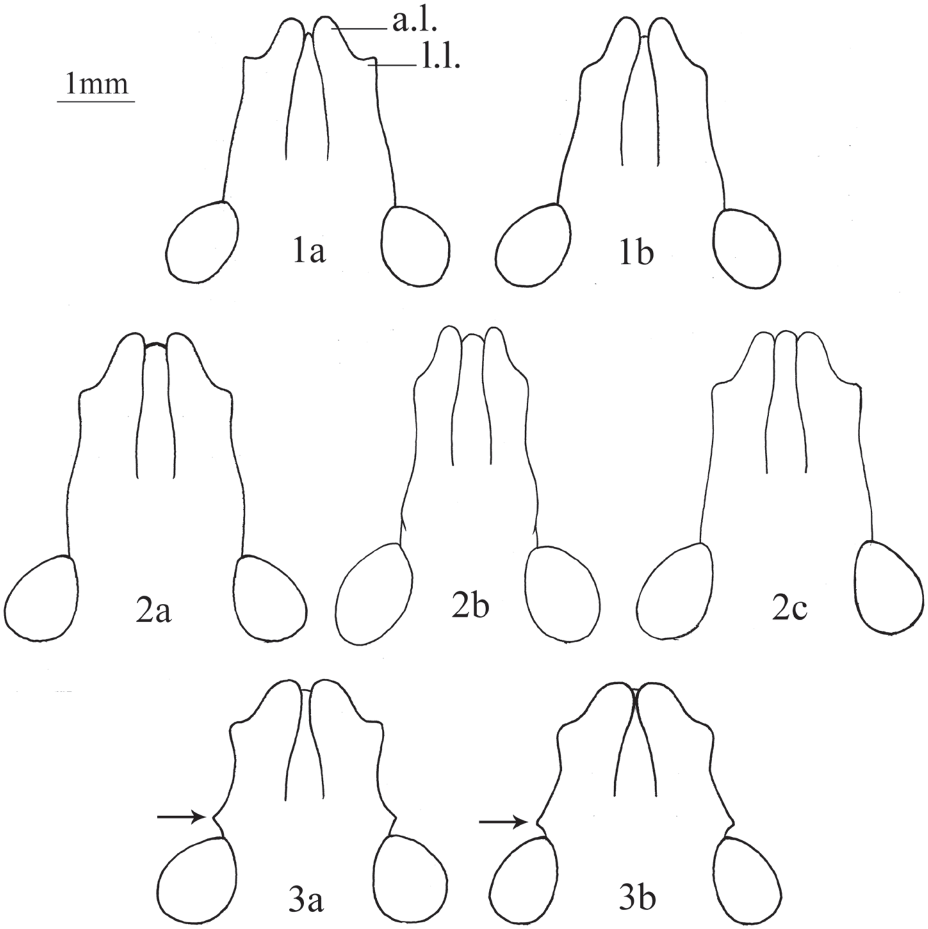
urn:lsid:zoobank.org:act:0ABF44CA-EE92-47D2-8864-68409E204BEA
http://species-id.net/wiki/Cahara_incisura
Figs 1a–1b, 4, 7–8, 13–20

Type material. Holotype male, pinned, **CHINA: Sichuan Province:** Mianning County, Liangshan Prefecture, 29. VIII. 2008, Kai DANG leg. **Paratypes**: all pinned, **CHINA: Sichuan Province:** 1 female, same data as holotype; 1 male, with genitalia in a separate microvial, same data as holotype.

Diagnosis. Rostrum reaching the middle of 3rd sternum, pronotal humeral angles not elevated upwards, apical meeting trend of mandibular plates are all similar to *C. tibetana*. But *C. tibetana* has a distinct angular process before each eye along the lateral margin of mandibular plate, mandibular plates about equal to or slightly longer than clypeus. While in this new species, mandibular plates are always longer than the clypeus, lateral margins of head sinuate and with no angular process before eye.

Body size Male, length 16.0mm , width between humeral angles 8.0mm. Female, length 17.0mm, width between humeral angles 8.5mm.

Description. Color and puncturing. Dorsum fuscous, darkly and thickly punctured, with several obscure patches formed by dense punctures: four or five longitudinal strips on the pronotum, five on the scutellum (one short oblique strip near each arcuate callus behind the fovea of scutellar basal angle, one patch on central disk, two short longitudinal stripes at the level of the posterior apices of frena), two or three patches on each corium. Scutellar apex paler and punctures finer. Calli on the anterior disk of pronotum ochraceous with punctures in the middle. Humeral angles piceous, tips a little pale, with several transverse furrows and wrinkles on the dorsal base. Hemelytral membrane fuliginous, except apices of veins paler. Head beneath black, except buccula and one obscure strip behind each antenniferous tubercle ochraceous. Thoracical pleura thickly and darkly punctured, each episternum with an ochraeous, laevigate and arcuate fascia distally. Mesosternum black strips laterally. Legs ochraceous, with irregular brown spots, tibiae paler in the middle third and darker in the apical third, first two tarsal segment and apex of the third one

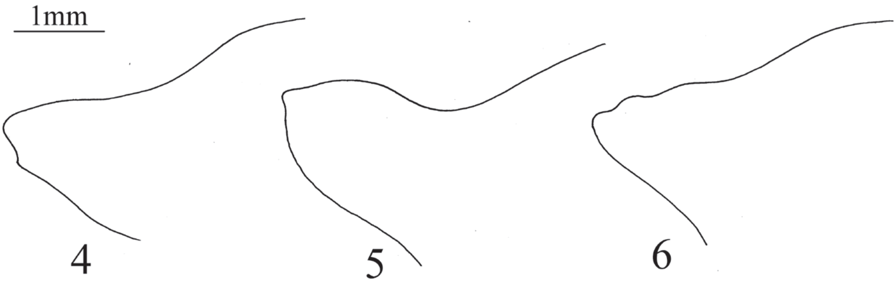


Figures 1–3. Heads in dorsal view. **1a–b**. *Cahara incisura* sp. n. (**a** holotype, **b** paratype). **2a–c** *C. nodula* sp. n. (**a** holotype, **b** paratype, **c** paratype) **3a–b** *C. tibetana* (**a** holotype, **b** allotype). (a.l. apical lobe of mandibular plate, l.l. lateral lobe of mandibular plate).

white dorsally. Ventral abdomen smooth at center, punctures gradually getting denser laterally. Middle third of each laterotergite with a transverse brown impunctate stripe.

Structure. Head. Mandibular plates longer than clypeus, apices with meeting trend but still separated, forming an incision before clypeus. Lateral lobes of mandibular plates are found angulate in the male holotype and the female paratype (Fig. 1a), but obtuse in the male paratype (Fig. 1b). Buccula with anterior angle not produced, gradually evanescent posteriorly. Antennae ochraceous, darker to the end, antennomere I paler except each lateral side, base of antennomere IV and basal third of antennomere V stramineous, IV> V>III >II>I in length. Rostrum reaching the middle of 3rd sternum, apex of 1st segment equal to the posterior end of buccula.

Thorax. Pronotum with anterior margin slightly convex in the middle, anterior angle produced laterad, anterolateral margins concave, crenulate along the anterior



Figures 4–6. Right humeral angles in cephalic view. **4** *Cahara incisura* sp. n. **5** *C. nodula* sp. n. **6** *C. tibetana*.

Figures 7–12. *Cahara* spp. **7–8** *C. incisura* sp. n., holotype **9–10** *C. nodula* sp. n., holotype **11–12** *C. tibetana,* allotype.

half, crenulation getting weaker posteriorly. Humeral angles horn-like, apices obtuse, slightly produced and not elevated upwards. Hemelytral membrane longer than the abdominal end. Peritreme groove shaped according to Kment and Vilímová (2010), which is narrow, long, curved, apex rounded, median furrow is well developed in most of its length. A narrow and long carina along the midline of mesosternum.

Abdomen. Connexiva exposed broadly, posterior angles sharp and produced. Mesial groove on ventral side not distinct.

Male genitalia. Ventral rim of pygophore with two separated processes on both lateral sides. Suspensory apodeme and infoldings of lateral rims developed. Paramere L–shaped, stem with a short basal process, apex of blade obtuse without any distinct process. Phallotheca cylindric, with a mesial process on the base of ventral side. Aedeagus with a pair of dorsal conjunctival processes, sclerotized and fingerlike, a trifurcate membraneous conjunctival lobe, a pair of ventral conjunctival processes, slightly sclerotized. Median penial plates oblong and narrow, about as long as the protrudent vesica.

Female genitalia. Paler in color, punctured on gonocoxites I and paratergites VIII, punctures on gonocoxites I finer. Mesial margins of gonocoxites I narrowly black, meeting each other along the basal halves, lateral margins of the fingerlike processes not vertical. Gonocoxite II with a transverse tumescent beam full of setae. Paratergits IX obtuse apically, slightly passing beyond the posterior margin of 8th sternum. Paratergites VIII not protrudent apically.

Etymology. The species name, *incisura*, refers to the longer mandibular plates that always leave an incision before clypeus. It's feminine.

Distribution. Southwest China (Sichuan)

Cahara nodula Fan & Liu, sp. n.

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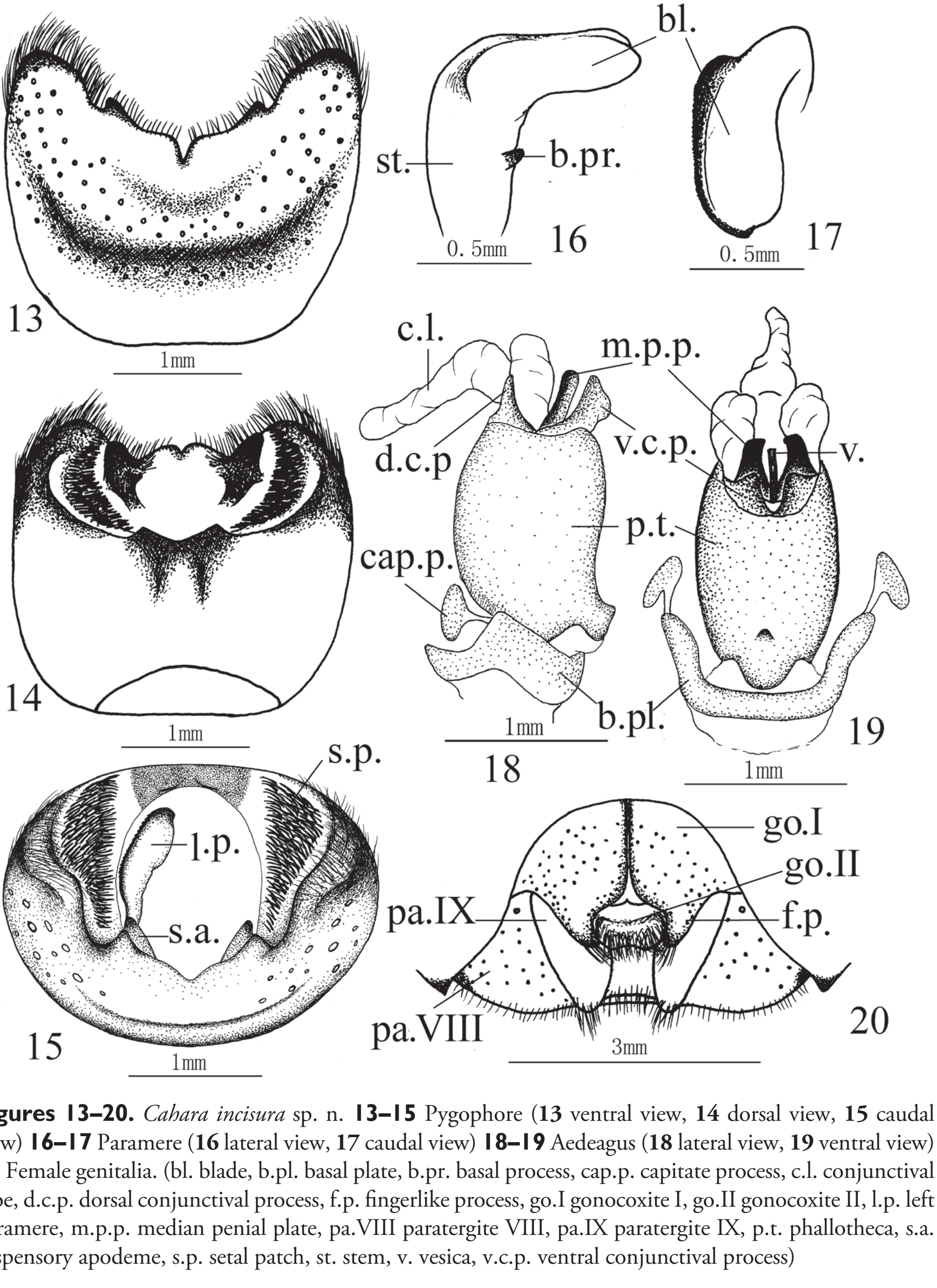
http://species-id.net/wiki/Cahara_nodula
Figs 2a–2c, 5, 9–10, 21–28

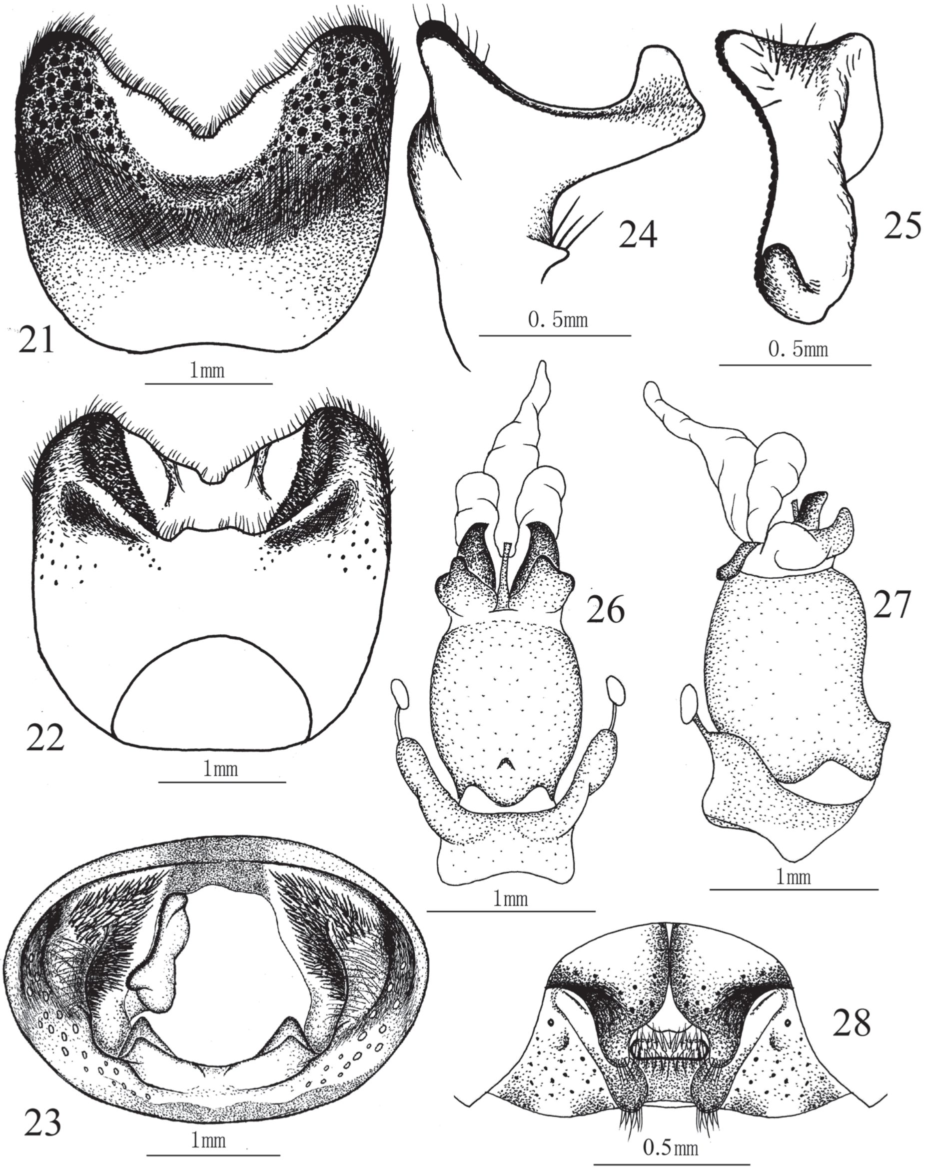
Type material. Holotype male, pinned, **CHINA: Yunnan Province:** Xiang Mount., 5. VIII. 1979, Huan–guang ZOU leg. **Paratypes**: all pinned, **CHINA: Yunnan Province:** 1 female, same place and collector as holotype, 2. VIII. 1979; 1 female, same place as holotype, 15.VIII.1979, Zuo–pei LING leg.; 2 males (one with genitalia in a separate microvial), 1 female, Kunming, VII. 1957; 1 female, same data as above except date, IV. 1986; 1 female, same data as above except date, V. 1986; 1 female, same data as above except date, VII. 1986; 1 male, same data as above except date, 17. VI. 1988; 1 male, Anning City, 12. V. 1988, Yun–xu WANG leg.; 1 female, Wushan Town, Mile County, alt. 2000m, 20. V. 1979, Guang–qiang YIN leg.; 1 male, with genitalia in a separate microvial, Santai Village, Dayao County, 13. VI. 1978; 1 female, Dayao County, VIII. 1980; 1 female, Dechang County, VI. 1958; 1 female, Weishan County, 4. VI. 1978; **CHINA: Guizhou Province:** 2 males, Huaxi District, Guiyang City, 23. V. 1987; 1 female, Changming Town, alt. 1050m, 9. IX. 2000, Chuan–ren LI leg.; 1 female, Fanjing Mount., alt. 1300m, 1. VIII. 2001, Wei–bing ZHU leg.



Figures 13–20. *Cahara incisura* sp. n. **13–15** Pygophore (**13** ventral view, **14** dorsal view, **15** caudal view) **16–17** Paramere (**16** lateral view, **17** caudal view) **18–19** Aedeagus (**18** lateral view, **19** ventral view) **20** Female genitalia. (bl. blade, b.pl. basal plate, b.pr. basal process, cap.p. capitate process, c.l. conjunctival lobe, d.c.p. dorsal conjunctival process, f.p. fingerlike process, go.I gonocoxite I, go.II gonocoxite II, l.p. left paramere, m.p.p. median penial plate, pa.VIII paratergite VIII, pa.IX paratergite IX, p.t. phallotheca, s.a. suspensory apodeme, s.p. setal patch, st. stem, v. vesica, v.c.p. ventral conjunctival process)

Diagnosis. Humeral angles nodular and elevated upwards (Fig. 5), rostrum longer to pass beyond the middle of the 4th sternum, mandibular plates without meeting trend apically, 1st rostral segment passing beyond the posterior end of buccula, ventral rim of pygophore without any distinct processes (see discussion part).

Body size. Male**,** length 16.0–18.0 mm, width between humeral angles 8.0–8.8 mm. Female, length 19.0–20.0 mm, width between humeral angles 9.0–10.0mm.



Figures 21–28. *Cahara nodula* sp. n. **21–23** Pygophore (**21** ventral view, **22** dorsal view, **23** caudal view) **24–25** Paramere (**24** lateral view, **25** caudal view) **26–27** Aedeagus (**26** ventral view, **27** lateral view). **28** Female genitalia.

Description. Color and puncturing Very similar to *C. incisura*, but with some differences: Punctures on dorsal head denser, while sparser and finer on the endocorium, pronotum with four or five longitudinal strips, laevigate parts of calli more distinct.

Stucture. Head. Mandibular plates about equal to clypeus or slightly longer than clypeus, apices porrect and having not convergent, both apical and lateral lobes obtuse distally, lateral margins before eye sinuate and without any distinct process. Apex of clypeus broadly exposed (Figs 2a–c). Antennae brown, antennomere I paler, with a longitudinal black strip laterally, apical two third of antennomere IV and apical half of antennomere V black, IV>III≥V>II>I in length. Buccula low, anterior angles pointed and protrudent, outer margins straight. Rostrum with 1st joint extending beyond the buccula, apex reaching to the middle of 4th sternum.

Thorax. Pronotum with anterior half depressed and posterior half tumescent, anterior margin broad, sinuate, slightly convex mesially, anterior angle small, angulate and produced laterad, anterolateral magins crenulate, humeral angles nodular, protrudent, elevated upwards. Scutellum longer than width, basal disk and longitudinal midline tumescent. Meso sternum flat with a mesial narrow carina. Peritreme similar to *C. incisura*. Hemelytral corium longer than scutellum, membrane extending beyond the abdominal end.

Abdomen. Connexiva exposed, posterior angles pointed and produced. Venter, from 3rd to 6th abdominal sternite, with a mesial shallow groove.

Male genitalia. Ventral rim of pygophore V–shaped excavated, sinuate along the margin but without distinct process. Suspensory apodeme and infoldings of lateral rims developed. Paramere L–shaped, stem broad with a small basal process, blade long with an apical process and a basal process, these two processes all directed caudad. Aedeagus with paired sclerotized dorsal conjunctival processes, a trifurcate membranous conjunctival lobe, and a pair of slightly sclerotized ventral conjunctival processes. Median penial plates oblong, apices obtusely angulate. Vesica slim, protrudent.

Female genitalia. Outer margins of gonocoxites I black, so are the apical halves of paratergites IX, pratergites VIII thickly punctured. Gonocoxites I strongly sinuate mesially, broadly and distinctly depressed in the middle of the lateral margins so the fingerlike processes bent dorsally and almost vertical. Apices of fingerlike processes reaching the apical third of paratergites IX. Gonocoxite II with a transverse tumescent beam. Paratergite IX base with a short oblique ridge, apex passing a little beyond the posterior margin of 8th sternum. Paratergites VIII obtuse distally.

Etymology. The name, *nodula*, refers to the bulbous, distinct nodular humeral angles of pronotum. It's feminine.

Distribution. Southwest China (Guizhou, Yunnan)

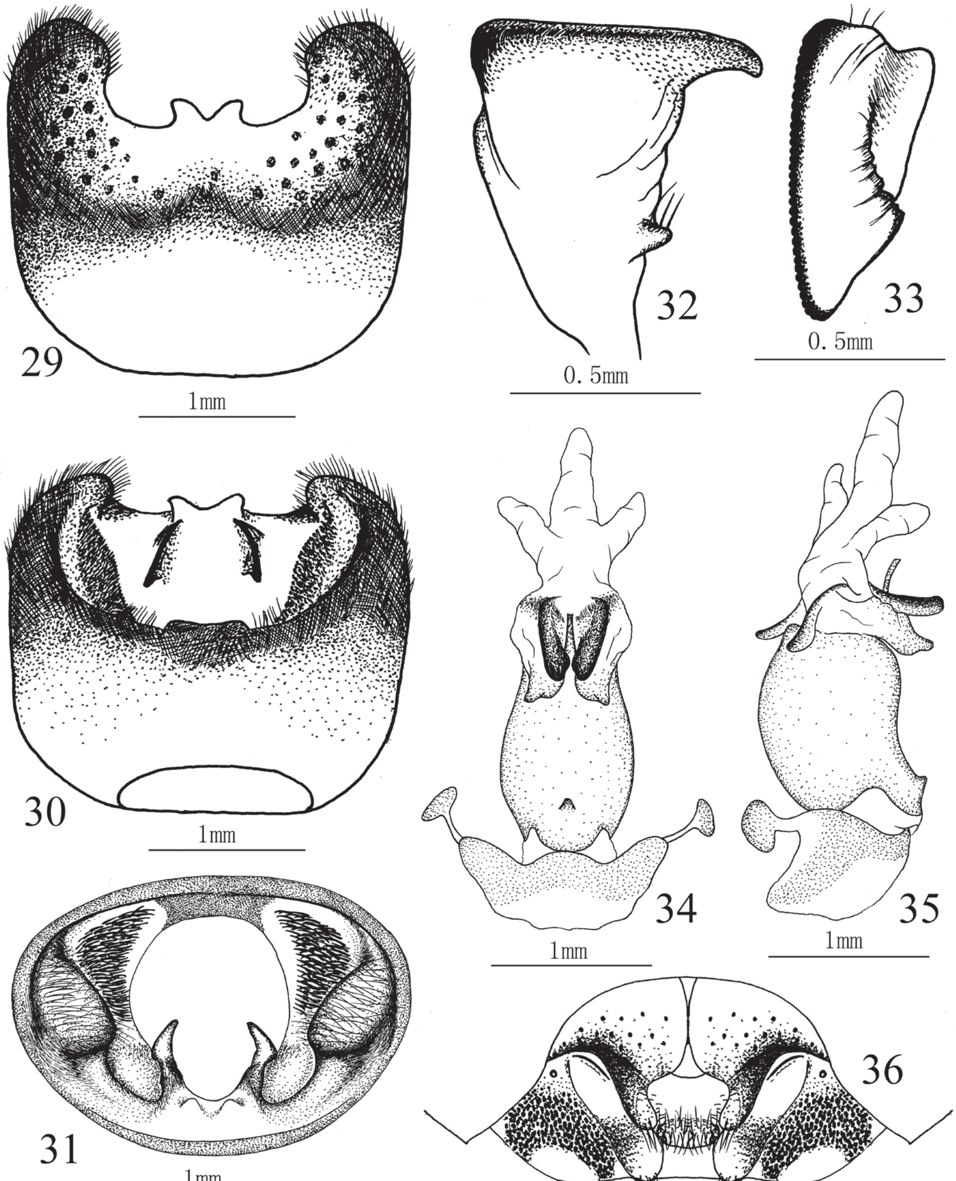
Cahara tibetana Zheng & Liu, 1986

http://species-id.net/wiki/Cahara_tibetana

Figs 3a, b, 6, 11–12, 29–36

Cahara tibetana Zheng and Liu 1986: 163; Rider 2006: 305; Xu and Zheng 1993: 18.

Type material examined. Holotype, male, pinned, with genitalia in a separate microvial, **CHINA: Xizang Autonomous Region**: Chayu County, alt. 1700m, 26. VI. 1978, Fa–sheng LI leg. **Allotype**, 1 female, pinned, same data as holotype.



Figures 29–36. *Cahara tibetana* Zheng & Liu. **29–31** Pygophore (**29** ventral view, **30** dorsal view, **31** caudal view) **32–33** Paramere (**32** lateral view, **33** caudal view) **34–35** Aedeagus (**34** ventral view, **35** lateral view) **36** Female genitalia.

Other material examined. CHINA: Xizang Autonomous Region: 1 female, Dongjiu Nature Reserve, 21. IX. 2007, Fu–min SHI leg.; 1 female, Motuo County, alt. 800m, VIII. 1984.

Diagnosis. See diagnosis of *C. incisura* sp. n. Besides, in this species, two processes on the ventral rim of pygophore connected basally, suspensory apodeme longer than those in the other two species, stem of paramere broad with two lateral margins not parallel. Gonocoxites I depressed along the lateral margin and fingerlike processes bent dorsally like *C. nodula*, but the transverse tumescent beam of gonocoxite II shorter in this species.

Distribution. Southwest China (Xizang)

Discussion

Ghauri (1978) gives both the external and internal diagnostic characters of *Cahara* to distinguish it from *Dalpada* s.s. Some of them are cited and discussed as follows:

1. "Juga longer than tylus". There are variations at least in *C. nodula* sp. n. and *C. tibetana*, but it's true that "juga" is never found shorter than "tylus".
2. "Pygophore, ventral margin with more or less deep concavity with a pair of median lobes." The mesial concavity is also present in many species of *Dalpada*. But the paired median processes play a vital role to identify the genus. It happens in most of the species of *Cahara*, but not in *C. nodula* sp. n.
3. "Female genitalia: … first valvifer produced posteriorly." In our views, this finger-like process elongated from the posterior apex of gonocoxite I is the most effective diagnostic character to distinguish *Cahara* from the other genera of Pentatominae in which it's rare. *Izharocoris* Afzel & Ahmad, 1981 (Pentatomidae: Halyini) is the other related genus that some of its species share this character. But it's different for having paramere with both the inner and the outer processes (Memon 2002) while only one inner basal process in *Cahara* (Figs 16, 24, 32). We placed the two new species in *Cahara* mainly basing on this point.
4. Ghauri (1977) indicates that *Sarju* is closely related to *Cahara*, and "the absence of median lobes in the concave ventral margin of pygophore" in *Sarju* is diagnostic. But as an exception, *C. nodula* sp. n. has no such "median lobes" either. The other useful diagnostic character is the antennomere II "distinctly bowed and appreciably swolen at apex" in *Sarju* instead of *Cahara* (Ahmad and Afzal 1984).

Those twelve *Cahara* spp. (nine species recorded by Ghauri (1978), three others here) are very similar by outlook. The useful characters to distinguish them are: the shapes of ventral rim of male pygophore, paramere distal apex, finger-like processes of gonocoxites I. By comparing the ventral rims of pygophore, the two new species *C. incisura* and *nodula* can be easily recognized from the five species of which male specimens are described in Ghauri (1978) (*C. brevivitta* (Walker), *C. murreeana* (Ghauri), *C. montana* (Ghauri), *C. kightleyi* (Ghauri), *C. jugatoria* (Lethierry)). While the other four species with only females described can be excluded by female genitalia characters (1. *C. confusa* (Distant), mandibular plates meeting in front of clypeus, paratergites

Table 1. Distribution information of twelve *Cahara* species.

Species	Locality	Geographic coordinates
C. bhowaliana	Bhowali, India	29.3833°N, 79.5167°E
C. brevivitta	Simla, India	31.1046°N, 77.1734°E
	Murree, Pakistan	33.9065°N, 73.3937°E
	*Koozagali, Pakistan	?
	*Cahar (Bowring), India	?
C. chaubattia	Chaubattia, India	29.6137°N, 79.4563°E
C. confusa	Murree, Pakistan	33.9065°N, 73.3937°E
C. incisura sp. n.	Mianning, China	28.5496°N, 102.1770°E
C. jugatoria	Kurseong, India	26.8800°N, 88.2783°E
	Gantok,Sikkim, India	27.3389°N, 88.6065°E
	*Himalayas Terai, India	?
C. kightleyi	Simla, India	31.1046°N, 77.1734°E
	Mashobra, India	31.1296°N, 77.2283°E
C. metallica	*Hardwicke Bequest, ??	?
	*??, Nepal	?
C. montana	Roorkee, India	29.8543°N, 77.8880°E
	Nainital, India	29.3803°N, 79.4636°E
	Almora, India	29.5984°N, 79.6615°E
	Ranikhet, India	29.6434°N, 79.4322°E
	Mussoorie, India	30.4553°N, 78.0741°E
C. murreeana	Murree, Pakistan	33.9065°N, 73.3937°E
	Ghora gali, Pakistan	33.8874°N, 73.3620°E
C. nodula sp. n.	Xiang Mount.,China	26.8910°N, 100.2160°E
	Anning City, China	24.9594°N, 102.4821°E
	Huaxi, China	26.3331°N, 107.1949°E
	Changming, China	27.8407°N, 108.7735°E
	Fanjing Mount., China	26.6474°N, 106.6301°E
C. tibetana	Chayu, China	28.6613°N, 97.4669°E
	Dongjiu, China	29.9601°N, 94.7792°E
	Motuo, China	29.3253°N, 95.3332°E

IX with inner margins bisinuate; 2. *C. chaubattia* (Ghauri), gonocoxites I with inner margins entirely separated from each other; 3. *C. bhowaliana* (Ghauri), processes of gonocoxites I much longer, passing beyond gonocoxites II; 4. *C. metallica* (Ghauri), finger-like processes of gonocoxites I very narrow, short and sharp, gonoxites II exposed widely. All the above distinctive characters are not existing in both *C. incisura* sp. n. and *nodula* sp. n.)

According to Ghauri (1978), the genus *Cahara* occurs in the subhimalayan region of India, Pakistan and Nepal, while the three species from southwest China are obviously from the northern Himalayan region. Till now, no distribution overlap between the southern and northern Himalayan species was found. We tried to make a distribution map (Fig. 37) of the twelve species of *Cahara* based on the published

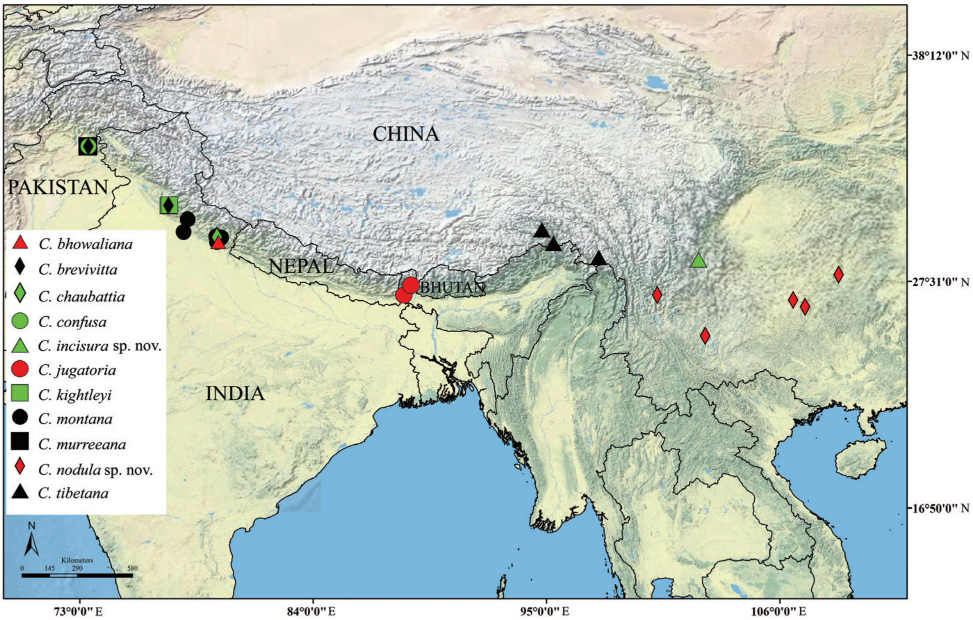


Figure 37. Geographical distribution of eleven *Cahara* spp.

distribution information (Ghauri 1978, Zheng and Liu 1986), but only eleven are showed on the map. The only two localities of *C. metallica* as well as several other localities, mentioned by "*" and "?" in Table 1, are excluded, because they look too obscure for mapping.

Acknowledgment

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First record of *Graphosoma inexpectatum* (Hemiptera, Pentatomidae, Podopinae) from Turkey with description of the female

Meral Fent[1], Ahmet Dursun[2], Serdar Tezcan[3]

1 *Trakya University, Faculty of Science, Department of Biology, 22030 Edirne, Turkey* **2** *Amasya University, Faculty of Arts and Science, Department of Biology, 05100 Amasya, Turkey* **3** *Ege University, Faculty of Agriculture, Department of Plant Protection, 35100 Bornova İzmir, Turkey*

Corresponding author: *Meral Fent* (m_fent@hotmail.com)

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Abstract

Graphosoma inexpectatum Carapezza & Jindra, 2008 is described from Syria, the southern neighbor of Turkey, and is known only from the type locality. The first observation of the species in Turkey dates back to 1995 with two females obtained from the provinces of Gaziantep (Şehitkamil–Aktoprak) and Adana (Pozantı–Bürücek Plateau). These two localities are situated inside the part of the Mediterranean region along the Syrian border. Females of the species, whose original description was based on males, are described here for the first time. A map showing the collecting localities and photographs of the female specimens are given.

Keywords

Hemiptera, Pentatomidae, Podopinae, *Graphosoma inexpectatum*, female description, first record, Turkey

Introduction

Graphosoma Laporte, 1833 is a Palaearctic genus belonging to the subfamily Podopinae Amyot & Serville, 1843 of the family Pentatomidae Leach, 1815. It is subdivided into two subgenera and includes nine species/subspecies (*Graphosoma* s.str. with eight species and *Graphosomella* Carapezza & Jindra, 2008 with one species). Among these nine species, *Graphosoma inexpectatum* Carapezza & Jindra, 2008, the only representative of *Graphosomella*, and the following six species of *Graphosoma* s.str. are distributed in Turkey: *G. lineatum* (Linnaeus, 1758), *G. semipunctatum* (Fabricius, 1775), *G. melanoxanthum* Horváth, 1903, *G. stali* Horváth, 1881, *G. consimile* Horváth, 1903 and *G. alkani* Lodos, 1959 (Rider 2006, Péricart 2010).

Among the Turkish representatives of the genus, the type localities of *G. stali* and *G. alkani* are in Turkey. *G. stali* was previously identified as *G. lineatum* var. *stali* by Horváth in 1881 from Asia Minor (Rider 2006). In the following years, the species was recorded in various parts of Anatolia; from Hatay–Akbez (Puton 1896, Horváth 1903) along the Syrian border and in Gaziantep (Önder et al. 1995) in the south, from Mardin (Horváth 1903, Önder et al. 1995) and Diyarbakır (Wagner 1959, Önder et al. 1995, Özgen et al. 2005) in the southeast and from Kars–Kağızman, Muş–Dom (Kiritshenko 1924) and Elazığ (Hazar Lake) in eastern Anatolia (Seidenstücker 1975). *G. stali* is a Mediterranean species whose distribution includes eastern and southern neighbors of Turkey – Iran, Iraq and Syria – and also Israel. *G. alkani* is an endemic species described by Lodos (1959) from Diyarbakır and Mardin in southeastern Anatolia. Both Carapezza and Jindra (2008) and Péricart (2010) expressed the opinion that *G. alkani* might be a junior synonym of *G. stali*. *G. lineatum* and *G. semipunctatum* are both widely distributed in the Mediterranean region and have been recorded in a number of localities in European (Turkish Thrace) and Asian (Anatolia) parts of Turkey (Önder et al. 2006). In contrast to the wide Palaearctic distribution of *G. lineatum*, the range of *G. semipunctatum* is limited to the Mediterranean region, Caucasus and Transcaucasia (Rider 2006, Péricart 2010). *G. melanoxanthum* was recorded in Iğdır–Tuzluca (=Kulp), Kazkoparan (=Kasikoparan) (Horváth 1903) and Kars–Sarıkamış (Kiritshenko 1918) along the Armenian border in eastern Anatolia, in Elazığ–Maden in more inner parts (Kıyak 1990), in Ankara–Kızılcahamam in Central Anatolia (Seidenstücker 1975) and in Yalova in northwestern Anatolia (Lodos et al. 1978). This species was also recorded, in addition to Anatolia, within an area including Georgia, Armenia, Azerbaijan and Iran, the northeast and east neighbors of Turkey (Rider 2006, Péricart 2010). *G. consimile* was reported in Anatolia from Kayseri–Yılanlı Dağ (Yılanlı Mountain) by Seidenstücker (1975) and from the vicinity of Elazığ–Hazar Lake by Kıyak (1990). The range of this Asian species includes Afghanistan, Azerbaijan, Georgia, Iran, Kazakhstan, Tajikistan, Turkmenistan and Uzbekistan (Rider 2006, Péricart 2010).

Graphosoma (s.str.) *interruptum* A. White, 1839 distributed only on the Canary Islands and *Graphosoma* (s.str.) *rubrolineatum* (Westwood, 1837) distributed in the Far East (China, Japan, Korea, Mongolia and Russian Far East) do not occur in Turkey (Rider 2006, Péricart 2010).

Graphosoma (Graphosomella) inexpectatum Carapezza & Jindra, 2008, the only species of the subgenus *Graphosomella* Carapezza & Jindra, 2008, is described from Syria (type locality: SW Syria, Bludan) based on two male specimens and has not been recorded in any other place so far. Two females were obtained during the present study from Adana and Gaziantep provinces, which are both very close to Syria.

Material and methods

The study material was collected in June–July of 1995 in two southern provinces of Turkey, Gaziantep (Şehitkamil–Aktoprak) and Adana (Pozantı–Bürücek Plateau), using a sweeping net. Aktoprak is a district of the city Şehitkamil. This area, located on the border between the southeastern Anatolian and Mediterranean regions of Turkey, has a transition climate which includes both Mediterranean and continental climate characteristics. Winters in the area are cold and wet, and summers are hot and dry. As a result of the climate, the flora of this territory is transitional between the vegetation types of the Mediterranean and the steppe elements of the southeastern Anatolian regions. Although forests are rare, the dominant trees oak (*Quercus* sp.) and red pine (*Pinus brutia* Ten.) were chosen in forested areas (www.markasehir.com/siteic.php~id=&altno=23&back=false.html).

The second locality, Bürücek Plateau, is 100 km away from Adana city center and is an upland with an altitude of 1300 m surrounded by pines (*Pinus* spp.), junipers (*Juniperus* spp.) and fruit trees at the foot of the Akdağ Mountains, Middle Taurus. Pozantı is 7 km away from the Bürücek Plateau and is under the effect of a Mediterranean climate with cold and wet winters and hot and dry summers. Snowfall is typical for winter, and rainfall, during the spring. Despite the hot weather conditions in spring and autumn, Bürücek Plateau is cool even in summer. The area is characterized by the Mediterranean phytogeographical region's vegetation formations under the influence of the climate. The dominant tree of the upland is generally the red pine (*Pinus brutia* Ten.) but the amount of mixed forest areas including both black pines (*Pinus nigra* Arnold) and red pines increases with higher altitudes; at higher altitudes black pine, cedar (*Cedrus libani* A. Rich.) and fir (*Abies cilicica* Carr.) formations exist in either mixed or pure areas. In addition, trees such as Syrian juniper (*Juniperus drupacea* Lab.), ash (*Fraxinus excelsior* L.), oak (*Quercus* sp.), willow (*Salix* sp.), hornbeam (*Carpinus betulus* L.), European cornel (*Cornus mas* L.), European bladdernut (*Staphylea pinnata* L.), hawthorn (*Crataegus* sp.), blackberry (*Rubus fruticosus* L.), service tree (*Sorbus domestica* L.) and spruce (*Picea* sp.) and annual plants such as St. John's worth (*Hypericum perforatum* L.), oregan (*Origanum vulgare* L.), thyme (*Thymus vulgaris* L.), speedwell (*Veronica officinalis* L.), wild garlic (*Alium ursinum* L.), chard (*Beta vulgaris* var. *cicla* L.), salep (*Orchis mascula* L.), horsemint (*Mentha longifolia* L.) and colchicum (*Colchicum autumnale* (L.)) are commonly seen (www.adanaliyiz.org/index.php?topic=48.0;wap).

Results

***Graphosoma* (*Graphosomella*) *inexpectatum* Carapezza & Jindra, 2008**
http://species-id.net/wiki/Graphosoma_inexpectatum

Material examined. Gaziantep province: Şehitkamil (Aktoprak), 11.VI.1995, 37°11'00"N; 37°17'00"E, ca 1035 m, 1 ♀, leg. F. Önder; Adana province: Pozantı

(Bürücek Plateau), 2.VII.1995, 37°25'40"N; 34°52'18"E, ca 1300 m, 1 ♀, leg. F. Önder (coll. Trakya University, Edirne, Turkey and Ege University, LEMT, İzmir, Turkey).

Host plants. The host plants for both specimens were recorded as weeds, so the plant on which specimens were collected is not known exactly.

Description of female (Fig. 1). Body ovoid, flat, moderately deep punctate and glabrous. Coloration pattern of body with black lines and markings on orange as in most species of *Graphosoma*. Body 1.75–1.80× as long as pronotum width. Body is slightly greater than in males (10.3–11.3 mm versus 10.66–10.80 mm) (Fig. 1A).

Head almost subtriangular, lateral sides nearly flat. Head: 1.77–1.99 mm long and 0.76–0.82× longer than wide across eyes; width across eyes 2.32–2.41 mm, interocular width 1.52–1.65 mm; jugae enclosing and widely exceeding the tylus, slightly diverging apically. Dorsal surface of head deeply punctate. Integument orange, with two black bands tapering and fusing distally. Length of antennomeres I: 0.54–0.62 mm, II: 1.0–1.13 mm, III: 0.64–0.66 mm, IV: 0.7–0.9 mm, V: 0.95–1.06 mm. First and second antennomeres are the shortest and the longest respectively. First antennomere brownish, yellowish distally; IV and V antennomeres dark brown (Fig. 1C). Antennae/Body length: 0.37–0.38. Head ventrally orange, anterior angle of eye with small black subtriangle spot, jugae anteroventrally with transverse black spot (Fig. 1D).

Pronotum transverse, 5.87–6.29 mm wide across lateral angles and 1.92–2.22× wider than long in the middle. Pronotum anteriorly rather narrower than posteriorly, lateral margins evenly rounded. Dorsal surface of pronotum deeply punctate and orange, anterior part with four longitudinal black bands, the external ones at their posterolateral angles joining two curved black bands running parallel to posterior half of lateral pronotal margin (Fig. 1A).

Scutellum subtriangular, distally widely rounded, 5,4–6,3 mm long and 1.28–1.34× longer than basally wide; contrary to species of *Graphosoma* s.str., scutellum does not reach to the end of abdomen and covers only two thirds of abdomen length. Lateral margins of scutellum convex in proximal half. Proximal margin of scutellum medially with a raised semicircular punctureless area between the internal margins of two lateral black bands; lateral margins of semicircular area extend to internal margins of lateral bands. Scutellum orange with four long black bands; lateral bands shorter than median ones, distally almost pointed and extending to half length of scutellum; median bands long but not reaching the apex of scutellum (Fig. 1A).

Hemelytra orange except for a triangular blackish brown spot at the apex of r+m vein, the external margin of exocorium with longitudinal black spot, distal with triangular spot, membran blackish–brown (Fig. 1A).

Paratergites with black spots along distal and proximal margins, spots of adjoining tergites merging to form an almost circular shape (Fig. 1A).

Abdomen maximum width 6.88–6.99 mm and 1.09–1.17× wider than long, ventrally orange and with irregular black spot. Proximal and distal angles of parasternites with black spots (Fig. 1B).

Rostrum reaching hind coxae; first three segments yellowish, IV dark brown (Fig. 1D). Length of rostral segments I–IV: 1.56, 1.13, 0.82, 0.53 mm.

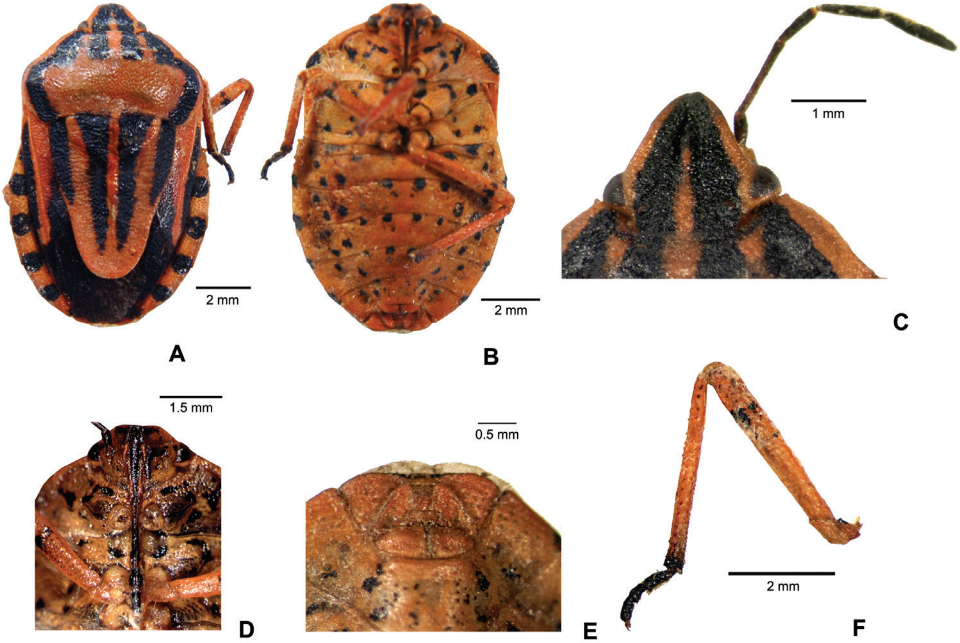

Figure 1. *Graphosoma inexpectatum*. **A** body, dorsal view **B** body, ventral view **C** head, dorsal view, and antenna **D** head, ventral view, and rostrum **E** female genitalia **F** leg, lateral view.

Legs orange, femora ventrally with two preapical black spots, apex of tibiae black, tarsi black (Fig. 1F).

Female genitalia reddish–brown, with shallow punctures. Eight gonocoxites convex, 9th gonocoxites medially excavated, lateral margins with black lines and centrally with black mark (Fig. 1E).

Comparative notes. The two female specimens examined in the present study show some differences in morphology and coloration when compared with the holotype of the species whose original description by Carapezza and Jindra (2008) was based on two male specimens. The antennomeres (I to V) of the holotype are 0.6 / 1.06 / 0.53 / 0.73 / 1.06 mm long, hence the shortest segment is III. Antennomeres II and V are of equal length, I is a bit longer than III, and IV is longer than I. Antennomeres of Turkish specimens (I to V) are (0.54–0.62), (1.0–1.13), (0.64–0.66), (0.7–0.9), (0.95–1.06) mm long. First and III antennomeres are the shortest with somewhat equal lengths and II is the longest. The ratio of antennal length to body length is 0.33 in the holotype and 0.37–0.38 in our specimens (Fig. 1C). The bands in the middle of the scutellum of the holotype are wide basally and gradually taper towards the middle of the scutellum and reach the end as thin bands. However, the narrowing after the middle in our specimens is not pronounced and bands are comparatively wide (Fig. 1A). Moreover, the black spots seen on proximal and distal margin of each paratergite are shaped as black bands in the holotype and the distal band of one segment and the proximal band of the next segment join to form a rectangular shape.

Figure 2. Distribution of *Graphosoma inexpectatum*.

These black spots on each segment are in semicircular shape in our specimens and form an almost circular shape when joined (Fig. 1A). Since the comparison was carried out between the males from Syria and the females from Turkey, it is impossible to conclude if the differences put into evidence depend on sexual dimorphism or on geographical variations.

Discussion

Two female specimens of *Graphosoma* (*Graphosomella*) *inexpectatum* were obtained in 1995 from two localities in Adana and Gaziantep provinces in the Mediterranean region of Turkey. This is the first record of the species in Turkey and the second record in the world. The number of *Graphosoma* species in Turkey rises to seven with this record. The presence of seven species of *Graphosoma* in Anatolia, out of the nine overall known in the genus, reinforces the notion that Anatolia and its immediate vicinities, as indicated by Carapezza and Jindra (2008), might be the center of origin of the genus.

This species was first described by Carapezza and Jindra (2008) from Bludan in SW Syria. Bludan is a locality situated in a mountain valley (1590–2100 m a.s.l.) with relatively rich steppe vegetation in the Anti–Lebanon Mountains, about 30 km NW of Damascus (Carapezza and Jindra 2008). The localities in Turkey are close to Syria and the presence of all currently known localities of the species in Mediterranean Region supports the possibility that the species is a Syrian–Anatolian element of east Mediterranean origin (Fig. 2).

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RESEARCH ARTICLE

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Comparative morphology of immature stages of four species of *Chinavia* (Hemiptera, Pentatomidae), with a key to the species of Rio Grande do Sul, Brazil

Brenda Bianca Rodrigues Jesse Fürstenau[1],
Cristiano Feldens Schwertner[2], Jocelia Grazia[1]

1 *Department of Zoology, Universidade Federal do Rio Grande do Sul (UFRGS), Av. Bento Gonçalves, 9500. Prédio 43435, sala 216 – 91501-970 Porto Alegre, Rio Grande do Sul, Brazil* **2** *Department of Biological Sciences, Universidade Federal de São Paulo (UNIFESP), Campus Diadema, Rua Prof. Artur Riedel, 275 – 09972-270 Eldorado, Diadema, São Paulo, Brazil*

Corresponding author: *Brenda Bianca Rodrigues Jesse Fürstenau* (brendabianca@gmail.com)

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Abstract

Chinavia Orian (1965) is one of the most diverse genera of Pentatomidae, distributed in the Afrotropical, Neotropical and Nearctic Regions. Thirty-two species are recorded for Brazil, some of them having potential economic impact because they are found on crops and referred to as pests. The morphology of the five nymphal instars of *C. armigera* (Stål, 1859), *C. aseada* (Rolston, 1983), *C. brasicola* (Rolston, 1983) and *C. runaspis* (Dallas, 1851) are described here. Through a comparative study, identification keys were developed to allow an early identification of the 12 *Chinavia* species of Rio Grande do Sul.

Keywords

Hemiptera, Heteroptera, Pentatomidae, nymphs, stink bugs, keys, pest, Brazil, Neotropical Region

Introduction

The majority of the morphological and taxonomic studies of stink bugs concerns only the adult forms. However, because of taxonomic, economic and ecological importance, the study of the immature forms has been increased in the last years. When associated with crops of economic importance, an oportune identification of the species allows an early adoption of pest control, reducing production losses (Brailovsky et al. 1992). Also, the description of the morphology of stink bug eggs and nymphs can contribute with new characters for classification and phylogenies (Matesco et al. 2009b). The knowledge of immature stages also enables more reliable estimation of the richness and abundance of species and helps to assess the impact of environmental changes (Costa et al. 2006, Mendonça et al. 2009).

The nymphal stage in Pentatomidae is divided into five instars, which can be distinguished by body size, general coloration, presence and distribution of maculae, and degree of development of scutellum and pterothecae in the first and second thoracic segments (DeCoursey and Esselbaugh 1962, Jones and Coppel 1963, Brailovsky et al.1992). The nymphal stages of Pentatomidae have characters that allow the construction of identification keys (DeCoursey and Allen 1968, Saini 1989) to recognize the instars or the families (Southwood 1956, Leston and Scudder 1956, Costa et al. 2006); these keys often give more emphasis to characteristics of the fifth instar.

The genus *Chinavia* was proposed in 1965 by Orian; it was treated as a subgenus of *Acrosternum* Fieber, 1860. On the basis of morphological evidence and in agreement with the proposals of Day (1965), Roche (1977) and Ahmad (1996), Schwertner and Grazia (2006) treated the taxon as a full genus. Currently, there are 84 species described for the genus, distributed in the Afrotropical, Nearctic and Neotropical regions (Schwertner and Grazia 2006). In Brazil, 32 species are recorded, 18 of which are endemic (Schwertner and Grazia 2007). Twelve species can be found in the state of Rio Grande do Sul, eight of which have the morphology of nymphs or some biological aspects known: *Chinavia erythrocnemis* (Berg, 1878) (Matesco et al. 2006), *C. impicticornis* (Stål, 1872) (Grazia et al. 1982), *C. longicorialis* (Breddin, 1901) (Matesco et al. 2009a), *C. musiva* (Berg, 1878) (Matesco et al. 2008), *C. nigridorsata* (Breddin, 1901) (Vecchio et al. 1988), *C. obstinata* (Stål, 1860) (Matesco et al. 2003), *C. pengue* (Rolston, 1983) (Matesco et al. 2007) and *C. ubica* (Rolston, 1983) (Schwertner et al. 2002).

This paper describes the morphology of the five nymphal instars of *Chinavia armigera* (Stål, 1859), *C. aseada* (Rolston, 1983), *C. brasicola* (Rolston, 1983) and *C. runaspis* (Dallas, 1851). The morphology of the eggs of these four species will be described and discussed in a future paper. Identification keys for each instar are also provided.

Material and methods

Adults and nymphs were collected in four locations in the state of Rio Grande do Sul, Brazil, between March 2007 and March 2011 (Table 1). Individuals were reared in the

Table 1. Collecting sites of four *Chinavia* species.

Species	Collecting site in Brazil	Geographical coordinates
Chinavia armigera (Stål)	Rio Grande, RS	32.5719S, 52.5593W
Chinavia aseada (Rolston)	Passo Fundo, RS	28.1546S, 53.2424W
Chinavia brasicola (Rolston)	São Francisco de Paula, RS	29.4239S, 50.3872W
Chinavia runaspis (Dallas)	Porto Alegre, RS	30.0693S, 51.2422W

laboratory under controlled conditions (24 ± 1°C; 70 ± 10% RH and photoperiod of 12 h). Eggs and first instar nymphs were kept in Petri dishes with a moistened cotton pad. From the second instar to adulthood, the insects were reared in 500-ml plastic pots covered with organdy. To maintain the humidity inside the pot, an Eppendorf tube containing water, covered with cotton, was used.

Green beans (*Phaseolus vulgaris* L.) (Fabaceae) and fruits of cherry tomatoes (*Lycopersicon esculentum* Mill.) (Solanaceae) were offered as food. Individuals of *C. aseada* and *C. brasicola* were also offered soybean (*Glycine max* L.) and peanut (*Arachis hypogaea L.)* (Fabaceae), respectively. The food was replaced twice a week. During both nymphal and adult stages, the pots were replaced by cleaned ones whenever necessary.

The color of the nymphs was observed in live individuals. The specimens selected for analysis of morphology were kept frozen and were fixed in 70% alcohol after completion of the study.

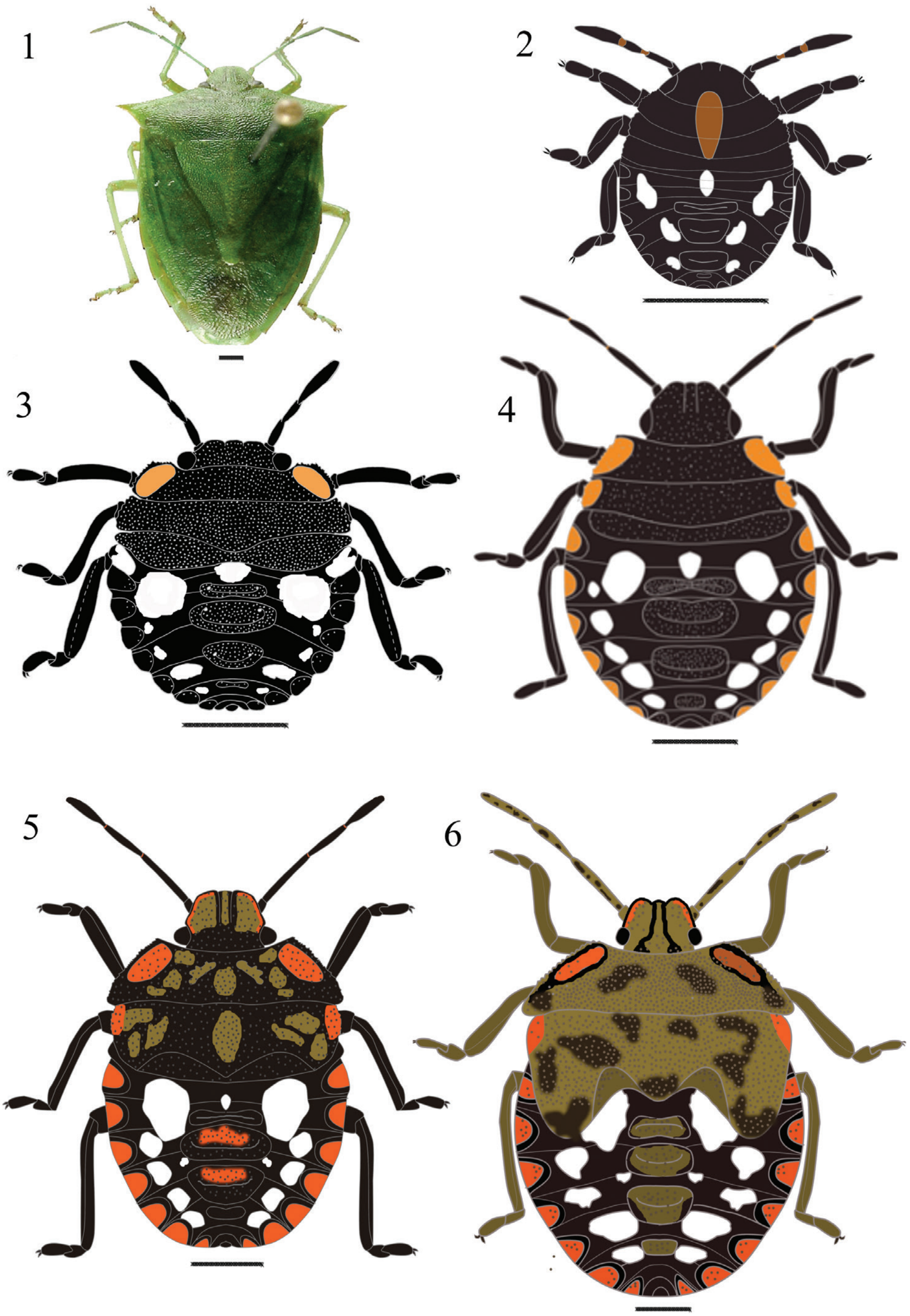
Terminology for eggs follows Matesco et al. (2006), and for nymphs Davidová-Vilímová and Podoubský (1999) and Matesco et al. (2009b). Measurements are in millimeters corresponding to mean ± SD, obtained according Matesco et al. (2009b). Photographs were obtained with a digital camera (Sony DSC-HX1 or Nikon Coolpix 995) attached to a stereomicroscope. Drawings were made with a camera lucida coupled to a stereomicroscope, digitally scanned and edited with Adobe Illustrator® and Adobe Photoshop®. Voucher specimens were deposited at the Entomological Collection of the Department of Zoology, Federal University of Rio Grande do Sul (DZRS).

Results

Chinavia armigera (Stål, 1859)

http://species-id.net/wiki/Chinavia_armigera
Figs 1–6

Remarks. Adults of *C. armigera* have a general body color green to dark green, with a median longitudinal line and margins of the body yellowish (Rolston 1983). The distribution includes Brazil (Rio Grande do Sul), Argentina and Uruguay (Schwertner and Grazia 2007). *Chinavia armigera* is associated with plants such as yerba mate *(Ilex paraguariensis* St. Hil) (Aquifoliaceae), soybean (*Glycine max* L.) (Fabaceae), sugarcane (*Saccharum* L.) (Poaceae), cotton (*Gossypium hirsutum* L.) (Malvaceae) and rice (*Oryza sativa* L) (Poaceae). The morphometric parameters of nymphal instars are shown in Table 2.



Figures 1–6. *Chinavia armigera* (Stål, 1859). **1** Adult **2** First instar **3** Second instar **4** Third instar **5** Fourth instar **6** Fifth instar.

Table 2. Morphometric traits of nymphs of *Chinavia armigera* (Stål, 1859) (n = 15) (mean ± standard deviation, mm).

Measures	1st instar	2nd instar	3rd instar	4th instar	5th instar
TL	2.02±0.09	3.39±0.26	4.69±0.31	6.23±0.15	8.23±1.05
TW	1.49±0.10	2.45±0.27	3.95±0.40	4.27±0.34	9.52±4.21
ID	0.62±0.15	0.75±0.06	1.1±0.08	1.21±0.11	1.54±0.13
I	0.10±0.08	0.15±0.05	0.2±0.09	0.29±0.09	0.38±0.11
II	0.20±0.08	0.43±0.09	0.72±0.05	1.2±0.08	1.27±0.24
III	0.17±0.09	0.36±0.05	0.62±0.08	0.85±0.15	1.34± 0.29
IV	0.39±0.09	0.47±0.12	0.93±0.09	1.12±0.19	1.33±0.09
RL	0.79±0.17	1.44±0.16	1.51±0.3	2.32±0.32	3.01±0.31
PL	0.24±0.08	0.59±0.10	0.98±0.33	1.17±0.22	2±0.12
PW	0.31±0.04	0.53±0.09	1.01±0.33	1.13±0.33	1.89±0.32

HL head length; ID interocular distance; PL pronotum length; PW pronotum width; RL rostrum length; TL total length; TW total width; I, II, III, IV length of antennal segments.

First instar (Fig. 2). Body round and convex, surface without punctuation. General color dark brown to black. Head conical and strongly declivent; black, with median orange macula, which extends from the posterior portion of the head to the posterior margin of metanotum; clypeus with apex obtuse, surpassing mandibular plates, these subtriangular shaped. Ocelli absent. Antennae black, intersegmental areas with light brown color; antennal segments with short hairs well distributed. Antennal segment I shortest and antennal segment IV longest; antennal segments II and III subequal. Rostrum black, reaching the metacoxae. Thorax mostly dark, except for the median orange macula. Legs black, with hairs uniformly distributed on all segments, tibiae ventrally cylindrical and dorsally flattened, tarsi with two segments, a pair of tarsal claws and pulvili. Abdomen dark brown to black with the three pairs (3+3) of white maculae located between lateral dorsal plates and the first three median dorsal plates, and a white rounded median macula located anteriad of the first median dorsal plate. Dorso-abdominal scent glands ostioles of anterior, median and posterior glands present on dorsal plates placed at intersegmental line between the abdominal terga 3-4, 4-5 and 5-6 respectively. Dorsal median and lateral plates black, without punctuation, the lateral semi-circular, adjacent to the lateral margin of each segment. Spiracles near anterior margin of lateral plates, on abdominal segments II to VIII. From urosternites III to VII, 1+1 trichobothria placed medially of an imaginary line across spiracles and near posterior margin of each segment.

Second instar (Fig. 3). Body oval, less convex than in the first instar. Head predominantly black colored, densely punctured on the dorsum. Clypeus with apex obtuse, subequal to mandibular plates, larger than in the previous instar. Eye diameter equal to width of clypeus at base. Rostrum black, not reaching metacoxae. Thorax with 1+1 orange maculae along the margins of the pronotum; margins of pronotum and mesonotum serrate and slightly deflected. Hairs more abundant on the tibiae. Abdomen mostly dark brown; dorsal abdominal maculae distributed as follows: 1+1 white, rounded, located between the lateral and the first dorsal median plates; a white macula, small, rounded, located anteriad of first median dorsal plate; 4+4 white maculae between the lateral and median dorsal plates. Dorsal median and lateral plates black and punctured. From urosternites III to VII, 2+2 trichobothria, one trichobothrium placed medially of the spiracular line and the other along that line. Other characteristics as described for the first instar.

Third instar (Fig. 4). Mandibular plates subtriangular, length subequal to clypeus, whose apex is obtuse. Thorax densely punctured, predominantly black, except for the orange maculae on anterolateral margins, which are finely crenulated. Abdomen with a pair (1+1) of white, large and rounded maculae, one on each side of the first dorsal median plate; small white macula anteriad of first dorsal median plate; four pairs (4+4) of white maculae between the lateral and median dorsal plates. Black median and lateral dorsal plates, strongly punctured. Lateral plates semicircular in shape, with orange macula in the center, emarginated in black. Other characteristics as described in previous instars.

Fourth instar (Fig. 5). Body oval, predominantly dark brown. Mandibular plates with broad bands and clypeus with a thin median strip straw-yellow. Rostrum black, not reaching metacoxae. Thorax predominantly black, except a straw-yellow macula without defined shape and an orange macula along the anterolateral margins. Posterior margin of mesonotum sinuous, denoting the scutellum and formation of wing pads, which reach the posterior margin of metanotum. Abdomen dark brown, sparse punctuation, not as dense as on the thorax, abdominal maculae distributed as follows: 1+1 white, round, large, located between the lateral plates and the first median dorsal plate; a white and oval macula located anteriad of the first median dorsal plate; 4+4 white maculae located between the dorsal median plates and the dorsal lateral plates; 1+1 white, small, rounded macula located along the posterolateral margins of the second median dorsal plate. Lateral plates semicircular, orange emarginated in black, slightly punctured; median plates predominantly black, coarsely punctured, with sparse brownish maculae. Other characteristics as described in previous instars.

Fifth instar (Fig. 6). Body oval to pyriform. Head flat, punctured. Mandibular plates predominantly straw-yellow, with black border and orange band extending from the anterior margin of the eyes to the apex of the clypeus, which is black, with a straw-yellow median strip, wider in the posterior portion, on the edge of the pronotum. Antennae generally straw-yellow, with black maculae. Thorax predominantly straw-yellow, with dark brown and sparse maculae, shapeless, producing a variegated appearance. Margins of pronotum and mesonotum serrate, with a pair (1+1) of anterolateral orange maculae. Pronotum wider; mesonotum more developed; scutellum well delimited. Wing pads well developed, surpassing the middle of abdominal segment III. Legs straw-yellow, with dark margins; hairs more abundant on the tibiae. Abdomen predominantly brown, with the same distribution and number of maculae observed in the 4th instar. Margin of the median dorsal plates darker than the center. Median dorsal plates predominantly orange. Urosternite VIII split longitudinally in females and entire in males. Other characteristics as described in previous instars.

Chinavia aseada (Rolston, 1983)

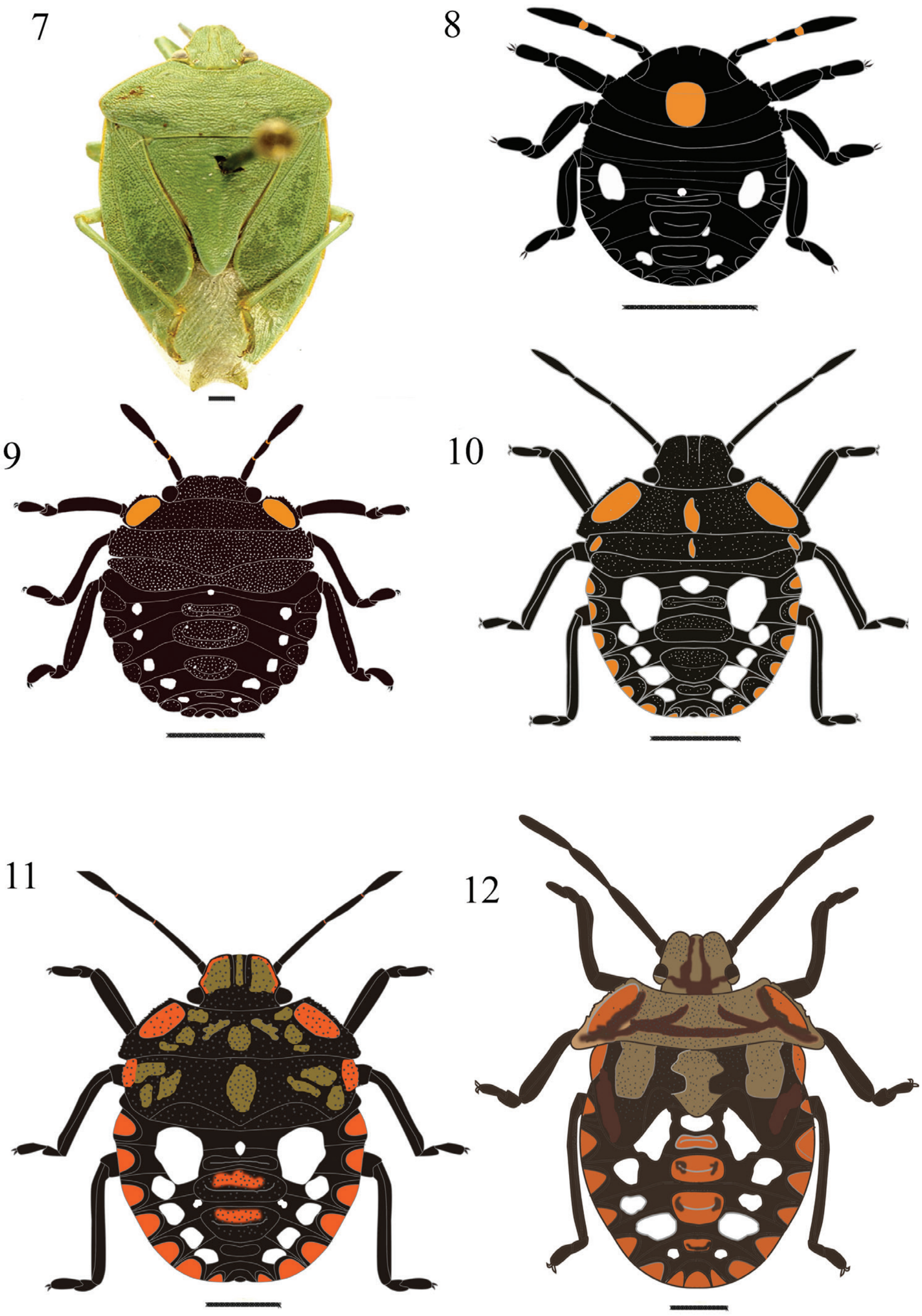
http://species-id.net/wiki/Chinavia_aseada
Figs 7–12

Remarks. Adults of *C. aseada* have general body color green and margins of the body, head, pronotum, hemelytra and connexivum reddish (Rolston 1983). Distribution includes Brazil (Pará, Mato Grosso, Distrito Federal, Paraná and Rio Grande do Sul) (Schwertner and Grazia 2007) and northern Argentina (Schwertner and Grazia 2007). The morphometric parameters of nymphal instars are shown in Table 3.

First instar (Fig. 8). Body round and convex, surface without punctuation. General color dark brown to black. Head conical and strongly declivent; black, with median orange macula, which extends from the posterior portion of the head to the posterior margin of metanotum; clypeus with apex obtuse, not surpassing mandibular plates, these subtriangular shaped. Ocelli absent. Antennae black, intersegmental areas with orange color; antennal segments with short and uniformly distributed hairs. Antennal segment I shortest and antennal segment IV longest. Antennal segments III and IV subequal in size. Rostrum black, surpassing metacoxae. Thorax mostly dark, except for the orange median macula. Legs black, with hairs uniformly distributed on all segments, tibiae dorsally flattened, tarsi with two segments, a pair of tarsal claws and pulvili. Abdomen predominantly black, with white maculae distributed as follows: one pair (1+1) round and large, located between the lateral plates and the first median dorsal plate; a small macula anteriad of first median dorsal plate; two pairs (2+2) of small, located along the margins of the lateroposterior margins of the second and third median dorsal plates. Median dorsal plates black; ostioles on median dorsal plates I-III. Lateral plates semicircular, black, without punctuation, adjacent to lateral margin of each segment. Spiracles near ventral anterior margin of lateral plates, on urosternites II to VIII. From urosternites III to VII, 1+1 trichobothria placed medially of an imaginary line across spiracles and near posterior margin of each segment.

Second instar (Fig. 9). Body oval and less convex than first instar. Head less declivent than in previous instar, predominantly black, coarsely punctured on the dorsum. Clypeus obtuse at apex, subequal in size to the mandibular plates, larger than in previous instar. Eyes almost as wide as clypeus at base. Rostrum black, not reaching the metacoxae. Thorax with 1+1 orange maculae along the anterolateral margins of pronotum; lateral margins of pro- and mesonotum slightly deflected. Legs black, dense hairs on tibiae. Abdomen predominantly black, with 5+5 white maculae between lateral and median dorsal plates, one white small macula anteriad offirst median dorsal plate. Median and lateral dorsal plates black punctured. On the ventral plates, 2+2 trichobothria on urosternites III to VII. One trichobothrium medially of the spiracular line and the other along that line. Other characteristics as described for the first instar.

Third instar (Fig. 10). Some specimens can have an orange band in the middle of each mandibular plate. Thorax densely punctured, predominantly black, except for a few orange spots, with irregular shape and size. Pronotum trapezoidal, with 1+1 orange maculae along the anterolateral margins, which are serrate. Margins of mesono-



Figures 7–12. *Chinavia aseada* (Rolston, 1983). **7** Adult **8** First instar **9** Second instar **10** Third instar **11** Fourth instar **12** Fifth instar.

Table 3. Morphometric traits of nymphs of *Chinavia aseada* (Rolston, 1983) (n = 5) (mean ± standard deviation, mm).

Measures	1st instar	2nd instar	3rd instar	4th instar	5th instar
TL	2.03±0.42	3.01±0.33	3.97±0.31	5.98±0.45	9.34±0.89
TW	1.54±0.23	2.36±0.27	4.06±0.27	4.89±0.22	10.09±1.23
ID	0.63±0.03	0.85±0.06	1.1±0.08	1.32±0.14	1.59±0.17
I	0.11±0.05	0.16±0.04	0.21±0.06	0.33±0.05	0.41±0.11
II	0.22±0.03	0.42±0.05	0.72±0.06	1.1±0.08	1.32±0.14
III	0.23±0.05	0.41±0.05	0.62±0.07	0.92±0.12	1.39±0.21
IV	0.41±0.08	0.65±0.11	0.95±0.08	1.17±0.09	1.43±0.12
RL	0.7±0.17	1.36±0.14	1.55±0.34	2.47±0.33	3.78±0.31
PL	0.33±0.03	0.58±0.07	1.06±0.34	1.27±0.32	2.01±0.27
PW	1.23±0.08	2.17±0.14	3.14±0.29	4.32±0.31	5.17±0.29

HL head length; ID interocular distance; PL pronotum length; PW pronotum width; RL rostrum length; TL total length; TW total width; I, II, III, IV length of antennal segments.

tum slightly serrate, with a pair (1+1) of orange maculae. Abdomen with a pair (1+1) of white, large maculae, which has approximately circular shape, located on each side of the first median dorsal plate. Lateral plates semicircular, orange outlined in black. A white and small macula, located above first median dorsal plate and two pairs (2+2) of white maculae between lateral and median dorsal plates. Median dorsal plates predominantly black, densely punctured, with irregularly shaped orange maculae located in the middle of the plate. Other characteristics as described in the previous instars.

Fourth instar (Fig. 11). Body oval, predominantly black. Head less declivent than in third instar, large light orange bands on mandibular plates, clypeus black. Antennae light brown. Maculae on the dorsum of the thorax shapeless, the same color as the bands on mandibular plates. Pronotum trapezoidal; mesonotum rectangular, posterior margin wide, "V" shaped, denoting the formation of scutellum. Wing pads slightly developed, reaching posterior margin of metanotum. Legs light brown with black borders. Rostrum black, reaching metacoxae. Abdomen light brown, punctuation sparse, not as dense as on the thorax; white maculae distributed as follows: one pair (1+1) of round-shaped, large, located between lateral and median plates; one rounded, located anteriad of first median dorsal plate; four pairs (4+4) of white maculae, located between lateral and median dorsal plates. Lateral plates semicircular, orange outlined in black, slightly punctured; second and third median dorsal plates predominantly black, coarsely punctured with sparse orange maculae located in the middle of the plates. Other characteristics as described in the previous instars.

Fifth instar (Fig. 12). Body oval to pyriform. Head flat, slightly punctured. Eyes with transverse straw-yellow band. Mandibular plates predominantly straw-yellow, with black margins. Clypeus predominantly black, with median straw-yellow band, wider in the posterior portion. Antennae predominantly straw-yellow. Thorax predominantly straw-yellow to light brown, with dark brown maculae, sparse, shapeless, producing a variegated appearance. Lateral margins of pronotum and mesonotum depressed, slightly serrate and deflected. Pronotum wide; mesonotum more developed; scutellum well delimited. Wing pads well developed, surpassing the middle of abdominal segment III. Legs straw-yellow to dark brown, with dark margins; hairs more abundant on the tibiae. Abdomen predominantly light brown, with same number and distribution of maculae observed in fourth instar. Median plates predominantly orange. Urosternite VIII split longitudinally in females and entire in males. Other characteristics as described in the previous instars.

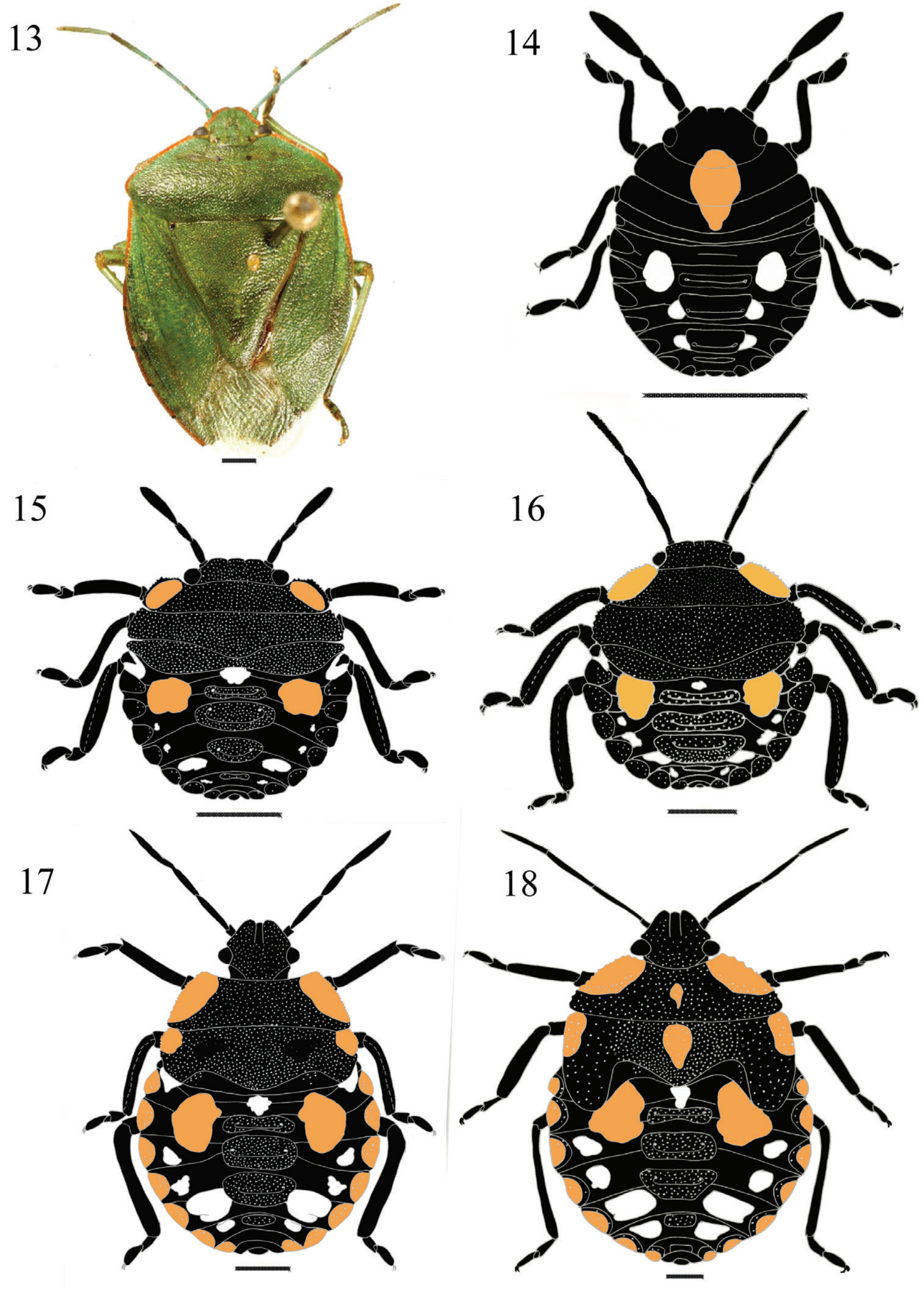
Chinavia brasicola (Rolston, 1983)

http://species-id.net/wiki/Chinavia_brasicola
Figs 13–18

Remarks. Adults have general body color green, connexivum red-orange with black maculae on posterolateral angles (Rolston 1983). The distribution includes the Brazilian states of São Paulo, Santa Catarina and Rio Grande do Sul (Schwertner and Grazia 2007). The single sitting record is a fern *Dennstaedtia globulifera* (Poir.) Hieron (Pteridophyta) (Schwertner and Grazia 2007). The morphometric parameters of nymphal instars are shown in Table 4.

First instar (Fig. 14). Body round and convex surface without punctuation. General coloration dark brown to black. Head conical and strongly declivent; black, with median orange macula, which extends from the posterior portion of the head to the anterior margin of mesonotum; clypeus with apex obtuse, slightly surpassing the mandibular plates, these subtriangular shaped. Ocelli absent. Antennae black; intersegmental areas with orange color; antennal segments with short and uniformly distributed hairs. Antennal segment I shortest and antennal segment IV longest. Antennal segments III and IV subequal in size. Rostrum black, reaching anterior margin of urosternite II. Thorax mostly dark, except for the orange median macula. Legs black, with hairs uniformly distributed on all segments, tibiae dorsally flattened, tarsi with two segments, a pair of tarsal claws and pulvili. Abdomen predominantly black, with three pairs (3+3) of white maculae, located between lateral and median plates. Median dorsal plates black; ostioles on median dorsal plates I-III. Lateral plates semicircular, black, without punctuation, adjacent to lateral margin of each segment. Spiracles near anterior margin of lateral plates, on urosternites II to VIII. From urosternites III to VII, 1+1 trichobothria placed medially of an imaginary line across spiracles and near posterior margin of each segment.

Second instar (Fig. 15). Body oval and less convex than first instar. General color black, with punctuation on the dorsum of the head, thorax, median and lateral plates. Head less declivent than in previous instar. Clypeus obtuse at apex, subequal in size to the mandibular plates, which are broader than that observed in previous instar. Eyes almost as wide as base of clypeus. Rostrum black, surpassing the anterior margin



Figures 13–18. *Chinavia brasicola* (Rolston, 1983). **13** Adult **14** First instar **15** Second instar **16** Third instar **17** Fourth instar **18** Fifth instar.

Table 4. Morphometric traits of nymphs of *Chinavia brasicola* (Rolston, 1983) (n = 15) (mean ± standard deviation, mm).

Measures	1st instar	2nd instar	3rd instar	4th instar	5th instar
TL	2.11±0.38	3.5±0.25	4.83±0.33	6.89±0.56	10.34±0.78
TW	1.69±0.04	2.68±0.25	4.04±0.26	5.24±0.34	11.52±17.23
ID	0.65±0.06	0.89±0.06	1.3±0.08	1.46±0.11	1.72±0.17
I	0.13±0.04	0.18±0.05	0.2±0.05	0.36±0.08	0.42±0.12
II	0.23±0.06	0.47±0.09	0.79±0.05	1.2±0.08	1.67±0.14
III	0.23±0.04	0.39±0.05	0.64±0.08	0.96±0.11	1.44±0.22
IV	0.44±0.09	0.67±0.12	0.92±0.09	1.22±0.09	1.63±0.12
RL	0.8±0.17	1.46±0.16	1.57±0.3	2.67±0.32	3.98±0.41
PL	0.32±0.04	0.63±0.09	1.02±0.33	1.26±0.22	2±0.2
PW	1.31±0.08	2.29±0.14	3.21±0.29	4.47±0.31	6.32±0.35

HL head length; ID interocular distance; PL pronotum length; PW pronotum width; RL rostrum length; TL total length; TW total width; I, II, III, IV length of antennal segments.

of urosternite III. Thorax with 1+1 orange maculae along the margins of pronotum; lateral margins of pro- and mesonotum slightly deflected. Legs black, hairs more dense on tibiae. Abdomen predominantly black, maculae distributed as follows: one, white, round maculae, located anteriad of first median plate; a pair (1+1) of white maculae, located on each side of the first lateral plates; a pair (1+1) of large, rounded, orange maculae, located between lateral plates and first median plate and four pairs (4+4) white, located between lateral and median plates, the third pair is the largest. Median and lateral dorsal plates black punctured. Urosternites III to VII with 2+2 trichobothria, one trichobothrium medially of the spiracular line and the other along that line. Other characteristics as described for the first instar.

Third instar (Fig. 16). Antennal segment I shorter, segments II and IV subequal in length, larger than segment III. Thorax punctured, predominantly black, except an orange maculae along each margin. Pronotum with margins slightly deflected and serrate. Legs black, except for the area between the femur and tibia, which has light brown color; hairs denser on the ventral surface of tibia and tarsus. Abdomen with a round white macula anteriad of first median plate; one pair (1+1) of orange maculae between the first median plate and lateral plates, and four pairs (4+4) of white maculae located between median and lateral plates of tergites IV-VII. Other characters as described for the previous instar.

Fourth instar (Fig. 17). Body oval, less convex than in earlier instars, predominantly black. Head less declivent than in previous instar, black, with punctures. Some specimens with an orange band in the middle of each mandibular plates. Antennae with abundant hairs on segments III and IV. Thorax predominantly black, with orange maculae at margins of pro- and mesonotum. Pronotum trapezoidal; mesonotum rectangular, posterior margin wide, V-shaped, denoting the formation of scutellum. Wing pads slightly developed, reaching posterior margin of metanotum. Dorsal abdominal maculae with the same color and distribution as observed in third instar, but wider. Lateral plates semicircular, predominantly orange, slightly punctured. Other characteristics as described in the previous instars.

Fifth instar (Fig. 18). Body oval to pyriform, predominantly black. Head flat; mandibular plates wide, each with orange band present in some individuals. Thorax predominantly black, 1+1 orange maculae on pronotum and mesonotum along the anterolateral margins, median macula orange. Pronotum wider; mesonotum more developed; scutellum well delimited. Wing pads well developed, surpassing the middle of abdominal segment III. Legs black, hairs denser ventrally. Abdomen black, coarsely punctured with maculae dorsally distributed as follows: one pair (1+1) of orange maculae near first median plate, with another white, semicircular macula between the preceding two maculae; and four pairs (4+4) of white maculae, located near lateral plates, on segments IV to VII; lateral plates with semicircular orange maculae, outlined in black. Urosternite VIII split longitudinally in females and entire in males. Other characteristics as described in the previous instars.

Chinavia runaspis (Dallas, 1851)

http://species-id.net/wiki/Chinavia_runaspis
Figs 19–24

Remarks. Adults of *C. runaspis* have general body color light green to dark green, with reddish orange color on the margins of mandibular plates, pronotum, basal third of hemelytra and connexivum (Schwertner and Grazia 2007). *Chinavia runaspis* is recorded for Venezuela, Suriname, Colombia, Brazil (Amapá, Pará, Minas Gerais, Rio de Janeiro, São Paulo, Santa Catarina, Rio Grande do Sul), Peru, Paraguay and Argentina (Schwertner and Grazia 2007). The morphometric parameters of nymphal instars are shown in Table 5.

First instar (Fig. 20). Body round and convex, surface without punctuation. General coloration dark brown to black. Head conical and strongly declivent. Clypeus with apex obtuse, length subequal to that of mandibular plates, these subtriangular shaped. Ocelli absent. Diameter at eyes smaller than the base of clypeus. Antennae black, intersegmental areas light brown; antennal segments covered by few hairs sparsely distributed. Antennal segment I shortest and antennal segment IV longest. Antennal segments III and IV subequal in size. Rostrum black, slightly surpassing the mesocoxae. Thorax predominantly dark brown, with a large, rounded,orange macula, which extends from middle of the head to the posterior margin of mesonotum. Legs black, denser hairs on tibiae and tarsus; tarsi two-segmented with a pair of claws and pulvili. Tibiae dorsally flattened. Abdomen dark brown, with three pairs (3+3) of white maculae, located between lateral and median plates, which are black. Median dorsal plates black; ostioles on median dorsal plates I-III. Lateral plates semicircular, black, without punctuation, adjacent to lateral margin of each segment. Spiracles near anterior margin of lateral plates, on urosternites II to VIII. From urosternites III to VII, 1+1 trichobothria placed medially of an imaginary line across spiracles and near posterior margin of each segment.

Second instar (Fig. 21). Body oval and less convex than in first instar. Head less declivent than previous instar, predominantly black, coarsely punctured in the dorsum. Clypeus obtuse at apex, subequal in size to the mandibular plates, which

Table 5. Morphometric traits of nymphs of *Chinavia runaspis* (Dallas, 1851) (n = 15) (mean ± standard deviation, mm).

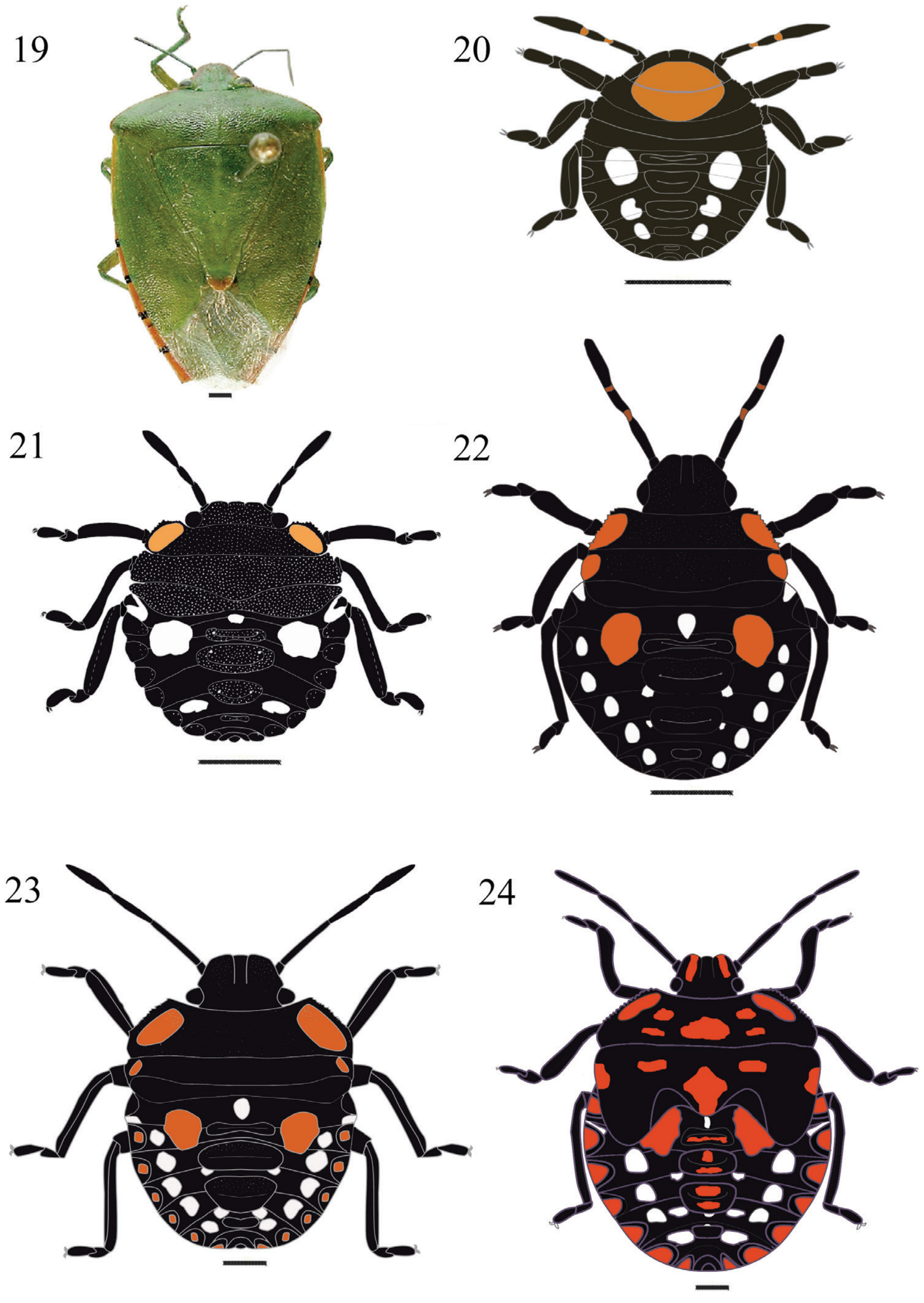
Measures	1st instar	2nd instar	3rd instar	4th instar	5th instar
TL	2.35±0.44	3.7±0.31	4.9±0.35	8.1±1.21	11.31±1.21
TW	1.72±0.07	3.1±0.18	4.3±0.36	6.1±0.45	9.53±2.12
ID	0.7±0.05	0.92±0.07	1.6±0.12	1.88±0.32	1.92±0.17
I	0.14±0.06	0.23±0.08	0.27±0.05	0.4±0.23	0.43±0.03
II	0.24±0.02	0.49±0.08	0.78±0.09	1.4±0.34	1.72±0.23
III	0.23±0.04	0.4±0.05	0.77±0.07	1.3±0.08	1.62±0.22
IV	0.43±0.05	0.71±0.09	0.96±0.11	0.98±0.08	1.67±0.14
RL	0.9±0.09	1.39±0.05	1.7±0.8	0.96±0.11	3.44±0.22
PL	0.38±0.09	0.66±0.11	1.4±0.44	2.22±0.09	2.1±0.52
PW	1.4±0.33	2.01±0.16	3.9±0.39	5.1±1.1	6.5±1.2

HL, head length; ID, interocular distance; PL, pronotum length; PW, pronotum width; RL, rostrum length; TL, total length; TW, total width; I, II, III, IV, length of antennal segments.

are broader than in previous instar. Eyes almost as wide as base of clypeus. Rostrum black, reaching the metacoxae. Thorax with 1+1 orange maculae along the margins of pronotum; lateral margins of pro- and mesonotum slightly deflected. Legs black, dense hairs on tibiae and tarsus. Abdomen predominantly dark brown, maculae distributed as follows: one pair (1+1) of orange, rounded and large maculae, and two pairs (2+2) of white and rounded maculae. Median and lateral dorsal plates black punctured. Urosternites III to VII with 2+2 trichobothria, one trichobothrium medially of the spiracular line and the other along that line. Other characteristics as described for the first instar.

Third instar (Fig. 22). Mandibular plates and clypeus subequal in length. Thorax predominantly black, coarsely punctured, with a pair (2+2) of orange maculae along anterolateral margins, which are depressed, slightly deflected and not serrate. Abdomen predominantly black, with maculae distributed as follows: a white small, round macula, anteriad of first median plate; one pair (1+1) of large, orange, semicircular, located between first median and lateral plates; five pairs (5+5) of white and round maculae, located between lateral and median plates; and two pairs (2+2) of white, small maculae located near second and third median plates. All median and lateral plates predominantly black and coarsely punctured; lateral plates semicircular. Other characteristics as described in the previous instars.

Fourth instar (Fig. 23). Body oval, less convex than in previous instars, predominantly black. Head less declivent than in third instar, clypeus black. Thorax predominantly black, except for shapeless, light orange maculae, on dorsum and margins. Maculae on the dorsum of the thorax light orange. Pronotum trapezoidal; mesonotum rectangular, posterior margin wide, V-shaped, denoting the formation of scutellum. Wing pads slightly developed, reaching posterior margin of metanotum. Lateral plates



Figures 19–24. *Chinavia runaspis* (Dallas, 1851). **19** Adult **20** First instar **21** Second instar **22** Third instar **23** Fourth instar **24** Fifth instar.

orange with black margin, with few punctures. Maculae on abdominal dorsum with the same coloration and distribution as in previous instar, but larger. Other characteristics as described in the previous instars.

Fifth instar (Fig. 24). Body oval to pyriform. Head flat, slightly punctured; mandibular plates wide, each a longitudinal orange band. Thorax predominantly black with a pair (1+1) of orange maculae on pronotum along anterolateral margins and laterally on mesonotum. In some individuals, additional orange maculae are dispersed on the dorsum of the thorax. Pronotum wider, anterolateral margins slightly convex; mesonotum more developed, scutellum well delimited. Wing pads well developed, surpassing the middle of abdominal segment III. Legs black, hairs more abundant ventrally. Abdomen predominantly black, densely dotted, with maculae distributed as follows: one white macula anteriad of the first median plate; one pair (1+1) of orange maculae between lateral and first median plates; four pairs (4+4) white maculae lon segments IV-VII. Lateral plates semicircular, orange with black margins, with few punctures. Median plates predominantly black, coarsely punctured, with orange maculae in the center of the plate. Urosternite VIII split longitudinally in females and entire in males. Other characteristics as described in the previous instars.

Key to identification of first instars of *Chinavia* in Rio Grande do Sul

1 Body color predominantly brown to black; median dorsal maculae along head and thoracic segments.......... **2**
– Body color predominantly green, variegated; median dorsal macula restricted to head.......... ***C. musiva* (Berg, 1878)**
2 Head and legs entirely with the same predominant color of the body.......... **3**
– Apex of head and areas of legs in a different color of the body coloration.......... ***C. erythrocnemis* (Berg, 1878)**
3 Median dorsal maculae orange or reddish orange.......... **4**
– Median dorsal maculae yellow.......... **5**
4 Abdominal dorsal maculae white.......... **6**
– Abdominal dorsal maculae white and yellow to yellowish-orange.......... ***C. obstinata* (Stål, 1860)**
5 Median macula oblong; macula anteriad to first median plate with twice the diameter of the eye.......... ***C. nigridorsata* (Breddin, 1901)**
– Median macula sub lozenge, macula anteriad to first median plate smaller than the diameter of the eye.......... ***C. impicticornis* (Stål, 1872)**
6 Dorsal surface of abdomen with three pairs (3+3) of white maculae, located between lateral and median plates; white, small macula before first median plate absent.......... **7**
– Dorsal surface of abdomen with white maculae arranged in a distinct pattern in addition to the white, small macula before first median plate.......... **8**
7 Median dorsal macula rounded, very large.......... ***C. runaspis* (Dallas, 1851)**

–	Median dorsal macula almost oval, smaller	***C. brasicola*** **(Rolston, 1983)**
8	White macula anteriad of first median plate	**9**
–	White, rounded maculae before all median plates	***C. ubica*** **(Rolston, 1983)**
9	Thorax without maculae on lateral margins	**10**
–	Thorax with maculae on lateral margins	***C. longicorialis*** **(Breddin, 1901)**
10	Median dorsal macula almost rounded, extending from base of head to posterior margin of pronotum	***C. aseada*** **(Rolston, 1983)**
–	Median dorsal macula in a different shape to the above mentioned, covering base of head and surpassing the posterior margin of pronotum	**11**
11	Median dorsal macula reaching the posterior margin of metanotum, white maculae surrounding first lateral plate	***C. pengue*** **(Rolston, 1983)**
–	Median dorsal macula reaching the posterior margin of mesonotum, median plates without adjacent maculae	***C. armigera*** **(Stål, 1859)**

Key to identification of second instars of *Chinavia* in Rio Grande do Sul

1	Body color predominantly brown to black	**2**
–	Body color predominantly green, variegated	***C. musiva*** **(Berg, 1878)**
2	Apex of the head, and areas of antennae and legs red, thorax without maculae	***C. erythrocnemis*** **(Berg, 1878)**
–	Head, antennae and legs entirely with the same predominant color of the body; thoracic maculae in pronotum and /or mesonotum	**3**
3	Thoracic maculae yellow to orange	**4**
–	Thoracic maculae reddish	**6**
4	Thoracic maculae yellow	**5**
–	Thoracic maculae orange	**7**
5	First pair of lateral plates surrounded by white maculae, the remaining lateral plates with a white macula between them...	***C. nigridorsata*** **(Breddin, 1901)**
–	First pair of lateral plates with a white macula near it; 5+5 white maculae between lateral and median plates	***C. impicticornis*** **(Stål, 1872)**
6	Body color predominantly brown, white maculae anteriad of median dorsal plates	***C. ubica*** **(Rolston, 1983)**
–	Body color predominantly black, one white macula anteriad of first median plate; 3+3 white maculae on abdomen	***C. pengue*** **(Rolston, 1983)**
7	Orange thoracic maculae on pronotal and mesonotal margins	***C. longicorialis*** **(Breddin, 1901)**
–	Orange thoracic maculae on pronotum margins only	**8**
8	Abdominal maculae white	**9**
–	Abdominal maculae in other colors	**10**
9	Abdomen with 5+5 small maculae	***C. armigera*** **(Stål, 1859)**

– Abdomen with 1+1 large and 4+4 small maculae ***C. aseada* (Rolston, 1983)**

10 Abdomen with 1+1 yellow maculae between first median and lateral plates .... ***C. obstinata* (Stål, 1860)**

– Abdomen with 1+1 orange maculae between first median and lateral plates... **11**

11 Abdomen with one white macula anteriad of first median plate; 1+1 orange maculae and 4+4 white maculae between median and lateral plates .... ***C. brasicola* (Rolston, 1983)**

– Abdomen with 1+1 orange maculae and 1+1 white maculae posterior to the third median plate .... ***C. runaspis* (Dallas, 1851)**

Key to identification of third instars of *Chinavia* in Rio Grande do Sul

1 Body color predominantly brown to black 2

– Body color predominantly green and variegated .... ***C. musiva* (Berg, 1878)**

2 Apex of the head, antenna segment I, apices of femora and bases of tibiae red .... ***C. erythrocnemis* (Berg, 1878)**

– Head, antennae and legs with the same predominant color of the body...... **3**

3 Median region of thorax without maculae; posterolateral angles of pronotum not produced **4**

– Median region of thorax with an orange macula; posterolateral angles of pronotum slightly produced .... ***C. aseada* (Rolston, 1983)**

4 Thoracic maculae yellow **5**

– Thoracic maculae orange **6**

5 Maculae on the abdominal segments white ..... ***C. impicticornis* (Stål, 1872)**

– Maculae on the abdominal segments yellow and white .... ***C. nigridorsata* (Breddin, 1901)**

6 Maculae on the abdominal segments white .... ***C. armigera* (Stål, 1859)**

– Maculae on the abdominal segments in other colors **7**

7 Median abdominal plates without maculae adjacent to its margins **8**

– Median abdominal plates with maculae adjacent to its margins **9**

8 Orange thoracic maculae on pronotal and mesonotal margins .... ***C. longicorialis* (Breddin, 1901)**

– Orange thoracic maculae on pronotal margins only .... ***C. brasicola* (Rolston, 1983)**

9 White maculae between median plates **10**

– White maculae laterad to median plates **11**

10 Abdomen with one pair (1+1) of yellowish maculae and four pairs (4+4) of white maculae between lateral and median plates .... ***C. ubica* (Rolston, 1983)**

– Abdomen with one pair (1+1) of yellowish maculae and one pair (1+1) of white maculae near the lateral plates in segments IV and V .... ***C. obstinata* (Stål, 1860)**

11 Abdomen with white maculae; lateral plates with orange maculae in the center .... ***C. pengue*** **(Rolston, 1983)**

– Abdomen with white and orange maculae; lateral plates black or with orange maculae in the center .... ***C. runaspis*** **(Dallas, 1851)**

Key to identification of fourth instars of *Chinavia* in Rio Grande do Sul

1 Body color predominantly brown to black **2**

– Body color predominantly green and variegated ..... ***C. musiva*** **(Berg, 1878)**

2 Mandibular plates, antennal segment I, apices of femora and bases of tibiae red .... ***C. erythrocnemis*** **(Berg, 1878)**

– Legs predominantly black to brown **3**

3 Maculae on pronotal and mesonotal margins yellow **4**

– Maculae on pronotal and mesonotal margins orange **5**

4 Pronotum trapezoidal; posterolateral angles produced .... ***C. nigridorsata*** **(Breddin, 1901)**

– Pronotum trapezoidal; posterolateral angles not produced .... ***C. impicticornis*** **(Stål, 1872)**

5 Median region of thorax and median abdominal plates with shapeless color maculae **6**

– Median region of thorax and median abdominal plates without color maculae **7**

6 Shapeless maculae straw-yellow .... ***C. armigera*** **(Stål, 1859)**

– Shapeless maculae orange .... ***C. aseada*** **(Rolston, 1983)**

7 Abdomen with white maculae between lateral and median abdominal plates .... ***C. pengue*** **(Rolston, 1983)**

– Abdomen with white and yellow or orange maculae between lateral and median abdominal plates **8**

8 Abdomen with white and orange maculae **9**

– Abdomen with white and yellow maculae **10**

9 White maculae on abdomen rounded and similar in size; one pair (1+1) of white maculae laterad to second and third median plates.... ***C. runaspis*** **(Dallas, 1851)**

– White maculae on abdomen of different sizes; median plates without laterad maculae .... ***C. brasicola*** **(Rolston, 1983)**

10 Mesonotum without maculae along the margins; one pair (1+1) of white maculae adjacent to first lateral plates .... ***C. obstinata*** **(Stål, 1860)**

– Mesonotum with maculae along lateral margins **11**

11 Mandibular plates with reddish orange bands; mesonotum with median maculae; white maculae along posterior margins of median plates .... ***C. ubica*** **(Rolston, 1983)**

– Mandibular plates without bands; mesonotum without median maculae; median plates without maculae .... ***C. longicorialis*** **(Breddin, 1901)**

Key to identification of fifth instars of *Chinavia* in Rio Grande do Sul

1 Body color predominantly brown to black **2**

– Body color predominantly green and variegated ..... ***C. musiva*** **(Berg, 1878)**

2 Mandibular plates, antennal segment I, apices of femora and bases of tibiae red ..... ***C. erythrocnemis*** **(Berg, 1878)**

– Legs predominantly black to brown **3**

3 Pronotum trapezoidal; posterolateral angles produced **4**

– Pronotum trapezoidal; posterolateral angles not produced **6**

4 Thorax variegated, predominantly straw-yellow ..... ***C. armigera*** **(Stål, 1859)**

– Thorax variegated, predominantly light brown, dark brown or black **5**

5 Macula anteriad of the first median plate wider than diameter of eye; light brown band covering almost the entire surface of clypeus; orange maculae covering almost entirely the median plates ..... ***C. aseada*** **(Rolston, 1983)**

– Macula anteriad of the first median plate smaller than diameter of eye; clypeus immaculate; orange maculae covering almost half of the median plates ..... ***C. nigridorsata*** **(Breddin, 1901)**

6 Lateral plates yellow emarginated in black ..... ***C. impicticornis*** **(Stål, 1872)**

– Lateral plates orange to red emarginated in black 7

7 Scutellum without median macula **8**

– Scutellum with median macula **9**

8 Median plates orange at the middle; abdomen with three pairs of white maculae, between lateral and median plates ..... ***C. pengue*** **(Rolston, 1983)**

– Median plates green at the middle; abdomen with four pairs of white maculae, between lateral and median plates ..... ***C. longicorialis*** **(Breddin, 1901)**

9 Abdominal maculae white; lateral and median plates with red orange maculae ..... ***C. ubica*** **(Rolston, 1983)**

– Abdominal maculae white and orange; lateral and median plates with orange maculae **10**

10 Mesonotum with small orange maculae, uniformly distributed ..... ***C. runaspis*** **(Dallas, 1851)**

– Mesonotum with maculae restricted to the median region and margins **11**

11 Scutellum at middle with a round macula anteriad of an oblong macula, both orange; abdomen with a pair (1+1) of orange maculae and four pairs (4+4) of small white maculae between lateral and median plates ..... ***C. obstinata*** **(Stål, 1860)**

– Scutellum at middle with a large orange macula; abdomen with a pair (1+1) of orange maculae and four pairs (4+4) of large white maculae between lateral and median plates ..... ***C. brasicola*** **(Rolston, 1983)**

Discussion

Recognition of *Chinavia* species at the nymphal stage is based on the general color pattern of the body and number, size and coloration of dorsal maculae (Grazia et al. 1982; Schwertner et al. 2002; Matesco et al. 2003). The first instar of *C. armigera*, *C. aseada*, *C. brasicola* and *C. runaspis* follow the pattern observed for other *Chinavia* species with described immatures: body coloration predominantly dark; head and thorax with a dorsal median yellow to reddish macula; abdomen with a series of white to orange maculae lateral to the first three median plates (Schwertner et al. 2002, Matesco et al. 2009a). *Chinavia musiva* differs from other species by having the general color of abdomen predominantly green and variegated, without maculae (Matesco et al. 2008). The four species studied here have the dorsal median macula orange colored; in *C. armigera* this macula is darker than in the other species. The shape and size of dorsal median macula may also vary. In *C. runaspis*, the shape is round and it is the largest size observed in the species studied so far. Furthermore, of all the *Chinavia* species found in the state of Rio Grande do Sul, only *C. obstinata* has white maculae surrounding all abdominal lateral plates, and the maculae lateral to first median plate are yellowish (Matesco et al. 2003). The remaining species have lateral plates entirely black, without surrounding white maculae. Furthermore, the first instar nymphs of the four species described here have only white maculae on the dorsum of the abdomen.

From the second instar on, nymphs of *Chinavia* have a pair (1+1) of maculae on lateral margins of pronotum, which differ in color as compared to other species: yellow in *C. impicticornis* and *C. nigridorsata*; reddish-orange in *C. pengue* and *C. ubica*, and orange in the remaining species, including those described here. On the abdomen, the anterior median white maculae, the presence of 1+1 yellow or orange maculae lateral to first median plate, and 1+1 white maculae surrounding the fore lateral plates are common features of *Chinavia* nymphs in general (Matesco et al. 2009a). However, *C. armigera* and *C. aseada* are distinguished by not having lateral plates surrounded by maculae and have the abdominal maculae exclusively white. The same can be observed in *C. pengue*, but this species shows areas of head and legs in red as diagnostic characters, besides not having maculae on lateral margins of pronotum.

In the third instar, all the dorsal maculae expand and other maculae with the same color can appear on the mandibular plates and lateral margins of mesonotum, which allow an easier identification of the species. Species that do not have maculae on the mandibular plates and margins of mesonotum are *C. brasicola* and *C. obstinata.* These two species differ from each other in the size of the white maculae located before the first median plate and abdominal maculae, which are broader in these two species. Bands on the mandibular plates, maculae in the middle of the thorax and in the center of median and lateral plates dorsally can appear from the fourth instar on. In *C. armigera*, *C. erythrocnemis* and *C. pengue*, bands on mandibular plates are pale straw-yellow, red and red-orange, respectively. In the fifth instar, the diagnostic characteristics become more evident, allowing easier identifications at the species level. Wing pads surpass or at least reach the posterior margin of the metanotum, and nymphs already exhibit sexual dimorphism: sternum VIII is entire in males and divided into two lobes in females (Dupuis 1947, Brailovsky et al. 1992).

The nymphs of *C. brasicola* are similar to those of *C. runaspis,* as they display a general color predominantly black, and white and orange maculae distributed on the dorsum of the thorax and abdomen. However, the white maculae observed in *C. brasicola* are larger than those observed in *C. runaspis.* In this instar, nymphs of *C. armigera*, *C. aseada* and *C. nigridorsata* are very similar in color pattern, and posterolateral angles of the pronotum are more acute than in the other species. However, the predominant color of the thorax, which is dark brown in *C. nigridorsata*, while predominantly light brown in the two other species may distinguish them. However, some individuals of *C. aseada* and *C. nigridorsata* may have thoracic coloration reddish instead of dark brown. Median dorsal plates of *C. aseada* have orange maculae and *C. nigridorsata* red-orange. Lateral plates of *C. armigera* and *C. nigridorsata* are predominantly orange to orange-red, outlined in black, as in *C. aseada*. However, the black margins of the lateral plates observed in *C. aseada* are narrower than in the two other species mentioned above. The number and distribution of trichobothria in the nymphs of *C. armigera*, *C. aseada*, *C. brasicola* and *C. runaspis* follow the pattern described by Schaefer (1975) for Pentatomoidea, which also has been previously observed in other species of *Chinavia* (Grazia et al. 1982, Matesco et al. 2003, 2007, 2009a).

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New distributional and bioacoustic data about *Cicadivetta goumenissa* from Peloponnese, Greece (Hemiptera, Cicadidae)

Matija Gogala[1], Sakis Drosopoulos[2], Tomi Trilar[3]

[1] Slovenian Academy of Sciences and Arts, Novi trg 3, SI-1000 Ljubljana, Slovenia *[2] Elatis 6, GR-14564, Nea Kifisia, Greece* *[3] Slovenian Museum of Natural History, Prešernova 20, SI-1000 Ljubljana, Slovenia*

Corresponding author: *Matija Gogala* (matija.gogala@guest.arnes.si)

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Abstract

Cicadivetta goumenissa, a small singing cicada described recently by Gogala, Drosopoulos and Trilar (2012), has been previously found only around the village of Goumenissa in northern Peloponnese. We visited this area again in June 2012 and tried to determine the distribution range of this species. We found *C. goumenissa* in some further localities, but all within a very small area of about 15 by 25 km. We also made more than one hour of new song recordings and extended our knowledge of the song repertoire of this species.

Keywords

Hemiptera, Cicadidae, *Cicadivetta goumenissa*, geographical distribution, song pattern

Introduction

We found and described this year the new cicada species *Cicadivetta goumenissa* Gogala, Drosopoulos, Trilar 2012 in just a small area in northern Peloponnese, Greece (Gogala et al. 2012). As mentioned in the paper, we first discovered this species in 2005 near the village of Goumenissa by its characteristic high pitched song with very fast repetitions of short echemes, interrupted by single long echemes. Until this year, we have never heard such sound pattern or ever collected this cicada in any other parts of the Peloponnese or elsewhere during our field work. Therefore, we decided to visit this area again this year (2012) to get more data on this peculiar cicada and to find out whether *C. goumenissa* is really restricted just to this locality and possibly why.

Materials and methods

We made a field trip to the Peloponnese from 9 to 11 of June, 2012. From previous visits to this area in 2005, 2006 and 2010 we knew that *C. goumenissa* could not be found in July or later in the year.

We were searching for the presence of this cicada with bioacoustic equipment described below in localities around Kalavrita, Goumenissa, Pteri, Manesi, Vlasia, Dendra, Mirali, Priolithos, Lagovouni and on Mt. Erymanthos (see Table 1).

For the names and spelling of localities we follow the local inscriptions and transliterations used in the maps of the "Road Editions", Nr. 4 and 5, Athens (1996).

The distribution map was created by GPS Visualizer (Schneider 2003–2012).

For acoustic detection and recording of songs we used the ultrasonic detector Pettersson D-200 (heterodyne system) with electret microphones of the same producer (frequency range 10–120 kHz), mounted in front of a Telinga reflector (57 cm diameter) or a Renault R-4 front light reflector and connected to the solid state recorders Marantz PMD-660 (sampling rate up to 48 kS) or Zoom H2 (sampling rate up to 96 kS). Due to the high frequency range (see Gogala et al. 2012), we would not have been able to hear the acoustic signals of this cicada species without ultrasonic detectors. For sound analyses we used RAVEN 1.4 (Cornell Lab of Ornithology) and AMADEUS Pro 2.0 (HairerSoft). We first localized cicadas acoustically and then, if possible, collected them with an entomological net.

For the nomenclature of cicadas we are following the publication of Puissant and Sueur (2010).

Collected specimens are deposited in the collection of the Slovenian Museum of Natural History (PMSL). Song recordings are deposited in the Slovenian Wildlife Sound Archive of the same museum. A sample of a selected recording is available on the web pages Songs of European singing cicadas (http://www.cicadasong.eu).

Results

Distribution area:

We visited 13 localities in June 2012 and two more in previous years in the neighbourhood of Goumenissa (covering more than 200 km^2) and tried to detect the characteristic sounds of *C. goumenissa*. Reference to other cicada species found is also given (Table 1). Moreover, the visited localities are also shown on the map, where the places with presence of *C. goumenissa* are shown in red and those without this species in green (Fig. 2).

Table 1. List of localities, where we searched for *Cicadivetta goumenissa*. In the table are given the names of the localities (column 1), dates of visits (column 2), geographic coordinates with elevations (column 3) and names of the cicadas, heard (H), recorded (R), collected (C), observed (O) or photographed (P) in a particular locality (column 4). Included are also data from previous years. The shortened scientific names of species represent the following taxa:

C. goumenissa – *Cicadivetta goumenissa* Gogala, Drosopoulos & Trilar, 2012
C. flaveola – *Cicadivetta flaveola* (Brullé, 1832)
C. hannekeae – *Cicadetta hannekeae* Gogala, Drosopoulos & Trilar, 2008
C. atra – *Cicadatra atra* Fieber, 1776
C. orni – *Cicada orni* Linné, 1758
D. dimissa – *Dimissalna dimissa* (Hagen, 1856)
L. plebejus – *Lyristes plebejus* (Scopoli, 1763)
P. annulata – *Pagiphora annulata* (Brullé, 1832)
T. haematodes – *Tibicina haematodes* (Scopoli, 1763)
T. pygmea – *Tettigetula pygmea* (Olivier, 1790)

Kalavryta, Goumenissa	9. 6. 2005	N38°3.63', E22°1.87' 780 m	***C. goumenissa*** – R
Kalavryta, Goumenissa, deviation to Pteri	9. 6. 2005	N38°3.10, E22°1.72 740 m	***C. goumenissa*** – C, R *T. pygmea* – R
	9. 6. 2012	N38°3.10', E 22°1.63' 720 m	***C. goumenissa*** – C, R *T. pygmea* – R *D. dimissa* – R *T. haematodes* – H, O
	28. 6. 2006	N38°3.10', E22°1.72' 720 m	***C. goumenissa*** – C, R *C. atra* – H *T. haematodes* – C *D. dimissa* – H *T. pygmea* – R *C. flaveola* – C, F *L. plebejus* – H
	16. 7. 2010	N38°2.80', E22°1.30' 720 m	*C. orni* – H *L. plebejus* – H *T. haematodes* – H *C. flaveola* – C, R, P *C. atra* – H *T. pygmea* – R
Kalavryta, Petsaki, deviation to Valta	28. 6. 2006	N38°7.07', E22°3.32' 970 m	*C. flaveola* – R *C. atra* – H *D. dimissa* – H *L. plebejus* – P
Kalavryta, Skepasto (near the road to Goumenissa)	9. 6. 2012	N38°1.70', E22°2.77' 800 m	***C. goumenissa*** – R
Kalavryta, Mega Spileo	9. 6. 2012	N38°5.29', E22°10.36' 830 m	*D. dimissa* – R
Kalavryta, (deviation to Kerpini and Rogi)	9. 6. 2012	N38°3.28', E22°8.51' 740 m	***C. goumenissa*** – R *T. pygmea* – R *T. haematodes* – H *C. flaveola* – C, R

Kalavryta, road to Mt. Helmos	10. 6. 2012	N38°1.51', E22°7.75' 970 m	*C. hannekeae* – R *T. haematodes* – H *C. flaveola* – R *D. dimissa* – R
Kalavryta, Manesi	10. 6. 2012	N38°0.83', E21°56.69' 860 m	***C. goumenissa*** – R *T. pygmea* – R *T. haematodes* – H *C. flaveola* – R
Ano Vlasia, Mt. Erymanthos	10. 6. 2012	N37°58.00', E21°53.85' 1140 m	*C. hannekeae* – R *T. haematodes* – R
Kalavryta, Lagovouni	10. 6. 2012	N37°57.75', E22°3.40' 770 m	***C. goumenissa*** – R
Kalavryta, Lagovouni, deviation to Kandalos	10. 6. 2012	N37°57.11', E22°2.92' 750 m	*D. dimissa* – R *T. pygmea* – R *C. flaveola* – R *T. haematodes* – R
Klitoria, Priolithos, near the monument	10. 6. 2012	N37°54.97', E22°2.99' 1020 m	*T. pygmea* – R *C. flaveola* – R
Kalavryta, Kampigadi, Dendra	11. 6. 2012	N38°2.40', E21°52.94' 670 m	***C. goumenissa*** – C, R *P. annulata* – H *T. haematodes* – R *T. pygmea* – R *C. flaveola* – R *D. dimissa* – R
Halandritsa, deviation to Mirali	11. 6. 2012	N38°5.75', E21°48.76' 470 m	*P. annulata* – H *T. haematodes* – R *T. pygmea* – R *D. dimissa* – R
Pteri	28. 6. 2006	N38°8.79', E22°4.53' 1060 m	*C. hannekeae* – R *C. flaveola* – C, R, P

During the last eight years we have searched for cicadas in many other localities in Greece, including several field trips to other parts of the Peloponnese (Mt. Menalo, Mt. Parnon, Kastanitsa, Agios Andreas etc.) and have never heard, recorded or collected *C. goumenissa*. Therefore we assume that the distribution area of this species is really restricted to a very small area, not exceeding about 15 by 25 km.

Song pattern:

During our last excursion to the Kalavrita and Goumenissa region we made many new recordings (more than one hour) of the *C. goumenissa* song. Therefore, we can further comment on our description of the song pattern published previously (Gogala et al. 2012).

The main addition to this description is that the part of the song with longer echemes and a few or even without short echemes interspersed is apparently a regular part of the song and not an exception. Such phrases appear usually in the middle part of a song sequence (Fig. 3). The long echemes (LE) in such phrases can in extreme

Figure 1. Male of *Cicadivetta goumenissa* on leaves of Kermes Oak (*Quercus coccifera*) (Photo T. Trilar).

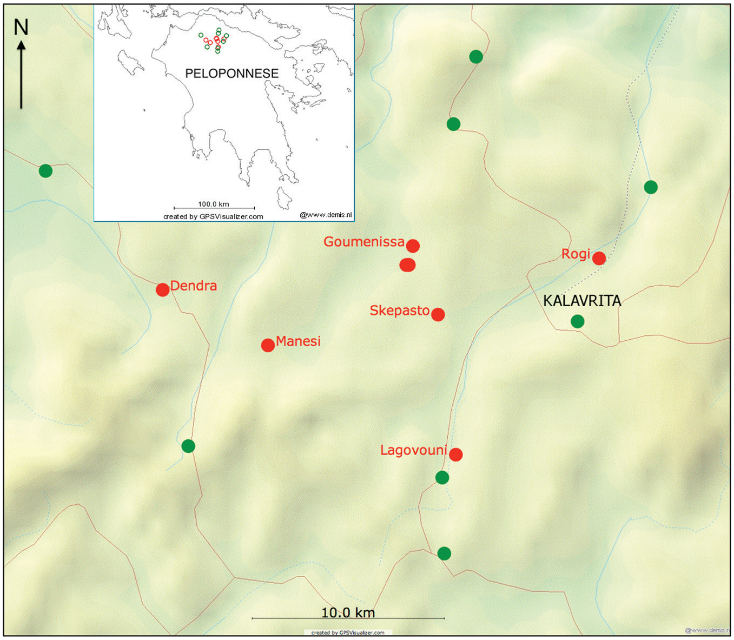

Figure 2. Distribution map of *Cicadivetta goumenissa.* Red points – localities with *C. goumenissa*, green points – localities where we searched for but did not find this species. Map created by GPS Visualizer (Schneider 2003-2012). Inset: position of localities on Peloponnese peninsula.

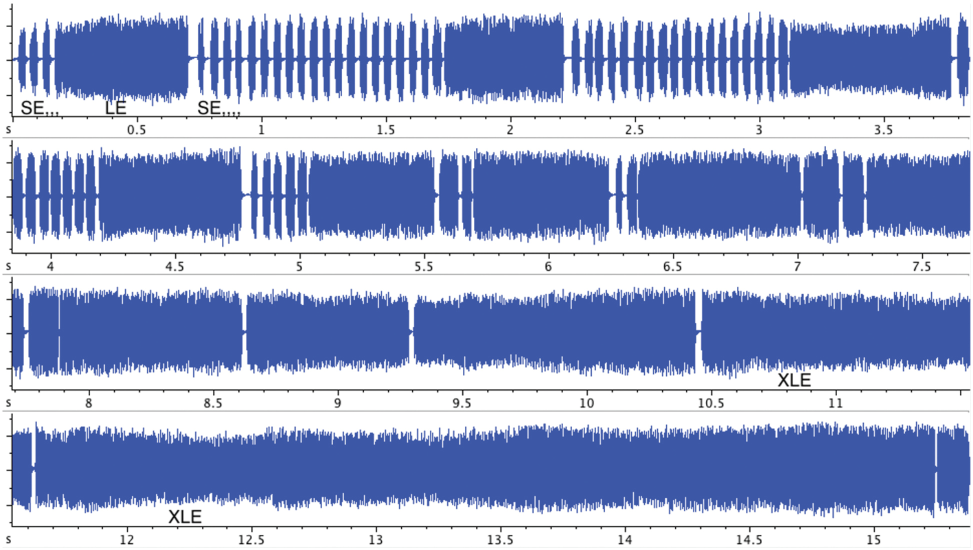

Figure 3. Oscillogram of the song selection of *Cicadivetta goumenissa* with the transition from prevailing phrases with SE sequence followed by LE toward the phrases with very long echemes XLE with a few SE or without them.

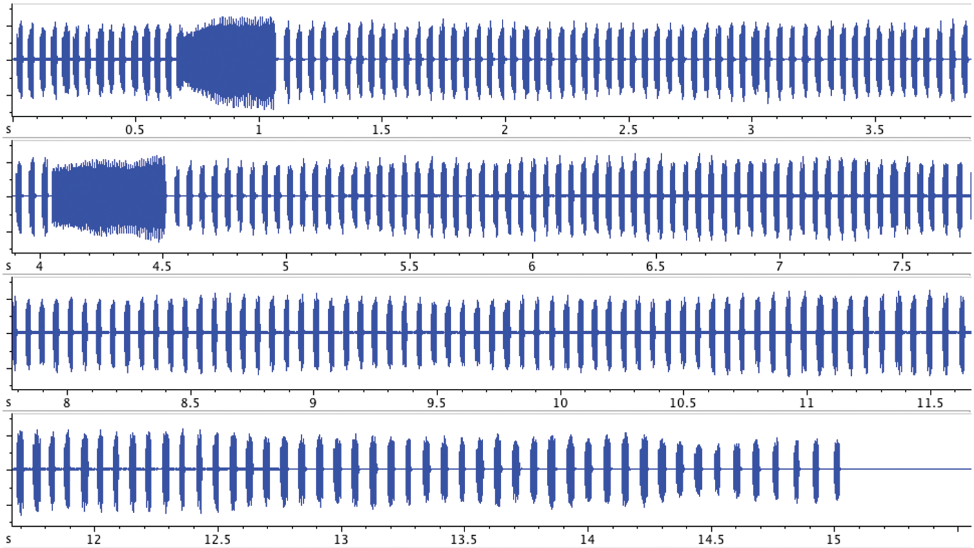

Figure 4. Oscillogram of the song selection of *Cicadivetta goumenissa* at the end of the song with long sequences of SE and with decreasing repetition rate.

cases fuse to the longest echemes (XLE), which can last up to 15 s. Therefore the part of a song with such extremely long echemes resembles the so called continuous song of *Cicadatra atra* or related species.

The whole song starts usually, but not always, with a long echeme followed by a sequence of short echemes (SE). The first long echeme may have also a preceding SE.

The main part of the song comprises phrases of some SE and one LE, as described previously (Gogala et al. 2012). At the end of a song there are usually longer sequences of SE, interrupted only by a few LE (Fig. 4). The repetition rate of SE is as described previously 19±3 SE/s and at the end of a song usually falls down to 10±2 SE/s. The whole song lasts between a few ten seconds and 3 – 4 minutes, and may be repeated without a longer pause or after a short silent period. We observed many times that the males in this silent period or at the end of a song fly away and change the singing post.

In most cases *C. goumenissa* males are perching and singing on branches of Kermes Oak (*Quercus coccifera*) as described earlier (Gogala et al. 2012) (Fig. 1). However, in one locality we observed and recorded some males for hours also on one and the same tree of Oriental Plane (*Platanus orientalis*).

Discussion

Why this cicada species is present only in such a restricted area, as described above, is one of the most puzzling questions concerning *C. goumenissa.* We do not see any reason why this cicada would not be able to move to other places, disperse and acquire similar habitats nearby. One possible explanation is that they are, unlike other cicadas, in the larval stage bound to restricted plant species. However, we do not have yet any sound evidence for this hypothesis. Nevertheless, the distribution of endemic cicada species of Evia shows clear similarities with the distribution of endemic plant species on this island (Gogala et al. 2011). Some endemic plants of the Peloponnese are also restricted to small mountainous areas similar to that of the present cicada, as is described by Kit Tan and Iatrou (2006). But we do not know if any of them is in any way connected with this insect.

The type of vegetation in the distribution area of *C. goumenissa* is everywhere very similar and can be described as garrigue or phrygana vegetation with Kermes Oak (*Quercus coccifera*) and other typical shrubs (Fig. 5).

Another possibility would be that this species was in the geological past confined to a small refugium and adapted to particular environmental conditions, which can be found only in the described habitat in this area. We have seen that one environmental parameter, the elevation of localities with *C. goumenissa*, is in all cases very similar. The lowest value is according to our measurements 670 m, the highest 860 m and the average 750 m. Is here hidden a hint for its limited distribution?

In the paper with the original description of *C. goumenissa* we have already mentioned the unusually high repetition rate of short echemes in the song (13-22 SE/s). In the southern part of Greece there are some other species with a high SE rate such as *Cicadivetta flaveola* (7-11 SE/s), which is found everywhere on the Peloponnese and in some other localities on the Greek mainland. This species occurs also in the distribution area of *C. goumenissa* in sympatry with the latter. Another example is also *Cicadivetta carayoni* (Boulard 1982), an endemic species of Crete with a similar rate of SE in its song (Trilar and Gogala 2010), which according to Puissant and

Figure 5. The garrigue or phrygana habitat in the locus typicus of *Cicadivetta goumenissa* near Goumenissa.

Sueur (2010) also belongs to the same genus. But even many species of the genus *Cicadetta* – e.g. *C. hannekeae* Gogala, Drosopoulos, Trilar 2008*, C. macedonica* Schedl 1999*, C. dirfica* Gogala, Trilar, Drosopoulos 2011 or *C. kissavi* Gogala, Drosopoulos, Trilar 2009 - all occurring in various regions of Greece, share with these species long sequences of short echemes and some long echemes. Nevertheless, none of them reaches such a high repetition rate of short echemes in their calling songs, as does *C. goumenissa*. Similarly high repetition rates of SE were reported for some western European species like some species of the genus *Tettigettalna* (Puissant and Sueur 2010).

Conclusions

Cicadivetta goumenissa occurs particularly in early June. It is, as expected, not restricted to the neighbourhood of the village Goumenissa, but can be found also in surrounding localities with a similar habitat. Nevertheless, we found it only in an area of about 15 × 25 km. From the new sound recordings here analysed we came to the conclusion that also the phrases with long echemes and without or with only a few short echemes are a regular component of its song and not just an exception.

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Photosharing websites may improve Hemiptera biodiversity knowledge and conservation

Marta Goula[1], José-Manuel Sesma[2], Luis Vivas[3]

1 *Universitat de Barcelona, Departament de Biologia Animal, Facultat de Biologia, Avda Diagonal 643, 08028 Barcelona, Spain* **2** *Invertebrate Gallery at Biodiversidad Virtual Website. Barcelona, Spain* **3** *Invertebrate Gallery at Biodiversidad Virtual Website. Valencia, Spain*

Corresponding author: *Marta Goula* (mgoula@ub.edu)

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Abstract

Internet photosharing websites is a very recent and powerful tool for the study of biodiversity, and a meeting point of general public fond of nature and professional naturalists. The article discusses when an uploaded picture is scientifically valuable, and the benefits of structured hosting websites for the most fruitful information retrieval. Examples are given of faunistic, biological, ecological and conservation results concerning Hemiptera provided by information download from photosharing websites.

Keywords

Macrophotography, entomology, Hemiptera, new technologies, Public Participation in Scientific Research, photosharing websites

Introduction

Illustration in science has always been an indispensible tool to make scientific communication more efficient. This general statement is particularly true regarding natural sciences, as for example geology, botany or zoology. Until the invention of photography (or its eve) in the 1810's by Niepce, the only chance for representing any subject were designs made by hand, either by the naturalist himself if picture-skilful, or by a designer collaborating with the naturalist to make scientifically valuable designs by highlighting the distinctive traits (Alamany 1997).

Photography was used by naturalist scientists very soon after being invented. From then onwards, and in a relatively short time, to take good pictures either in the field or in the laboratory has become progressively easier. The turning point was the advent of digital photography in the 1970's, which has made everyone of us a potential photographer on any subject, including nature (Marshall 2008). Accessibility of tools needed for digital photography, together with the ease of use and accessible prices of digital devices are driving factors in the increasing amount of nature pictures shot daily all over the world.

Generalized access to digital macro photography and to internet has greatly increased the uploading of insect images to internet photo sharing websites, founding a democratic revolution in the study of biodiversity (Marshall 2008). Wilson (2004) highlighted the powerful effect of combining both technologies. Google Search "Images Hemiptera" shows 614.000 results, "Images Heteroptera" 226.000 results, "Images True Bugs" 44.400.000 results, "Images Homoptera" 137.000 results, and "Images bugs" 256.000.000 results [accessed 14 November 2012]. A certain percentage of the images retrieved does not fit the hemipterist's target, as for instance erroneously identified pictures. However, the great bulk represents a huge image data base that hemipterists can no longer ignore, and hopefully in many cases may valuably help to the hemipterists' work in some way.

The aim of this work is to highlight how Heteropterists' research may be enhanced by implementing information provided by scientifically valuable uploaded pictures, in a fruitful collaboration between professional and amateur entomologists as an exercise of general public participated science.

When a Hemiptera uploaded photo is scientifically valuable?

Internet hosts a very high number of websites whose main focus is insect macro photography. A Google search under "Hemiptera photo gallery" showed approximately 41.600 results [accessed 14 November 2012].

Uploaded macro photographs may be scientifically valuable when they provides (a) shooting date; (b) shooting site data, including georeferenced data in current units as UTM or Latitude/Longitude; and (c) features needed to identify the specimen to species level. It is worth to note that date and site shot requirements parallel the field data stated in classical insect collection labels (Marshall 2008). Many uploaded insect pictures do fit the first two requirements i.e. shooting data. Unfortunately, high-quality beautiful insects shots are too often uploaded for the sake of aesthetics and not entomology, so identification of specimen is not possible. A great improvement in this matter could be achieved by a jointed collaboration of insect amateur photographers with professional entomologists, who could give advice on external characters taxonomically valuable for each insect group. Extra information contributing to the picture interest would be altitude, habitat, host plant, or other details which inform on the species biology. Reliability of data associated to uploaded pictures relies on photographer's ethics, as it has been also the case for centuries with author's ethics on published data. Carefully considered, uploaded pictures allow taking a glimpse of the specimen!

What are isolated uploaded Hemiptera images good for?

An identifiable Hemiptera image deprived of shooting date and site may still have a value for the professional hemipterists in certain circumstances. For example, images uploaded in the popular photosharing website BugGuide (http://bugguide.net/node/view/15740), may illustrate a scientific article, provided the contributor's license terms are respected. Identification reliability may be confirmed by the own borrower hemipterist taxonomic knowledge.

Also, pictures without shooting data are the rule in online visual identification guides. Generally speaking, websites hosting visual guides are organized according to a taxonomic system, either explicit in the website, as for example in the "Heteroptera of Slovenia" (http://www2.pms-lj.si/heteroptera/), or implicit in the taxonomic presentation order of uploaded photos. Examples of the latter are "British Bugs online identification guide of UK" (http://www.britishbugs.org.uk/links.html), or the corresponding websites for German bugs (Die Familien der Wanzen http://www.golddistel.de/wanzen/index.htm), Flanders bugs (Wantsen (Heteroptera) uit onze region http://users.telenet.be/roeland.libeer1/wantsen%20web/wantsen.htm) or Austrian Auchenorrhyncha (Auchenorrhyncha http://gallery.kunzweb.net/main.php?g2_itemId=258), among others. More sophisticated taxonomic digital tools are photographic keys (e.g. Umarán and Muñoz 2012 among many other examples), an application of new technologies that has inspired the specialized Canadian Journal of Arthropod Identification (http://www.biology.ualberta.ca/bsc/ejournal/ejournal.html). Last, Hemiptera pictures not labeled with date and site may be a very good complement to specialized taxonomic websites, for instance the Plant Bug Inventory website (http://research.amnh.org/pbi/), or the broader-scoped Encyclopedia of Life website (http://www.eol.org) in which image databases are intended to be progressively built. The driving force of uploading macro photos in visual guides or specialized Hemiptera websites is to illustrate, improve or facilitate knowledge of their taxonomy. Thus, picture uploading is limited by the geographic area scoped by the website (i.e. Heteroptera from the Iberian Peninsula http://www.flickr.com/groups/iberianbugs/). Also, to guarantee a reliable species identification, only Hemiptera experts can contribute to the website. Reliable visual guides and specialized websites may help professional hemipterists when studying specimens out of their usual geographic area of study.

The use of isolated uploaded pictures becomes much more fruitful when they at least provide information on the shooting site and date. The use of these pictures ranges from species conservation to faunistics or biology.

Conservation photography, a growing developing discipline stemmed from nature photography, creates pictures to serve the purpose of conserving nature (Mittermeier 2006). The increasing importance of conservation photography is highlighted by the foundation of the International League of Conservation Photographers (iLCP's) (http://www.ilcp.com/) and the creation of the biennial International Conservation Photography Awards (ICP Awards) (http://www.icpawards.com/index.php). A high-quality Hemiptera picture portraying a red-listed species contributes to its conservation when the associated data enlarges its distribution area, or confirms its existence after a long period of time without being found. For instance, *Parahypsitylus nevadensis* E. Wagner, 1957 (Miridae: Orthotylinae) is an Iberian endemic species which deserves the status of "vulnerable" in the Spanish Red List. Uploaded pictures (Jiménez 2010 http://www.biodiversidadvirtual.org/insectarium/Parahypsitylus-nevadensis-img144923.html) report the species more than 50 years after being described (Baena 2011).

Faunistics may benefit from uploaded, fully labelled photographies. A great effort is being made to catalogue all biota. Nowadays technology, with which creation of digital insect collections is much facilitated, may heavily contribute to this purpose (Wilson 2004). It is estimated that the remaining 90% unknown species will be discovered within the time of a human generation (25 years). In a more limited scope, partial Hemiptera catalogues may be enlarged, or doubtful occurring species confirmed, by contributed photographies. *Zelus renardii* Kolenati, 1856 (Reduviidae, Harpactorinae) (Fig. 1) is an American species aloctonous to the Iberian fauna. In 2010 the species was found in Europe for first time (Davranoglou 2011). The species was reported in the Iberian Peninsula by uploaded pictures (Vivas 2012a). The presence of *Heegeria tangirica* (Saunders, 1877), an eremic Alydidae scarcely recorded in the Iberian Peninsula, is fully confirmed in this geographic area by uploaded pictures (Burger 2011 http://www.biodiversidadvirtual.org/insectarium/Heegeria-tangirica-img400707.html).

Biology of a species may be described or better profiled with uploaded pictures documenting host plant or habitat, or labeling altitude of shot. Dated pictures may enlarge the known species period of activity or increase the knowledge of the species phenology.

Last and beyond the purpose of macrophotographies currently available internet photosharing websites, is the uploading of multiple-view high-resolution images to produce e-types. The profit to all taxonomists is out of doubt, as accessing available e-types is a quicker and afordable procedure than visiting museums or asking for type specimens loans (Wilson 2004). Harvard University launched in 2006 the "E-Type initiative", a 25 years project aiming at developing "Web-accessible electronic cataloguing and imaging of primary type specimens that are available for use by taxonomists and others in the research community" (Harvard University http://insects.oeb.harvard.edu/etypes/index.htm). Presently, 33 Hemiptera type-specimens may be downloaded [accessed 15 November 2012].

Website structure helps to enhance the scientific value of uploaded pictures

The examples presented in the previous section refer to Hemiptera macro photos hosted in simply structured websites, either with or without general public contributions.

Figure 1. *Zelus renardii* Kolenati, 1856 (Reduviidae, Harpactorinae). Photo K. Kamppeter. Determination L. Vivas.

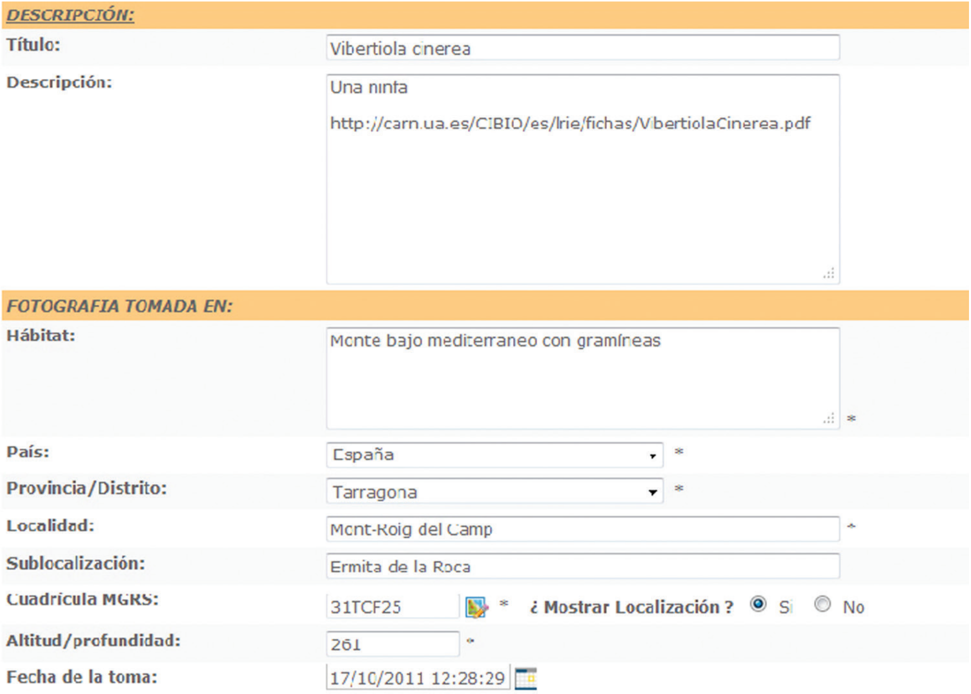
In these websites, photographs may be very well documented, but they are unlinked from each other, so that retrievable information, although valuable, is very limited.

Much more flexible and fruitful information may be retrieved when the hosting website links pictures and associated data to a data base file, i.e. an excel file. The turning point is how to ensure that contributing photographers will include required associated data in the uploading process. The description given below on photosharing procedures is taken from the Spanish internet photosharing website "Biodiversidad Virtual"(http://www.biodiversidadvirtual.org/).

As the first step, when uploading a picture the author is constrained to fill a list of obligatory fields, the shortest list being (Fig. 2) shooting date and locality, including country, district or province and georeference data through the selection of the locality on a digital cartography. Also very valuable are habitat description and altitude.

Once in the photosharing website system, the picture is confidently identified. Tentative identification may be proposed by the author, or by the website administrators. Checking by an expert is always advisable and compulsory when identification is not so straightforward. Thus, part of the website administrators' job is to organize a network of experts who may attend consultations.

Filled data and species identification are automatically downloaded to an excel file, so that data linked to each uploaded photograph will contribute to website database. A friendly windows interface allows consulting photo sharing website database according to one or more filled fields (Fig. 3), and a large amount of new information may be generated, including all the cases commented before in relationship with isolated uploaded pictures. For the sake of simplification, only a few



DESCRIPCIÓN:

Título: Vibertiola cinerea

Descripción: Una ninfa
http://carn.ua.es/CIBIO/es/lrie/fichas/VibertiolaCinerea.pdf

FOTOGRAFIA TOMADA EN:

Hábitat: Monte bajo mediterraneo con gramíneas *

País: España *

Provincia/Distrito: Tarragona *

Localidad: Mont-Roig del Camp *

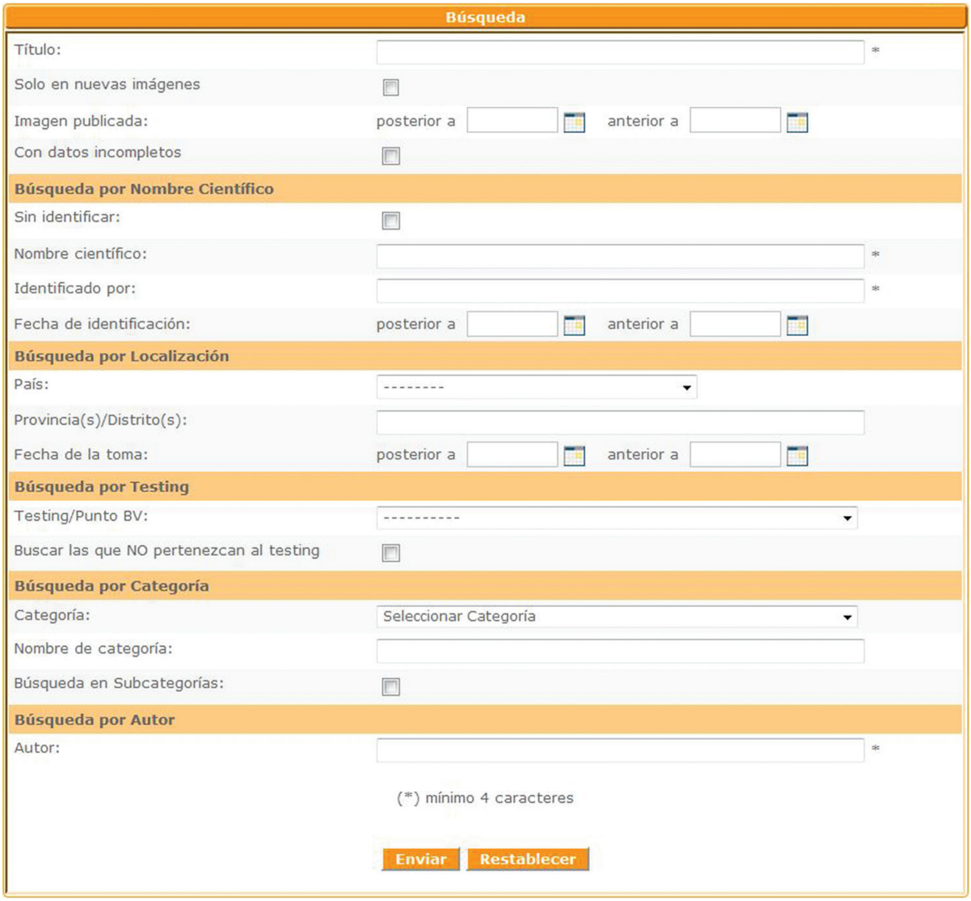
Sublocalización: Ermita de la Roca

Cuadrícula MGRS: 31TCF25 * ¿ Mostrar Localización ? ● Si ○ No

Altitud/profundidad: 261 *

Fecha de la toma: 17/10/2011 12:28:29

Figure 2. Fields to be filled when uploading pictures to Biodiversidad Virtual internet photosharing website. An asterisk (*) states for obligatory fields.



Búsqueda

Título: *

Solo en nuevas imágenes ☐

Imagen publicada: posterior a anterior a

Con datos incompletos ☐

Búsqueda por Nombre Científico

Sin identificar: ☐

Nombre científico: *

Identificado por: *

Fecha de identificación: posterior a anterior a

Búsqueda por Localización

País: --------

Provincia(s)/Distrito(s):

Fecha de la toma: posterior a anterior a

Búsqueda por Testing

Testing/Punto BV: ----------

Buscar las que NO pertenezcan al testing ☐

Búsqueda por Categoría

Categoría: Seleccionar Categoría

Nombre de categoría:

Búsqueda en Subcategorías: ☐

Búsqueda por Autor

Autor: *

(*) mínimo 4 caracteres

Enviar Restablecer

Figure 3. Windows interface implemented in Biodiversidad Virtual internet photosharing website to retrieve information from database set.

examples, not overlapping those previously stated, are given below. Examples will deal with conservation, faunistics, biology and ecology. Describing completely the retrieval power of a database-linked photosharing website is beyond the scope of this article.

Conservation

Vibertiola cinerea Horváth, 1909 (Reduviidae, Harpactorinae) (Fig. 4) is a Mediterranean species extending to the Sinai and Yemen. *V. cinerea* is presentd as Vulnerable (D2) in the Spanish Invertebrate Red List (Ribes Español et al. 2011). Two out of the seven localities stated are known only by photographies uploaded in the photosharing website Biodiversidad Virtual, enlarging the already known Iberian distribution area of *V. cinerea* ca. 150km southwards.

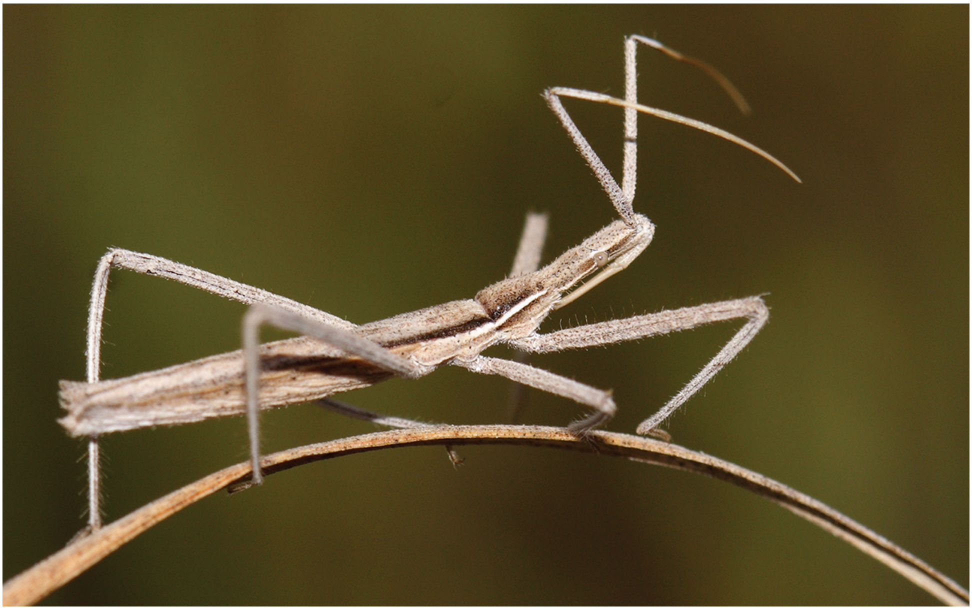


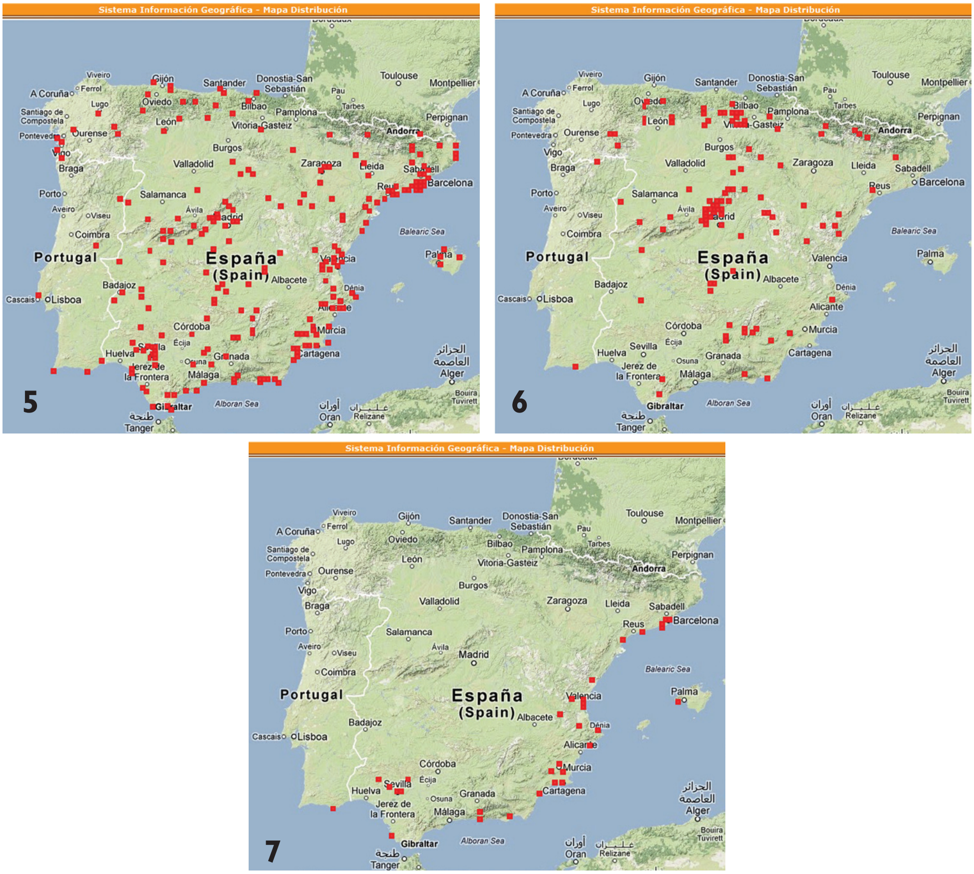
Figure 4. *Vibertiola cinerea* Horváth, 1909 (Reduviidae, Harpactorinae). Photo JM Sesma. Determination L. Vivas.

Faunistics

Spilostethus is a bigsized Lygaeinae genus with only three species belonging to the Iberian fauna. *S. pandurus* (Scopoli, 1763) and *S. saxatilis* (Scopoli, 1763) are very commonly found, but *S. furcula* (Herrich-Schaeffer, 1850) is scarcely observed along the Iberian Mediterranean climate area. All three species show a bright black and red color pattern, which may mislead a non-expert observer. Size and color make them a frequent target for macro photography, while *Spilostethus* species are often neglected in field trip collections as they are considered frequent and banal. Vivas (2012b) compiled information from georreferenced pictures in "Biodiversidad Virtual", and charted a high number of localities for all three Iberian *Spilostethus* species (Figs 5–7).

Ecology

Spilostethus furcula (Lygaeidae) is an afrotropical species, extending to the Maghreb and the Iberian Mediterranean coast. Northern Iberian localities, as documented in the shooting data from uploaded pictures (Fig. 7), may highlight how living conditions for this species occur now in areas previously hostile to it, thus perhaps illustrating an effect of global warming (Goula and Mata 2011).



Figures 5–7. 5 *Spilostethus pandurus* (Scopoli, 1763)(Lygaeidae, Lygaeinae) **6** *Spilostethus saxatilis* (Scopoli, 1763) (Lygaeidae, Lygaeinae) **7** *Spilostethus furcula* (Herrich-Schaeffer, 1850) (Lygaeidae, Lygaeinae) citations according to retrieved information from 399 pictures hosted at Biodiversidad Virtual internet photosharing website.

Biology

Due to its big size, abundance and frequency, *Nezara viridula* (Linnaeus, 1758) is a largely portrayed Pentatominae. Except for the very young instars, *N. viridula* nymphs may be identified to species level thanks to their distinctive color pattern. 550 pictures confidently belonging to *N. viridula* were uploaded to Biodiversidad Virtual from December 2008 to November 2012. Nymphs and adults were equitably represented in this pool. Summarizing shooting dates results in a phenology graph (Fig. 8), which shows that adults may overwinter, and nymphs are observed from April to October, with maximum nymphs numbers in summer.

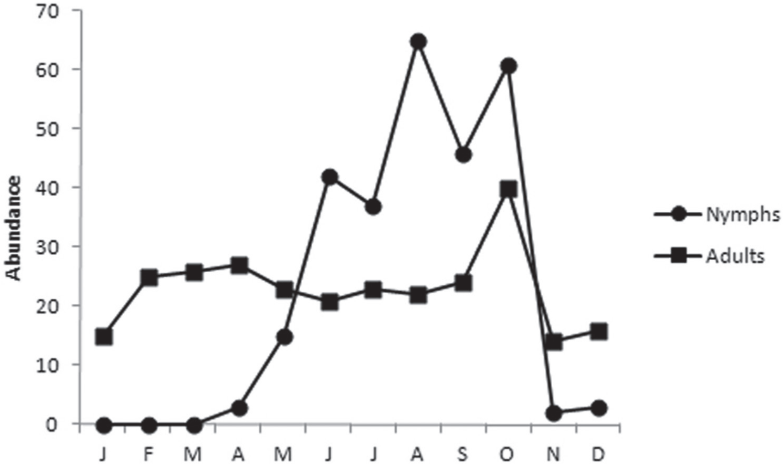


Figure 8. Phenology of *Nezara viridula* (Linnaeus, 1758) between December 2008 and November 2012, according to data from 550 pictures hosted in Biodiversidad Virtual internet photsharing website.

What are the limits of photosharing website databases?

Pictures shot and uploaded to a photosharing website do not arise from a previously planned sampling. Most probably, the contents on a photosharing website are biased towards the most colorful, bigsized, abundant or frequent species. Moreover, the distribution of shoots is uneven within any given territory. For example, natural protected areas, due to its potentially more interesting and diverse biota, may differentially attract nature photographers. Also, accessibility by private or public transportation means may favor certain areas over others, or the generally uneven distribution of human population may result in more shoots in accessible or crowded areas *vs*. less shoots in the isolated or uncrowded areas. Holiday periods will contribute to uneven shooting activity along the year, as also will cold and warm months. Compilation of all published data on any ubiquitous Hemiptera species concerning Catalan territory shows that field results are also spatially unvently distributed (Biodiversity data bank of Catalonia http://biodiver.bio.ub.es/biocat/index.jsp#pas18). Last but not least, many species will never be identifiable in a picture, as examination of genitalia is the only reliable method to verify species identity. With these handicaps in mind, some of them severely affecting the quantification of the retrieved information, internet photosharing websites are still a useful and valuable complementary source of information for the professional hemipterist.

Phtosharing websites, science and society

An increasing number of non-biologist amateurs are approaching nature in general, and insects in particular, by the practice of macrophotography. In fact, photo shooting and sharing is an accessible way to enjoy nature. When pictures are hosted in a website appropriately designed as previously described, the pleasure of photosharing increases with the pleasure of contributing scientifically valuable information. In fact photo sampling may bring together the general public, fond of nature and photography, to the scientific world, in an exercise close to Public Participation in Scientific Research (PPSR), lacking in this case an intentional design and a previous training (Shirk et al 2012). However, administrators of internet photosharing website may launch intentional designed projects, as for example occurred when the administritators of Biodiversidad Virtual website called the community to perform photosampling specifically on Hemiptera specimens during June 2011. In this case, 2340 pictures were uploaded, belonging to 170 species, 17 of them new for the website (Angulo 2011). On the other hand, scientists may profit froom photosharing websites by accessing extra information at very low effort and cost, and at disposal at the shortest period of time.

Conclusions

Scientific information has traditionally being retrieved from specialized books and journals. In the case of entomology, the publication of field sampling results has been the cornerstone of biodiversity datasets. Availability of modern digital photograph technologies, together with worldwide access to internet is profoundly modifying the study of biodiversity. Hemiptera is a good target group to be approached through the combination of these news technologies in reason of their frequency, and some results may be already retrieved from uploaded photographic data.

Full retrievable information power from internet photosharing websites is still to come. Biases and pitfalls due to unplanned photosampling underpinning uploaded photographies will always handicap websites. Website administrators may contribute to minimize those undesirable imperfections by encouraging specific photosampling addressed to areas, groups or periods of time underrepresented in the website database. However, only website database exploitation coherent with those intrinsic limitations may give scientifically fruitful and valuable results.

Internet photosharing websites are a pleasant, accessible and encouraging tool to implement Public Participated Scientific Research in relationship to Hemiptera biodiversity. Much work is needed to catalogue, document and portray the ca. 40.000 estimated bug species living on earth. The help of thousands of volunteer macro photographers uploading their valuable high-quality pictures should not be discarded.

Acknowledgments

The authors are grateful to the thousands of volunteer macro photographers who upload their photographs and share them graciously with us, to Coen Spithoven and Luis Mata for revision of English text, and valuable suggestions.

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REVIEW ARTICLE

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Aquatic Heteroptera (Nepomorpha, Gerromorpha) in small intermittent rivers of Ukraine steppe zone

Maria A. Grandova[1]

1 *UkrSCES, Frantsuzskiy Blvd., 89, Odessa, Ukraine*

Corresponding author: *Maria A. Grandova* (nepa@mail.ru)

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Abstract

Small intermittent rivers are some of the most widespread types of water currents in the steppe zone. In the ecosystems of the intermittent rivers we have found 28 species of water bugs that compose the majority of the described fauna in the south Ukraine. Our study added two new species to the faunistic list of this zone (*Sigara fossarum*, *Hydrometra gracilenta*), and finally confirmed the presence of *Micronecta scholtzi* in Ukraine. We also studied the seasonal changes of biotopic distribution and quantitative characteristics of aquatic Heteroptera. It was shown that for water bugs the ecosystem of the small intermittent rivers consists of three closely connected components: the riverbed, the flooded areas and the extra inundated constant basins. During the droughty period when the riverbed is dry, the extra inundated basins (including artificial ones – sandy pits) serve as refugia. The wintering of many species takes place there, especially when the riverbed is not filled before the cold period. However, the reproduction of most species takes place in the riverbed and associated flooded areas. Thus, this work is a confirmation and development of the concept for "a uniform architectonic complex of a river valley".

Keywords

Aquatic Heteroptera, Nepomorpha, Gerromorpha, steppe zone, small intermittent rivers

Introduction

The small intermittent rivers are some of the most widespread types of water currents in the south of Ukraine steppe zone. Under droughty climate conditions, they and the associated water bodies serve as refugia for aquatic organisms (Dyadichko 2008, 2009), while valleys serve as "ecological corridors" for the distribution of species from other landscape-climatic zones (Gramma 1974), playing a significant role in formation and maintenance of biodiversity in the steppe zone. The overall studying of small intermittent rivers is essential for understanding the function of the entire steppe biocenosis. Special studies of aquatic Hemiptera in this region haven't been carried out yet.

Materials and methods

The materials of our own expeditions (2007–2011), the collections of V. Dyadichko, A. Martynov and V. Martynov, as well as the collection of the Zoology Department of Donetsk National University were examined in this study. During the study, small intermittent rivers and associated water bodies of Odessa, Nykolaev and Donetsk areas were examined. For the study of quantitative characteristics, the material from the middle Tiligul River and associated water bodies in the Berezovkij wildlife reserve was used (Fig. 1).

The following typical biotopes were studied:

1. The riverbed. The bottom is sandy or oozy and sandy, sometimes with stones. Depth up to 1,5 m, current speed up to 1 m/s. The vegetation is abundant including marsh (*Carex* spp., *Iris* spp., *Typha* spp., *Phragmites* spp.), and submerged forms (*Ceratophyllum* spp., *Utricularia* spp., *Chara* spp., *Ranunculus* spp., filamentous algae). At the end of May-June, the current decreases, then it turns into several small pools and by the end of July - the beginning of August completely dries up. In October-November or later, depending on precipitation, autumn filling of the riverbed occurs.
2. The flooded area can be divided into three zones: a) the water meadows with land cereals that are flooded at a high water level and dry at the end of April-May; b) the inundated lowlands which dry up after water meadows (at the end of May - the beginning of June), and where land and marsh vegetation are combined; c) inundated pools with an oozy bottom which dry last, and vegetation includes sedge, mosses and cane.
3. The constant extra inundated basins are not connected directly to the river, but they are filled with the river water filtering through the soil. They can be both natural and artificial (sandy, clay pits). The surface area is up to 200 m^2, depth is up to 2-3 m, usually with a shallow coastal strip. Vegetation is poor. Some of these basins do not dry out even in the driest summer.

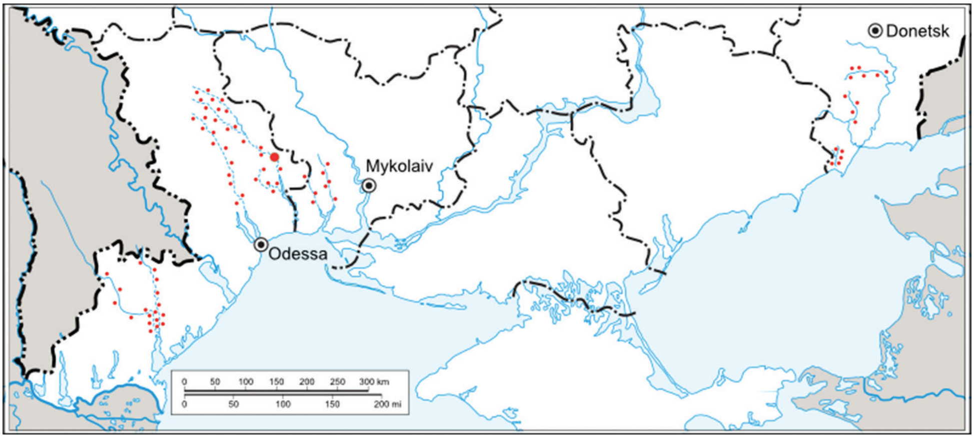

Figure 1. The studied area of Ukrainian steppe zone (sampling sites were marked with small red dots, the site of quantitative sampling – with a large red dot).

The periodization for the steppe intermittent rivers was offered by Dyadichko (2008). His division includes five periods, suitable also for aquatic Hemiptera:

1. **The early-spring period** continues from the ice melting and floods formation at the end of February – the beginning of March till the beginning of water vegetation growth at the end of March – April. Light day duration is about 10,9–12,3 h.
2. **The spring period** begins at the end of March, when water vegetation starts growing. It lasts till the depression of the water level in the flooded areas and the beginning of *Phragmites* spp. and *Typha* spp. growth at the end of April. Light day duration is about 12,4–14,2 h.
3. **The late-spring period** lasts through the end of April and May. It is characterized by desiccation of the flooded areas, normal water level in the riverbed, vegetation of *Phragmites* spp. and *Typha* spp., and flowering of iris marsh. Light day duration is about 14,3–15,4 h.
4. **The summer-autumn period** continues from June till the beginning of October. It is characterized by desiccation of the riverbed and many small basins. In June, the current is practically absent, water temperature is 24–27°C, and the semi-shipped vegetation (*Carex* spp., *Typha* spp., *Phragmites* spp.) and filamentous algae grow. Usually up to the end of July the riverbed has completely dried.
5. **The autumn-winter period** lasts from the filling of the riverbed in October – November till water freezing in December – the middle of February.

Quantitative samples were taken approximately every two weeks with the help of a Balfour-Browne hand net or hydrobiological drag, and also using meiobenthic methods for Micronectidae and nymphs of younger stages. Modified fish-traps and light attraction were also used for general collecting. In total, about 10000 specimens of aquatic Hemiptera were studied. They were identified based on the works of Kanyukova (2006), Savage (1989), Poisson (1957) and Wroblewski (1958). The systematic order is after Aukema and Rieger (1995) and Nieser (2002). The numbers and biomass of aquatic bugs from the quantitative samples were calculated per square meter.

Results and discussion

In the ecosystems of the intermittent rivers, we have found 28 species of water bugs from 9 families of Nepomorpha: Corixidae – 12 (Corixinae – 11, Cymatiinae – 1), Micronectidae – 1, Naucoridae - 1, Nepidae – 2, Notonectidae – 2, Pleidae – 1, and Gerromorpha: Gerridae – 6, Hebridae – 1, Hydrometridae – 1, Vellidae – 1 (Table 1). This is the majority (67%) of the known fauna for the steppe zone in the south of Ukraine (Putshkov and Putshkov 1996). Two new species are added to the faunistic list of this zone (*Sigara fossarum, Hydrometra gracilenta*) and new data on biology and presence of recently confirmed in Ukraine *Micronecta scholtzi* (Grandova and Prokin 2012) are added. It has been found only in intermittent rivers and small steppe basins.

The results of quantitative characteristics of water bugs are shown on Fig. 2. Data on numbers and biomass of Micronectidae species will be discussed separately.

During **the early-spring period**, the specific structure and quantitative characteristics of water bugs in different biotopes are defined by weather conditions during the year, the period of previous autumn filling of the riverbed playing a very important role.

During the autumn of 2007, the riverbed was filled in October, therefore a portion of the water bugs remained there for wintering. Next year the first specimens, which belonged to *Sigara stagnalis,* were caught in the riverbed in the middle of February, soon after ice melting. At the beginning of March, water bugs were observed both in the riverbed and in the flooded areas, and *Sigara striata, S. stagnalis, S. lateralis, Hesperocorixa linnaei* prevailed.

In 2008 the autumn filling of the riverbed occurred late, therefore the water bugs did not winter there and during the next early-spring period were absent in the quantitative samples from the riverbed. During general collecting we found singular specimens of Gerridae. The highest numbers and biomass were observed in extra inundated basins (sandy pits) where the majority of Nepomorpha wintered. The highest numbers during this period belonged to Corixidae. The maximum of biomass at the beginning of this period also belonged to Corixidae, but from the beginning of March Notonectidae started to dominate by biomass. In 2009 the numbers at this period reached 48,15 ind./m^2, the biomass – 871 mg/m^2. The highest numbers belonged to *Sigara lateralis,* the highest biomass - to *Notonecta glauca*.

In the early-spring period the overwintered nymphs of Micronectidae gather near the shore line, and their numbers can reach high values. At the beginning of March 2009, their numbers were 0,37 ind./m^2, and the biomass – 0,19 mg/m^2

During **the spring period,** water bugs migrated to the flooded areas and the riverbed. The area of suitable habitats sharply increased and as a result, the number and the biomass of water bugs per square meter decreased. At the beginning of the spring

Table 1. List of species and occurrence of water bugs in small intermittent rivers and associated water bodies.

Family	Species	Occurrence index (%)
Nepidae	*Nepa cinerea* Linnaeus, 1758	3,92
	Ranatra linearis (Linnaeus, 1758)	1,96
Corixidae	*Corixa affinis* Leach, 1817	3,92
	Corixa dentipes Thomson, 1869	15,69
	Cymatia rogenhoferi (Fieber, 1864)	11,76
	Hesperocorixa linnaei (Fieber, 1848)	74,51
	Paracorixa concinna (Fieber, 1848)	9,80
	Sigara assimilis (Fieber, 1848)	13,73
	S. fossarum (Leach, 1817)	1,96
	S. iactans Jansson, 1983	9,80
	S. lateralis (Leach, 1817)	78,43
	S. nigrolineata (Fieber, 1848)	7,84
	S. stagnalis (Leach, 1817)	64,71
	S. striata (Linnaeus, 1758)	66,67
Micronectidae	*Micronecta scholtzi* (Fieber, I860)	19,61
Naucoridae	*Ilyocoris cimicoides* (Linnaeus, 1758)	21,57
Notonectidae	*Notonecta glauca* Linnaeus, 1758	27,45
	N. viridis Delcourt, 1909	29,41
Pleidae	*Plea minutissima* Leach, 1817	29,41
Hebridae	*Hebrus ruficeps* Thomson, 1871	1,96
Hydrometridae	*Hydrometra gracilenta* Horvath, 1899	1,96
Veliidae	*Microvelia reticulata* (Burmeister, 1835)	5,88
Gerridae	*Gerris argentatus* Schummel, 1832	25,49
	G. asper (Fieber, 1860)	3,92
	G. lacustris (Linnaeus, 1758)	1,96
	G. odontogaster (Zetterstedt, 1828)	13,73
	G. thoracicus Schummel, 1832	23,53

S. stagnalis, *S. striata*, *S. lateralis*, *H. linnaei* belong to dominants, *N. glauca*, *N. viridis*, *P. minutissima*, *G. argentatus*, *G. thoracicus, I. cimicoides* – to subdominants.

period, the majority of Nepomorpha continued to remain in the extra inundated basins, therefore the numbers and the biomass of water bugs there exceeded these values both in the riverbed and in the flooded area.

At the end of March 2009, the numbers of water bugs in the riverbed were 0,83 ind./m^2, the biomass was 14,17 mg/m^2, while in the flooded area, the numbers were 1,11 ind./m^2, and the biomass 12,84 mg/m^2. In the quantitative samples only Corixidae were found (*Sigara striata, S. stagnalis, Hesperocorixa linnaei* dominated), and during general collecting singular specimens of other families were found. In the extra inundated basins the quantitative characteristics were more than 10 times higher: the numbers were 19,68 ind./m^2, the biomass was 220,79 mg/m^2, dominated by *S. stagnalis, S. lateralis, S. assimilis* and *H. linnaei*. In quantitative samples besides Corixidae, there were also species of Pleidae, Gerridae, Notonectidae.

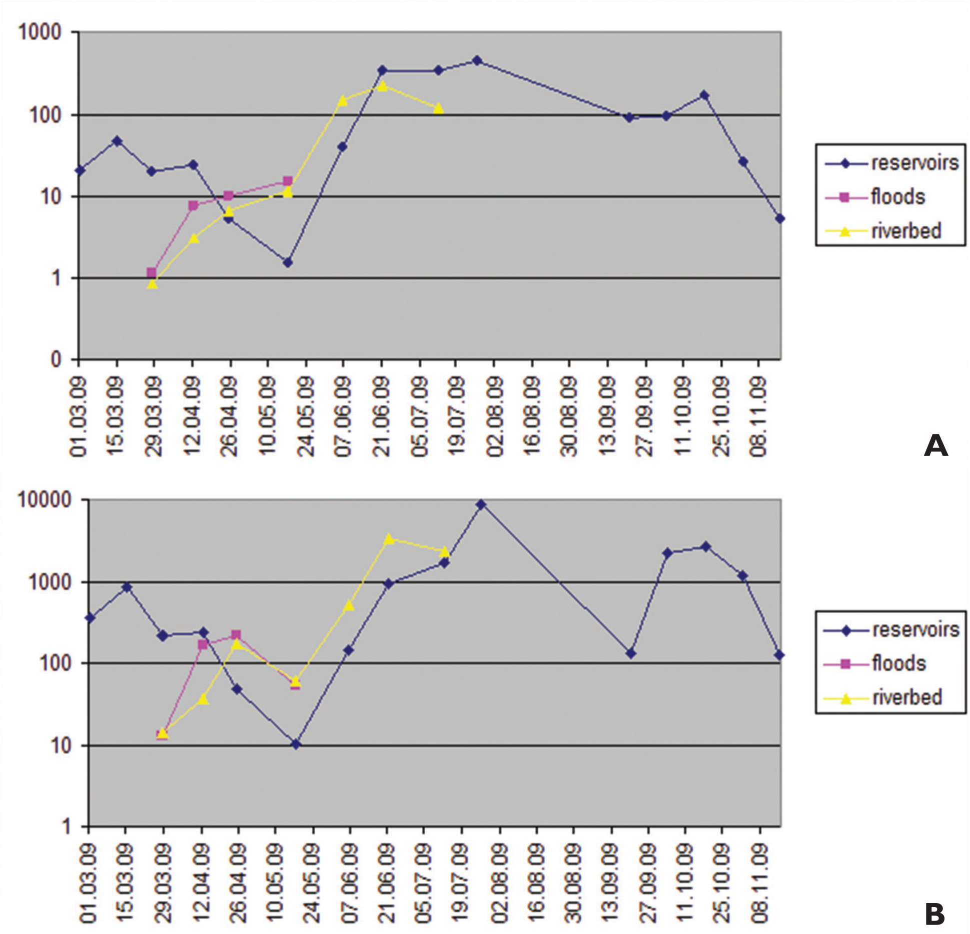

Figure 2. Seasonal changes in numbers (**A** ind./m^2) and biomass (**B** mg/m^2) of water bugs in Tiligul River and associated water bodies.

Throughout the next two weeks, the numbers and the biomass of water bugs in the riverbed and the flooded area continued to increase quickly. In the riverbed the numbers reached 3,02 ind./m^2, the biomass - 36,19 mg/m^2. In the flooded area the numbers went up 7 times (up to 7,58 ind./m^2), and the biomass – almost 14 times (up to 167,07 mg/m^2). The higher increase of the biomass in comparison with the numbers of water bugs was due to migration of larger species – *Notonecta viridis*, *N. glauca*, *Ilycoris cimicoides,* to the flooded area, but the main contribution to the biomass and the numbers in these biotopes still belonged to Corixidae (6,16 ind./m^2, 58,99 mg/m^2). In the riverbed the four dominant Corixidae species were presented approximately in a peer ratio, in the flooded area *Sigara stagnalis* prevailed.

Closer to the middle of the spring period the majority of overwintered Gerridae species (*Gerris argentatus*, *G. odontogaster*, *G. thoracicus*) occupied not only the riverbed and the flooded areas but also the extra inundated basins, so the total numbers and biomass there increased a little, despite of migration of water bugs to the inundated water bodies. In the middle of April 2009, the numbers in the inundated basins reached 24,22 ind./m^2, the biomass - 237,56 mg/m^2, and Corixidae (*Sigara stagnalis, S. lateralis*) continued to dominate.

In the middle of the spring period (in April) the highest number and biomass per square meter and the greatest numbers of species were observed in the flooded area where mating of the wintered imagoes and oviposition took place. Up to the middle of April 2009, the numbers in the riverbed reached 6,67 ind./m^2, the biomass - 169,44 mg/m^2, while in the flooded area - 10 ind./m^2, and 213,7 mg/m^2 respectively. During this time in the flooded area, *Plea minutissima* and *Microvelia reticulata* appeared and started reproduction. In both types of inundated biotopes, Corixidae dominated by numbers (in the riverbed 3,7 ind./m^2, in the basins 5,56 ind./m^2), and Naucoridae - by biomass (74,81 and 130,74 mg/m^2 respectively). The numbers and the biomass of water bugs in the extra inundated basins decreased by several times (to 5,4 ind./m^2 and 47,62 mg/m^2, respectively), by both indicators Corixidae dominated.

During **the late spring period** in the riverbed and the flooded area, the numbers continued to increase, and the biomass decreased, due to the appearance of nymphs and the death of overwintered imagoes. The first nymphs of Corixidae and Notonectidae appeared in flooded area in the middle of May. On 17.05.2009 the numbers were 11,39 ind./m^2 in the riverbed, and 14,89 ind./m^2 in the flooded area, the biomass – 61,39 and 52,79 mg/m^2 respectively. The maximum numbers in the flooded area coincided with the minimum numbers in the extra inundated basins. In 2009 the minimum of the numbers and the biomass was 1,56 ind./m^2 and 10,22 mg/m^2 respectively. In the years with lower water levels (as for example 2008), the flooded area was smaller, they started to dry up at the end of April and therefore the difference in the numbers of water bugs between inundated and extra inundated basins was not so great.

During the late spring period, the highest numbers in the riverbed and the flooded area belonged to *Plea minutissima* imagoes (9,72 and 11,1 ind./m^2 respectively), in the flooded area an essential contribution was also made by young nymphs of Notonectidae. In the extra inundated basins nymphs appeared later, therefore in the middle of May there were only single adult specimens, among which *Sigara stagnalis* and *S. lateralis* prevailed.

During this period the overwintered nymphs of Micronectidae became adults and started reproduction. They did not move to the flooded area, some imagoes moved to the riverbed, but generally they remained in the extra inundated basins. The numbers of Micronectidae in the basins in the middle of May were 52,78 ind./m^2 and the biomass – 50 mg/m^2.

At the end of the late spring period (the end of May – the beginning of June) nymphs of Naucoridae, Veliidae, Gerridae appeared, and up until the middle of June the first nymphs of Pleidae were noticed. After desiccation of the flooded area, the riverbed became an optimum habitat for reproduction and development of water bugs. Some adult specimens came back to the extra inundated basins. In the basins, nymphs appeared approximately two weeks later than in the flooded area and the riverbed, possibly due to the later heating of these biotopes. Most of the nymphs developed in the riverbed; therefore the quantitative characteristics there were much higher than in the extra inundated basins. The numbers were 34,4 ind./m^2 in the basins, and 150 ind./m^2 in the riverbed, the biomass – 170,4 and 498,89 mg/m^2 respectively. The ratio between nymphs and imagoes was about 2,5:1 in the basins, and 14:1 in the riverbed. Young nymphs of Corixidae and Notonectidae dominated, but certain nymphs of small species of Corixidae (*Sigara stagnalis*, *S. lateralis*) and some Notonectidae (*Notonecta glauca*) in the riverbed had already managed to reach the fourth stage.

At the beginning of **the summer-autumn period** quantitative characteristics in the riverbed and in the extra inundated basins continued to increase. Biomass/numbers ratio in the riverbed was higher, than in the basins. It implies more favorable conditions for the development of the nymphs in the riverbed and so they matured earlier. At the end of June 2009, the numbers in the riverbed were lower than in the basins (223,33 and 340,83 ind./m^2 respectively), while the biomass, on the contrary, was higher (3403,89and 914,44 mg/m^2 respectively). The numbers of the nymphs in 1st-2nd stages in the riverbed were almost 3 times lower, than in the basins (104,44 and 284,17 ind./m^2 respectively), and the numbers of the nymphs in 4th-5th stages in the riverbed was 7 times higher (31,1 and 4,15 ind./m^2 respectively).

The first nymphs of the new generation of Micronectidae also appeared in the riverbed and the extra inundated basins at the beginning of the summer-autumn period. At the beginning of June 2009 the numbers of Micronectidae nymphs were 25,19 ind./m^2 in the basins, and 2,2 ind./m^2 in the riverbed.

In June the riverbed began to dry. The adult water bugs moved from the drying riverbed to the extra inundated basins, as a result the numbers in the riverbed decreased. The biomass continued to be rather high, due to the high numbers of nymphs growing to 4th-5th stages and imago. Drying of the riverbed in 2009 started at the end of June - the beginning of July. In the middle of June 2009, the numbers in the riverbed were 52,78 ind./m^2, and the biomass - 50 mg/m^2. Dominant in numbers was the nymphs of *Plea minutissima* of elder stages, while dominant in biomass were the nymphs of elder stages and imago of *Notonecta glauca*, *N. viridis*, *Ilyocoris cimicoides*, *Hesperocorixa linnaei.*

When the riverbed completely dries, water bugs gather in the extra inundated basins where the second reproduction of polivoltine species takes place. In 2009 the riverbed completely dried up at the end of July. The adult *Hesperocorixa linnaei* dominated in numbers and biomass. At the same time the first nymphs of the second generation of *Plea minutissima*, *Sigara stagnalis* and *S. lateralis* appeared.

In the middle of July, most nymphs of *Micronecta scholtzi* also finished their development, and separate individuals managed to couple and oviposite so that at the end of July the first nymphs of the next generation appeared. The second generation of polivoltine Corixidae was probably rather extended, because nymphs of younger stages were found until the beginning of November. The nymphs of Corixidae in 1st–2nd stages dominated in numbers and biomass in September samples (20.09.2009, 88,9 ind./

m^2 and 115,56 mg/m^2). At the beginning of October, nymphs of 4th–5th stages prevailed, but imagoes mostly belonging to *Sigara lateralis* had the highest total number. The highest biomass was due to the adult Notonectidae. Up until the end of October the majority of Corixidae turned into imago. At the end of October-November in the extra inundated basins there were a large numbers of species which gathered for wintering. High numbers were shown by *Sigara striata* (up to 57,22 ind./m^2), *S. lateralis* (up to 67,2 ind./m^2), and also *S. stagnalis* (up to 10,56 ind./m^2), *Hesperocorixa linnaei* (up to 12,78 ind./m^2), *Notonecta glauca* (up to 4,4 ind./m^2) and *N. viridis* (up to 6,67 ind./m^2).

In the south of Ukraine, *Micronecta scholtzi* most likely had a partial third generation where the first nymphs appeared at the end of September. Nymphs of younger stages were observed up to the middle of November – most likely, the majority of them managed to reach the 4^{th} stage and safely overwintered. Imagoes were observed up to the beginning of November, after which there were only nymphs, and the wintering stages prevailed. The decrease in numbers at the beginning of November in comparison with October samples was probably due to them leaving the shoreline for wintering in the bottom remote parts of the basins.

Next settling of the riverbed depends on the period of its autumn filling. During a late filling, bugs don't manage to occupy the riverbed and winter only in the constant extra inundated basins; during an early filling, a part of the bugs gathers for wintering in the riverbed, concentrating in creeks. It's a risk, because during cold years the riverbed can freeze to the bottom, and water bugs trapped there die. On the other hand, because of the faster warming up of the riverbed in spring, the individuals wintering there can start the reproduction earlier.

Our study of seasonal changes in the numbers of Heteroptera imagoes and nymphs gives an opportunity to clarify some characteristics of the life cycle for the following mass species:

Notonecta glauca in the studied area usually has one generation per year. Mating is observed in March; first nymphs appear in the middle of May, imagoes of new generation – from the middle to the end of June. Therefore, most of *N. glauca* nymphs grow in the flooded areas, and after their desiccation in the riverbed; then during the imago stage, they move to the extra inundated basins, where they dispause. This diapause is optional, and during the warm years *N. glauca* can also have a partial second generation.

Notonecta viridis also has one generation per year, but the term of its development differs so the first imagoes of the new generation appear at the beginning of July. Therefore, not all the nymphs of *N. viridis* have enough time to finish their development before the complete desiccation of the riverbed; that is why *N. viridis* stays for reproduction in the extra inundated basins more often than *N. glauca,* and their number in the extra inundated basins is higher than the number of *N. glauca.*

Hesperocorixa linnaei in the studied area also has one generation per year. First imagoes of the new generation appear in June, reaching the maximum number in the middle of July. This fact fits with the literary data that another close species, *H. castanea,* is also univoltine (Saulich and Musolin 2007). In the literature for *H. castanea,* a partial second generation was reported, and most likely during the warm years, *H. linnaei* can also have a partial second generation.

Sigara stagnalis and *S. lateralis* belong to polivoltine species which have at least two generations per year in the region. Imagoes of the first generation appear from the middle to the end of June, imagoes of the second generation – in September. These facts fit with the literature data about the life cycle of *S. lateralis* in Rostov area (Russia) (Sokolskaya and Zhiteneva 1973) They may have a partial third generation, at least, in September we observed the nymphs of younger stages, but it is not clear if they belong to the third generation or to the late second generation. Maximum numbers of imagoes of these species was observed in October.

Plea minutissima is also polivoltine species which has at least two generations. Nymphs of the first generation appear from the beginning to the middle of June, in the middle of July they imaginate and begin to mate, and soon the first nymphs of the second generation appear. Almost all the first cycles of reproduction take place in the flooded areas and the riverbed, and the second in the extra inundated basins.

Reproduction of *Ilyocoris cimicoides* starts at the end of May. Oviposition is prolonged; therefore nymphs of different stages may be noticed simultaneously through the whole summer.

Conclusions

In the studied rivers and associated water bodies we have found 28 species of water bugs belonging to 10 families and 15 genera. That is 67% of the total number of species registered in the steppe zone of the south Ukraine. This fact shows the important role of intermittent rivers in the forming of regional biodiversity of water bugs. Two species (*Sigara fossarum* and *Hydrometra gracilenta*) were registered for the first time in south Ukraine, and for *Micronecta scholtzi* this is the first proven record in the Ukraine.

Seasonal changes in species numbers, biomass and number of water bugs in the ecosystem of small intermittent rivers are undulating and depend on the climatic conditions of each year and peculiarities of life cycles of the dominant species. Among registered species there are polivoltine (*Sigara stagnalis*, *S. lateralis*, *Plea minutissima*) and univoltine (*Notonecta glauca*, *N. viridis*, *Hesperocorixa linnaei*, *Ilyocoris cimicoides*) species, but some univoltine species may have a partial second generation. Almost all species overwinter as imago, excluding Micronectidae wintering at a nymphs' stage, usually at the 4th stage. Wintering at the egg stage was not registered.

During the early spring period, the maximum of quantitative indicators was observed in the extra inundated basins. During the middle of the spring period, maximum of the numbers, and later of the biomass was observed in the flooded area. During the late spring period and the beginning of the summer-autumn period, the maximum of quantitative indicators was observed in the riverbed. Maximums of the numbers (449 ind./m^2) and the biomass (8811 mg/m^2) were observed in the extra inundated basins in the middle of summer-autumn period (the end of July – the beginning of August) after desiccation of inundated biotopes and appearance of nymphs of the second generation of polivoltine species. Thus, during the droughty period when the riverbed is dry, the extra inundated basins (including artificial ones – sandy pits) serve as refugia for aquatic Heteroptera. The wintering of many species takes place there, especially when the riverbed is not filled before the cold period. However, the reproduction of the most species takes place in the riverbed and associated flooded area. Thus, this study is a confirmation and development of the concept for "a uniform architectonic complex of a river valley" (Beklemishev 1970).

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RESEARCH ARTICLE

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Sex chromosome pre-reduction in male meiosis of *Lethocerus patruelis* (Stål, 1854) (Heteroptera, Belostomatidae) with some notes on the distribution of the species

Snejana Grozeva[1], Valentina G. Kuznetsova[2], Nikolay Simov[3],
Mario Langourov[3], Svetla Dalakchieva[3]

1 *Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, Tsar Osvoboditel Blvd 1, 1000 Sofia, Bulgaria* **2** *Zoological Institute, Russian Academy of Sciences, Universitetskaya nab. 1, 199034 St Petersburg, Russia* **3** *National Museum of Natural History, Bulgarian Academy of Sciences, Tsar Osvoboditel Blvd 1, 1000 Sofia, Bulgaria*

Corresponding author: *Snejana Grozeva* (sgrozeva@yahoo.com)

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Abstract

The karyotype and meiosis in males of giant water bug *Lethocerus patruelis* (Heteroptera: Belostomatidae: Lethocerinae) were studied using standard and fluorochrome (CMA_3 and DAPI) staining of chromosomes. The species was shown to have 2n = 22A + 2m + XY where 2m are a pair of microchromosomes. NORs are located in X and Y chromosomes. Within Belostomatidae, *L. patruelis* is unique in showing sex chromosome pre-reduction in male meiosis, with the sex chromosomes undergoing reductional division at anaphase I and equational division at anaphase II. Cytogenetic data on the family Belostomatidae are summarized and compared. In addition, the structure of the male internal reproductive organs of *L. patruelis* is presented, the contemporary distribution of *L. patruelis* in Bulgaria and in the Northern Aegean Islands is discussed, and the first information about the breeding and nymphal development of this species in Bulgaria is provided.

Keywords

Karyotype, NOR, meiosis, sex chromosome pre-reduction, male reproductive organs, distribution, *Lethocerus patruelis*, Belostomatidae, Heteroptera

Introduction

The genus *Lethocerus* Mayr, 1853 is a member of the family Belostomatidae (electric light bugs, toe biters), the subfamily Lethocerinae (Perez Goodwin 2006). The giant water bug *Lethocerus patruelis* is the largest European true bug and the largest European water insect. The adult bugs reach 80 mm in length. The information on the karyotypes of the genus *Lethocerus* has been recently summarized by Bardella et al. (2012). In *Lethocerus* species, chromosome numbers vary from 2n = 4 to 2n = ca. 30 with intermediate numbers of 2n = 8, 26 and 28. The cytogenetic mechanisms of sex determination are also diversified with XY, neo-XY and multiple X_nY encountered in different species. In several species, a pair of m-chromosomes (= microchromosomes) has been described (Ueshima 1979). As is common in Belostomatidae and in Heteroptera as a whole, all so far studied species of *Lethocerus* have been shown to have an inverted meiosis for the sex chromosomes in males (the so-called "sex chromosome post-reduction") with the sex chromosomes undergoing equational separation during the first division while reductional segregation during the second division (Ueshima 1979, Papeschi and Bressa 2006, Bardella et al. 2012).

In the present work, we studied for the first time the structure of the internal reproductive organs, karyotype and meiosis in males of *Lethocerus patruelis* (Stål, 1854). In addition, we summarize here data on the contemporary distribution of *L. patruelis* in Bulgaria and in the Northern Aegean Islands, and provide the first information on the reproduction of this species in Bulgaria.

Material and methods

Insects

Males of *Lethocerus patruelis* were collected in 2001–2012 in different regions of southern Bulgaria. Collections were made either in water bodies using plankton net or (predominantly) by light traps. Two adults and three larvae were reared in the laboratory using small fishes (*Gambusia affinis*, *Pseudorasbora parva* and *Carassius gibelio*) as a food. Cytogenetic study was based on three males collected in the area of the border checkpoint Kapitan Andreevo, Bulgaria.

Specimens examined: BULGARIA: Black Sea Coast: Burgas, Lukoil Oil Refinery, 29 m a.s.l., May 2011, 4 specimens, K. Popov leg.; **Tundzha River Valley**: Kazanlak, 370 m a.s.l., 15.x.2012, 1♀, Z. Antonova leg.; Elhovo, 113m a.s.l., October 2011, at light, 1♀, G. Hristov leg.; **Maritsa River Valley**: Kapitan Andreevo Checkpoint, 46 m a.s.l.: August–September 2011, at light, more than 60 specimens per night, E. Galabova obs.; 5.ix.2011, at light, 2♂, 4♀, S. Grozeva leg.; 5.x.2011, 4♂, E. Galabova leg.; 12.x.2012, 1♂, at light, E. Galabova leg.; Plovdiv, Plovdiv Thermal Power Station, 170 m a.s.l., October 2011, 1♀ and more than 70 specimens observed in the sewer, Zh. Vlaykov leg; Plovdiv, 168 m a.s.l., autoparking in the northern part of the town, 19.viii.2012, at light, 2 specimens, V. Dimitrov obs.; Peshtera, 435 m a.s.l., October 2011, 1 specimen dead on the road, D. Kajnarov obs.; **Eastern Rhodopes Mts.**: Madzharovo, Vulture Center, above Arda River, 160 m a.s.l., 16.ix.2009, in light trap, 2♂, 1♀, B. Zlatkov leg.; **Kresna Gorge:** above Oshtavska River, 315 m a.s.l., 10.x.2004, at light, 3 specimens, S. Beshkov leg.; Tisata reserve, 250 m a.s.l., 13.x.2012, at light, 1♀, B. Zlatkov & O. Sivilov leg.; **Struma River Valley:** Rupite, 115 m a.s.l., 20.viii.1997, 1 specimen, at light, M. Langourov leg.; Marena artificial pond close to General Todorov Village, 104 m a.s.l.: 28.vi.2009, 1♀, on the vegetation above water surface, V. Gashtarov obs.; 01.viii.2011, 1♀, in the water, M. Langourov leg.; 25.vii.2012, 3 larvae and 2 exuviae, in the water, N. Simov leg.; quarry near General Todorov Village, 113 m a.s.l., 23.x.2010, 1♂, in a puddle near the road, B. Zlatkov & O. Sivilov leg.; **MACEDONIA: Dojran Lake**, 144 m a.s.l., 1996-1997, many specimens, V. Krpach obs.; **GREECE: Thassos Island:** Astris Village, Astris Beach, 7.ix.2011, 1♀, dead on the beach, N. Simov & M. Langourov leg.; Astris Village, small beach N of Astris, 9.ix.2010, 1♀, in the sea, N. Simov & T. Stefanov leg.; Pefkari, 7 m a.s.l., 3.ix.2010, 1♂, dead under street lamps, T. Stefanov leg.

Preparations

To examine the internal reproductive organs, the abdomen of chloroform-anaesthetized males was opened and the entire reproductive system was dissected. For chromosome studies, the gonads were dissected out from the adults and fixed in Carnoy's fixative consisting of 96% ethanol and glacial acetic acid (3:1) and stored at 4°C. Cytological preparations were made by squashing a piece of the testis in a drop of 45% acetic acid on a slide. The coverslip was removed using a dry-ice technique (Conger and Fairchild 1953).

Standard staining of chromosomes

For this staining, the method described in Grozeva et al. (2010) with minor modifications was used. The preparations were first subjected to hydrolysis in 1 N HCl at 60°C for 8 min and stained in Schiff's reagent for 20 min. After rinsing thoroughly in distilled water, the preparations were additionally stained in 4% Giemsa in Sorensen's buffer, pH 6.8 for 20 min, rinsed with distilled water, air-dried, and mounted in Entellan.

Fluorochrome staining of chromosomes

For revealing the base composition of C-heterochromatin, staining by GC-specific chromomycin A_3 (CMA_3) and AT- specific 4-6-diamidino-2-phenylindole (DAPI) was used following the method described in Grozeva et al. (2010). C-banding pretreatment was carried out using 0.2 N HCl at room temperature for 30 min, followed by 7-8 min treatment in saturated $Ba(OH)_2$ at room temperature and then an incubation in 2xSSC at 60°C for 1 h. The preparations were then stained first with CMA_3 (0.4 µg/ml) for 25 min and then with DAPI (0.4 µg/ml) for 5 min. After staining, the preparations were rinsed in the McIlvaine buffer, pH 7 and mounted in an antifade medium (700 µl of glycerol, 300 µl of 10 mM McIlvaine buffer, pH 7, and 10 mg of N-propyl gallate).

Microscopy

The chromosome preparations were examined using the light and fluorescent microscope Axio Scope A1 with digital camera ProgRes MFcool Jenoptik at 100× magnification.

Results

Testes

In *L. patruelis* males, the internal reproductive organs consisted of a pair of testes united by vasa deferentia (*v d*) with a median unimpaired tube, ductus ejaculatorius (*d e*) (Fig. 1). Each vas deferens was dilated to form a large vesicula seminalis (*v s*). The testes were colorless and spherical in form, and each consisted of a single very long tube (seminal follicle) rolled up into a ball. The follicle decreased in diameter from the apex to the vas deferens and showed synchronized divisions in different parts, with only sperms in its thinner part. There were no bulbus ejaculatorius and accessory glands.

Male karyotype and meiosis

All three studied *L. patruelis* males presented the same chromosome complement. Spermatogonial metaphases showed 26 chromosomes including four larger and two very small ones, and the rest of the chromosomes formed a gradual size row. There was also a pair of very small m-chromosomes (= microchromosomes) (Fig. 2b) but these were not apparent in many nuclei (Fig. 2a). The chromosomes had no primary constrictions, i.e. centromeres. Two of larger chromosomes showed each a subtelomeric unstained gap, or secondary constriction, representing the nucleolus organizing region (NOR). These chromosomes are X and Y sex chromosomes as was revealed by the observation of meiotic stages (see below).

During meiotic prophase, the sex chromosomes were united and visible as a large, positively heteropycnotic body brightly fluorescent after CMA_3 staining (Fig. 3). Cells at metaphase I (MI) showed 13 bivalents, including a small and negatively heteropycnotic pair of m-chromosomes ($n = 13$). At this stage, all bivalents were distributed randomly relative to each other. Distinguishing between bivalents of autosomes and XY pseudobivalent involved difficulties since the latter was only slightly heteromorphic in

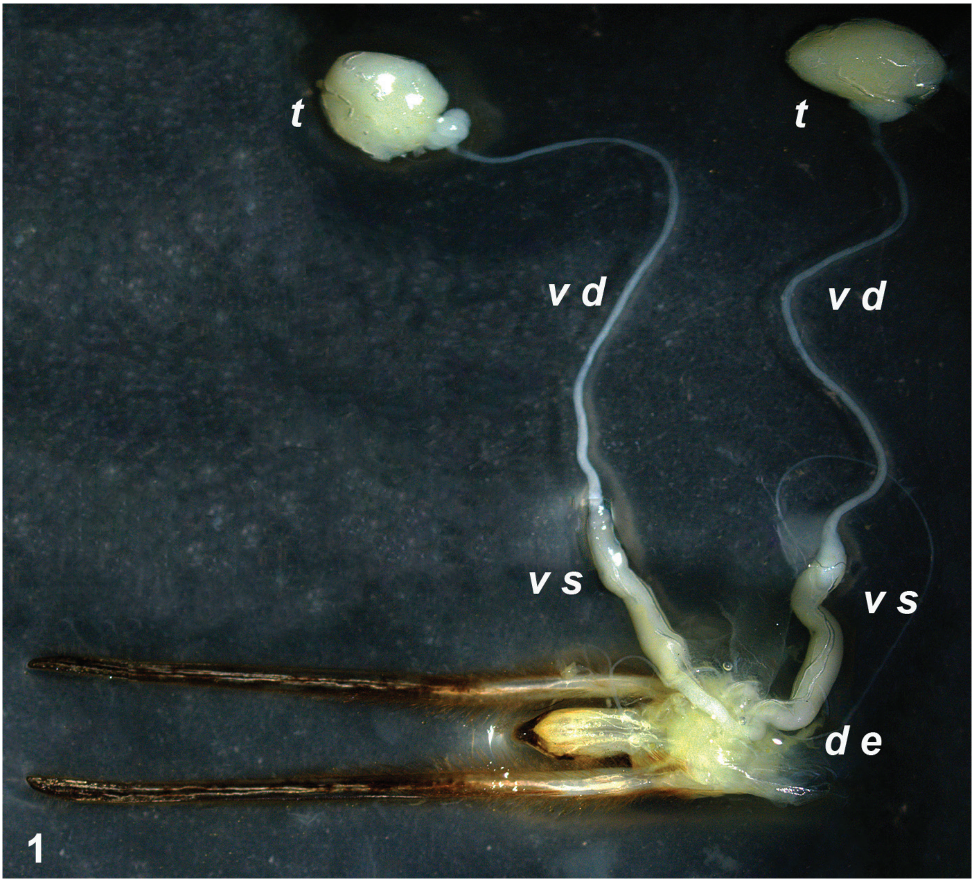

Figure 1. Internal male reproductive system: ***t*** testis; ***v d*** vas deferens; ***v s*** vesicula seminalis ***d e*** ductus ejaculatorius.

form due to the size resemblance of X and Y chromosomes (Fig. 4). However CMA_3-staining appeared a foolproof method for the identification of sex-pseudobivalent as one of the largest pairs with GC-rich NORs located in X and Y chromosomes (Fig. 5). At anaphase I (AI), all the chromosomes segregated to opposite poles resulting in two daughter metaphase II (MII) cells with 11A + m + X and 11A + m + Y, respectively (Fig. 6a). In the studied MII plates, X and Y- chromosomes were distributed randomly among other chromosomes (Fig. 6b). DAPI staining did not reveal any differentiation along the length of the chromosomes (Fig. 7).

Notes to the distribution and reproduction in Bulgaria

In 2008 and 2011, we collected adult specimens of *L. patruelis* in water bodies in Struma River Valley near Rupite (Bulgaria). Several water bodies in Struma River Val-

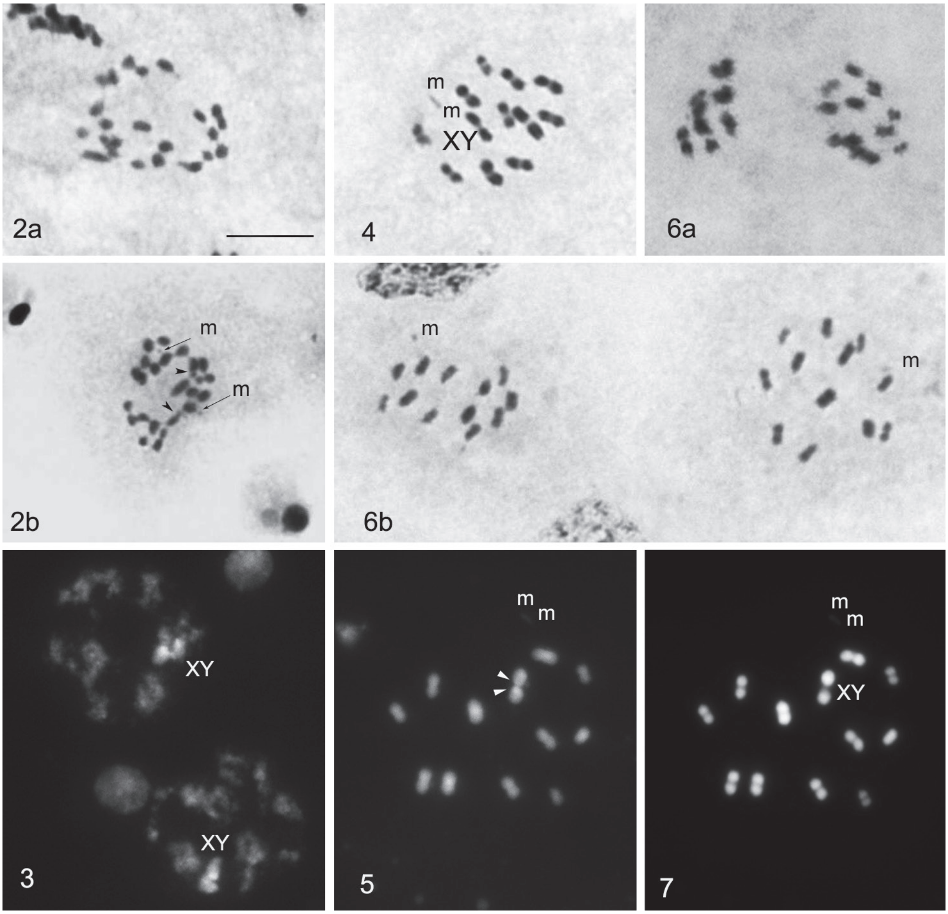

Figure 2–7. 2 Spermatogonial metaphases: two of larger chromosomes, X and Y, each show a subtelomeric unstained gap, representing the nucleolus organizing region (NOR) (arrow head) (routine staining) **3** Meiotic prophase: sex chromosomes are visible as a large, positively heteropycnotic and brightly fluorescent body (CMA_3 staining) **4** Metaphase I (n = 13) (routine staining) **5** Metaphase I: GC-rich NORs located on both X and Y chromosomes (CMA_3 staining) **6** After the first meiotic division all the chromosomes segregate to opposite poles (6a) resulting in two daughter MII cells (6b) with 13 elements each, 11A + m + X and 11A + m + Y, respectively (routine staining) **7** Metaphase I: DAPI staining did not reveal any differentiation along the length of the chromosomes. Bar = 10μm.

ley, close to these localities were checked by plankton net, and in July 2012, four larvae and five exuviae were found in the Marena artificial pond near General Todorov Village representing thus the first evidence of breeding of *L. patruelis* in Bulgaria. Marena would be classified as semi-natural mesotrophic to eutrophic lake with macrophytic vegetation (Tzonev et al. 2011). The hydrophytic coenoses in Marena make complexes with various hygrophytic communities, e.g. strips or patches of *Typha* spp., *Scirpus lacustris*, tall sedges (*Carex* spp.). Submerged vegetation are mixed by *Myriophyllum* and *Potamogeton*. Larvae were found close to the shoreline, in the regions with submerged vegetation. In laboratory, we observed that larvae and adults had used the stems of *Myriophyllum* as resting place or during stalking/ambush attacks against their preys (electronic supplementary material, video S1).

Discussion

The range of *L. patruelis* includes Balkan Peninsula, Anatolia, Israel, Syria, Saudi Arabia, Yemen, the United Arab Emirates, Kuwait, Iraq, Iran, Afghanistan, Oriental Region (Pakistan, India, Nepal, Burma), and recently this species was recorded from Italy (Polhemus 1995, Protić 1998, Perez Goodwyn 2006, Olivieri 2009, Fent et al. 2011).

In Bulgaria, only few records of *L. patruelis* specimens migrating from southern parts of the Balkan Peninsula, attracted to light, were published up to 2000 year (Buresch 1940; Josifov 1960, 1974, 1986, 1999) (Fig. 8). During the last ten years, many new findings of *L. patruelis* were made by us in Bulgaria: Kresna Gorge, eastern Rhodopes, Maritsa River Valley (from Kapitan Andreevo to Peshtera) and southern Black Sea Coast (near Burgas). In some of these regions, this species was very abundant; more than 60 specimens per night were attracted to light (Kapitan Andreevo Checkpoint, August–September 2011).

A number of facts (records of the breeding population in Marena; the existence of similar habitats in other regions with records of *L. patruelis* at light; the last years' tendency to milder winters) led us to suppose that this species would breed successfully also in other regions in southern Bulgaria (Maritsa River Valley, Burgas lakes). If such is the case, it would be a further evidence of the recent changes of European bug fauna caused by climate changes and global warming (Rabitsch 2008).

We have studied *L. patruelis* in respect of male reproductive organs, karyotype and meiosis. The internal reproductive system in this species appeared to be quite similar to that in *Diplonychus rusticus* (Fabricius, 1871) (Belostomatinae), the only belostomatid species studied so far on this point (Pendergrast 1957, as *Sphaerodema rusticum*). In *L. patruelis*, each testis consists of the only follicle which is rolled up into a ball; each vas deferens is dilated to form a large vesicula seminalis; bulbus ejaculatorius (representing usually, if present, a dilated anterior end of the ductus ejaculatorius) and accessory glands (diverticula of the ductus ejaculatorius) are absent. Pendergrast (1957) found a similar condition in *D. rusticus*, however he did not provide information about the number of follicles in testes.

We found that *L. patruelis* had 2n = 26 (22 + 2m + XY). The eight *Lethocerus* species studied so far with respect to karyotypes (Table 1) represent a large proportion of the 22 species currently known in this genus (Perez Goodwyn 2006). Hence, some preliminary inferences about cytological features of *Lethocerus* and also of the family Belostomatidae as a whole can be deduced.

Belostomatidae are composed of 3 subfamilies (Belostomatinae, Horvathiniinae, Lethocerinae) with 10 genera and approximately 150 species (Lauck and Menke 1961, Schuh and Slater 1995, Perez Goodwyn 2006, Ribeiro 2007). Up to now, there have

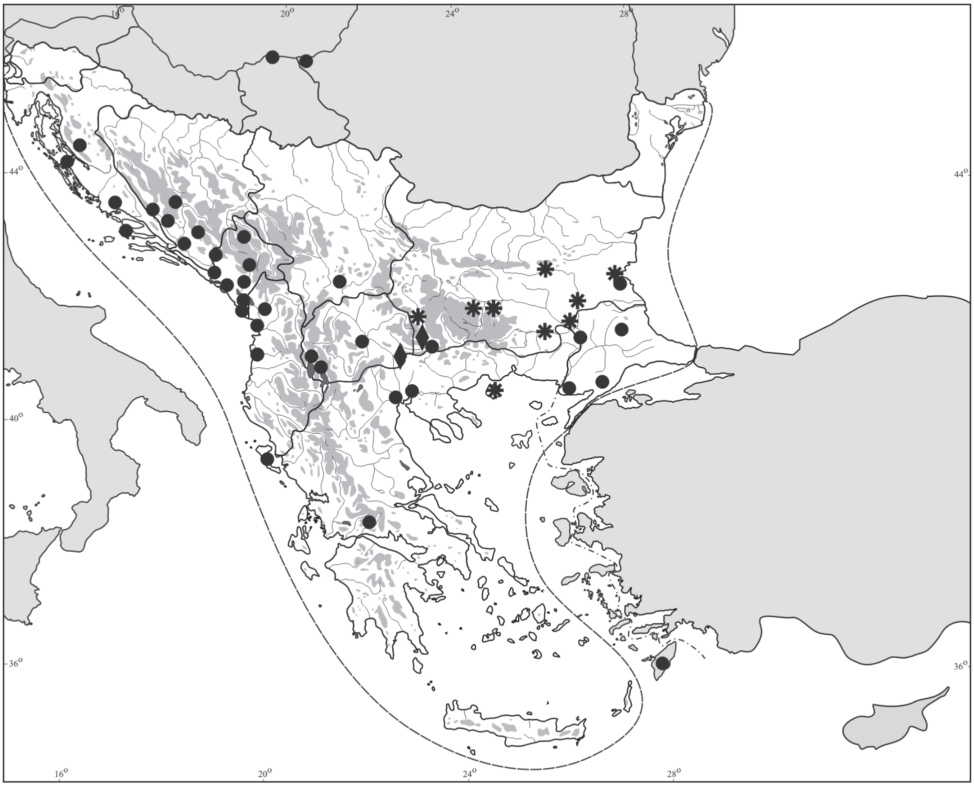

Figure 8. Distribution of *Lethocerus patruelis* (Stål, 1854) on Balkan Peninsula: ● published records; ♦ new records with data of breeding; ✱ new records of specimens attracted to light.

been cytogenetically analyzed 32 species of the following 6 genera: *Abedus* (1 species), *Belostoma* (18 species) and *Diplonychus* (3 species) from Belostomatinae and *Benacus* (1 species), *Kirkaldyia* (1 species) and *Lethocerus* (8 species) from Lethocerinae (Table 1). In Belostomatidae, chromosome numbers vary from 2n = 4 in *Lethocerus* sp. from Michigan to 2n = ca. 30 and 2n = 30 in *L. uhleri* and *Belostoma dilatatum*, respectively. Similarly, the cytogenetic mechanisms of sex determination are variable. Among those, there is the simple XY system (inherent in each of the genera), and the derived neo-XY (in *Lethocerus*) and multiple X_1X_2Y or $X_1X_2X_3Y$ (in *Belostoma*) systems. In several species, both from Belostomatinae (*Belostoma* and *Diplonychus*) and Lethocerinae (*Lethocerus*), the presence of m-chromosomes has been reported.

The genus *Lethocerus* shows a fairly wide range of chromosome numbers, with both extreme for Belostomatidae 2n = 4 and 2n = ca. 30, and three intermediate ones of 2n =8, 26 and 28 (Table 1). The species studied share the conventional cytological features of Heteroptera, such as holokinetic chromosomes (lacking centromeres, that facilitates karyotype evolution via occasional fusion/fission events; Kuznetsova et al. 2011), an XY sex chromosome system (with derivative neo-XY and multiple X_nY systems presumed to be inherent in three species), and m-chromosomes (detected to date

Table 1. Cytogenetical data for the family Belostomatidae.

Taxon	2n ♂	Karyotype formula ♂	Sex chromosome division in male meiosis	NOR location	Remarks	Reference
Belostomatinae Leach, 1815						
Abedus indentatus (Haideman, 1854)	29	24 + 2m + X_1X_2Y	Post-reduction	data absent		Ueshima 1979
Belostoma bergi (Montandon, 1899)	29	26 + X_1X_2Y	Post-reduction	data absent		Papeschi and Bressa 2006
B. bifoveolatum Spinola, 1852	29	26 + X_1X_2Y	Post-reduction	data absent		Papeschi 1991
B. candidulum Montandon 1903	16	14 + XY	Post-reduction	sex chromosomes	Technique: CMA$_3$ - Bardella et al. 2012	Bardella et al. 2012
B. cummingsi De Carlo, 1935	29	26 + X_1X_2Y	Post-reduction	sex chromosomes	Technique: Ag-staining, acridine orange, Hoechst 33258 - Papeschi and Bidau 1985. The authors did not specify whether NORs are located on every sex chromosome or only on some of them.	Papeschi and Bidau 1985
B. dentatum (Mayr, 1863)	29	26 + X_1X_2Y	Post-reduction	a pair of autosomes	Technique: Ag-staining, acridine orange, Hoechst 33258 - Papeschi and Bidau 1985	Papeschi and Bidau 1985
B. dilatatum (Dufour, 1863)	29	26 + X_1X_2Y	Post-reduction	data absent		Papeschi and Bressa 2006
	30	26 + $X_1X_2X_3Y$	Post-reduction	the terminal region of a medium-sized autosome pair	Technique: DAPI dull/CMA3-bright band on terminal position on one of the medium-sized autosomal bivalents - Chirino and Bressa 2011; CMA$_3$ - Bardella et al. 2012	Bardella et al. 2012
B. discretum Montandon, 1903	29	26 + X_1X_2Y	Post-reduction	data absent		Papeschi and Bressa 2006
B. elegans (Mayr, 1871)	29	26 + X_1X_2Y	Post-reduction	a pair of autosomes	Technique: CMA$_3$ - Papeschi and Bidau 1985; FISH - Papeschi and Bressa 2006	Papeschi and Bidau 1985 Papeschi and Bressa 2006
B. elongatum Montandon, 1908	29	26 + X_1X_2Y	Post-reduction	data absent		Papeschi and Bressa 2006
B. flumineum Say, 1832	24	20 + 2m + XY	Post-reduction	data absent		Chickering 1916, 1927b (after Ueshima1979)
B. gestroi Montandon, 1900	29	26 + X_1X_2Y	Post-reduction	data absent		Papeschi and Bressa 2006
B. martini (Montandon, 1899)	29	26 + X_1X_2Y	Post-reduction	data absent		Papeschi 1991

Taxon	**2n ♂**	**Karyotype formula ♂**	**Sex chromosome division in male meiosis**	**NOR location**	**Remarks**	**Reference**
B. micantulum Stål, 1860	16	14 + XY	Post-reduction	sex chromosomes	Technique: CMA_3, FISH -Papeschi, Bressa 2006	Papeschi 1988
B. orbiculatum Estévez and Polhemus, 2001	16	14 + XY	Post-reduction	data absent	Sex chromosome polymorphism (XY/X_1X_2Y)	Papeschi, 1996: as *Belostoma* sp. (species identification is provided by Papeschi and Bressa 2006)
B. oxyurum (Dufour, 1863)	8	6 + XY	Post-reduction	sex chromosomes	Technique: $AgNO_3$, acridine orange, Hoechst 33258 - Papeschi and Bidau 1985; CMA_3, FISH - Papeschi and Bressa 2006	Papeschi and Bidau 1985
*B. plebejum (*Stål, 1860)	16	14 + XY	Post-reduction	data absent	polymorphism for sex chromosomes (XY/X_1X_2Y) and number of autosomes (13/14)	Papeschi 1994
Belostoma sp.	24	20 + 2m + XY	Post-reduction	data absent		Montgomery 1901, 1906: as Zaitha (after Ueshima 1979)
Diplonychus annulatus (Fabricius, 1781)	28	24 + 2m + XY	Post-reduction	data absent		Jande 1959: as *Sphaerodema* (after Ueshima 1979)
D. rusticus (Fabricius, 1781)	28	26 + XY	Post-reduction	data absent		Bawa 1953: as *Sphaerodema*, Jande 1959: as *Spherodema* (after Ueshima 1979)
D. molestus (Dufour, 1863)	28	26 + XY	Post-reduction	data absent		Jande 1959: as *Sphaerodema subrhombeus*, in Ueshima 1979: as *Diplonychus subrhombeus*
Lethocerinae Lauck & Menke, 1961						
Benacus griseus (Say, 1832)	28	24 + 2m + XY	Post-reduction	data absent		Chickering 1927b (after Ueshima 1979: as *Lethocerus*
Kirkaldyia deyrolli (Vuillefroy, 1864)	26	24 + XY	Post-reduction	data absent		Muramoto 1978: as *Lethocerus*
Lethocerus americanus (Leidy, 1847)	8	6 + XY	Post-reduction	data absent		Chickering 1927b (after Ueshima 1979)

Taxon	**2n ♂**	**Karyotype formula ♂**	**Sex chromosome division in male meiosis**	**NOR location**	**Remarks**	**Reference**
L. annulipes (Herrich-Schaeffer, 1845)	28	26 + XY	Post-reduction	data absent		Papeschi and Bressa 2006
Lethocerus indicus (Lepeletier & Serville, 1825)	26	22 + 2m + XY	Post-reduction	data absent		Banerjee 1958, Bagga 1959, Jande 1959: as neo-XY (after Ueshima 1979)
Lethocerus melloleitaoi De Carlo, 1933	28	26 + XY	Post-reduction	data absent		Papeschi and Bressa 2006
Lethocerus patruelis (Stål, 1854)	26	22 + 2m + XY	Pre-reduction	sex chromosomes	Technique: CMA_3	present paper
Lethocerus uhleri (Montandon, 1896)	ca. 30	?	Post-reduction	data absent		Chickering and Bacorn 1933: multiple sex chromosomes? (after Ueshima 1979)
Lethocerus sp. 1 (from New Orleans)	28	?	Post-reduction	data absent		Chickering 1932 (after Ueshima 1979, n=15)
Lethocerus sp. 2 (from Michigan)	4	?	Post-reduction	data absent		Chickering 1927a, 1932, Chickering and Bacorn 1933: as 2 + neoXY: (after Ueshima 1979)

in *L. patruelis* and suggested in *L. uhleri*, see Table 1). Within the genus, *L. patruelis* seems to be similar to *L. indicus* in chromosome complement. This resemblance is confined not only to chromosome number and the presence of m-chromosomes but also to that the sex chromosomes in *L. patruelis* (present paper) and *L. indicus* (Bagga 1959, Jande 1959) are indistinguishable from autosomes at meiotic metaphases if a routine staining is used. In *L. patruelis*, it was due to the size resemblance of X and Y chromosomes causing the almost homomorphic form of the XY-pseudobivalent at MI. Noteworthy however that *L. indicus* was speculated to have the sex chromosome system of a neo-XY type originated as a result of the evolutionary translocation of both sex chromosomes to one pair of autosomes in the ancestral karyotype (Jande 1959). Another example of a neo-XY system seems to be *Lethocerus* sp. from Michigan. For this species, Chickering and Bacorn (1933) reported 2n = 4 with no distinguishable sex chromosomes. These authors suggested that this karyotype might has originated via a translocation of X and Y chromosomes to one pair of autosomes with a subsequent fusion between two more pairs of autosomes.

Ueshima (1979) considered the karyotype of 2n = 24 + 2m + XY as the modal (the commonest) in the genus *Lethocerus* and the ancestral (i.e., plesiomorphic) one in its evolution. All other karyotypes were suggested to have originated from this ancestral one through autosome fusions and fragmentations, translocations of sex chromosomes to autosomes and loss of m-chromosomes (see Fig. 12 in Ueshima 1979). However, here it should be noted that the most common karyotype needs not to be plesiomorphic in a group (White 1973). In addition, the data available at that time for *Lethocerus* (see Table 4 in Ueshima 1979) were in fact not indicative of the modality of 2n = 24 + 2m + XY in the genus, and some data presented in Ueshima's scheme were not universally correct (Fig. 9). For example, in the karyotype formulae of some of the species (for instance *Lethocerus* sp. from New Orleans) Ueshima included m-chromosomes which however have not been mentioned in the original paper (Table 1).

On the other hand, the ancestrality of a XY sex determination in *Lethocerus* is beyond question, since neo-XY and X_nY systems occurring in Belostomatidae (both), including *Lethocerus* (at least neo-XY), are clearly derivative being originated by X-autosome fusions or X-chromosome fissions, respectively. It cannot be doubted also that low chromosome numbers such as 2n = 8 in *L. americanus* and 2n = 4 in *Lethocerus* sp. from Michigan, are the derived characters brought about a series of autosome fusions during the course of evolution in this genus.

It seems likely that the ancestral karyotype in *Lethocerus* includes 26 autosomes and XY mechanism as found in many representatives of this genus and Belostomatidae as a whole (Table 1). It is not possible even to suggest whether this karyotype includes a pair of m-chromosomes as was speculated by Ueshima (1979). It is evident that these minute chromosomes easily escape detection by bug cytogeneticists, and hence many species recorded as lacking m-chromosomes in fact have them in their karyotypes.

CMA_3 staining of *L. patruelis* C-banded chromosomes revealed GC-rich sites corresponding to NORs in the X and Y chromosomes. This is the first case of NOR detection in *Lethocerus*. On the other hand, ribosomal genes have been already located in

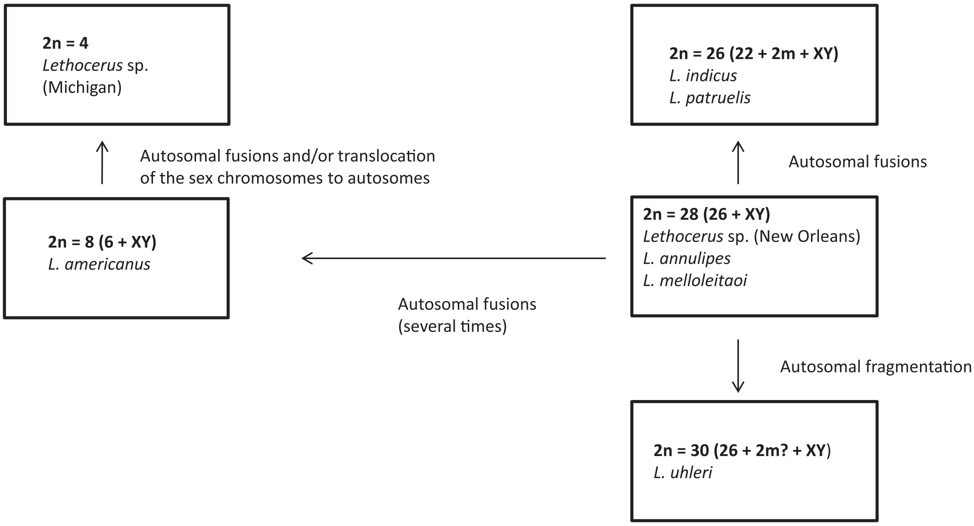

Figure 9. Suggested pathways of karyotype evolution in the genus *Lethocerus*.

Belostoma chromosomes using various techniques such as fluorochrome staining, silver staining and FISH (Table 1). In *Belostoma*, five species were shown to have NORs also in sex chromosomes while three other species in a pair of autosomes. Noteworthy, the species with the same chromosome complement sometimes differ in rDNA location (for example, in sex chromosomes in *B. cummingsi* while in autosomes in *B. dentatum*, both with 2n = 26 + X_1X_2Y).

In the greatest majority of living organisms, during the first division of meiosis all chromosomes reduce in number (reductional division), whereas during the second division the chromatids separate (equational division), and this pattern is named "pre-reduction" (White 1973). However true bugs characteristically have an inverted sequence of sex chromosome divisions in male meiosis, the so-called sex chromosome "post-reduction" when sex chromosomes undergo equational division at anaphase I and reductional division at anaphase II (Ueshima 1979, Kuznetsova et al. 2011), and this is also true for Belostomatidae (Table 1). Interestingly, *L. patruelis* appeared unique in showing no inverted sequence of sex chromosome divisions in male meiosis. In this species, X and Y chromosomes form a pseudobivalent at prophase and segregate to opposite poles at anaphase I, and the first division of meiosis is thus reductional both for autosomes and sex chromosomes. As a result of sex chromosome pre-reduction, second spermatocytes carry a single sex chromosome, either X or Y. The second division is then equational for all the chromosomes. Although pre-reduction of sex chromosomes is not usual in Heteroptera, it does occur in some groups (for example, all so far studied species of the family Tingidae have shown pre-reduction; Ueshima 1979, Grozeva and Nokkala 2001). Moreover, closely related species occasionally differ in this pattern (Ueshima 1979, Grozeva et al. 2006, 2007) as is also true of *Lethocerus* species.

Male meiosis in Heteroptera can further be characterized by radial configuration of one or sometimes both MI and MII plates. In this case, autosomal bivalents at MI and autosomes at MII form a ring on the periphery of the spindle, while the sex chromosomes are located in the center of this ring (Ueshima 1979). However in *L. patruelis*, both MI and MII plates are non-radial with random distribution of all the chromosomes on the spindle.

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Appendix

Electronic supplementary material video S1. (doi: 10.3897/zookeys.319.4384.app) File format: MPEG Video File (mpg).

Explanation note: A stalking/ambush attack of *Lethocerus patruelis* larva against small topmouth gudgeon (*Pseudorasbora parva*).

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New Aradidae from Ecuador (Hemiptera, Heteroptera, Aradidae)

Ernst Heiss[1,†]

1 *Research Entomologist, Tiroler Landesmuseum, Josef Schraffl Strasse 2a, A 6020 Innsbruck, Austria*

† *urn:lsid:zoobank.org:author:A4B5783D-568C-4928-86CB-3315714AC586*

Corresponding author: *Ernst Heiss* (aradus@aon.at)

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Abstract

As an addition to the presently poorly known aradid fauna of Ecuador, 3 new genera and 4 new species are described: *Osellaptera setifera* **gen. n.**, **sp. n.**; *Kormilevia ecuadoriana* **sp. n.** both belonging to Mezirinae; and Carventinae *Cotopaxicoris cruciatus* **gen. n.**, **sp. n.** and *Onorecoris piceus* **gen. n.**, **sp. n.** An updated key is provided for all species of the Neotropical genus *Kormilevia* Usinger & Matsuda, 1959.

Keywords

Hemiptera, Heteroptera, Aradidae, Mezirinae, Carventinae, new genus, new species, apterous, micropterous, Ecuador

Introduction

The aradid fauna of Ecuador was first assembled and catalogued by Froeschner 1981 reporting 15 species, belonging to the subfamilies Aneurinae Douglas & Scott, 1865 (2 spp.) and Mezirinae Oshanin 1908 (13 spp.). This reflects very poorly on the known flat bug fauna of this country, which is expected much more diverse and numerous because of its different biotops and suitable habitats. Later additions were recorded in Kormilev and Froeschner's synonymic list of the "Flat Bugs of the World" in 1987 and again updated by Coscaron and Contreras in their "Catalog of Aradidae for the Neotropical Region" in 2012.

A small lot of Aradidae from Central Ecuador in the authors collection contained – not unexpectedly – several new taxa. Although only single specimens are available, their striking morphological differences from other Neotropical Aradidae justify the erection of new genera for them. They are illustrated and described below as *Osellaptera setifera* gen. n., sp. n.; *Kormilevia ecuadoriana* sp. n. both belonging to the subfamily Mezirinae; and *Cotopaxicoris cruciatus* gen. n., sp. n. and *Onorecoris piceus* gen. n., sp. n. of the subfamily Carventinae. An updated key is proposed for all species of the Neotropical genus *Kormilevia* Usinger & Matsuda, 1959.

Material and methods

The specimens upon which the descriptions are based are dry-mounted and preserved in the collection of the author at the Tiroler Landesmuseum, Innsbruck, Austria (CEHI). As specimens of these apterous and pilose new taxa were mostly covered by detritus or incrustations, they were cleaned by treatment in 10% KOH for the study of abdominal structures. Photos were taken with an Olympus SZX 10 binocular microscope and a Olympus E 3 digital camera, processed with Helicon Focus 4.3 software, using Adobe Photoshop and Lightroom 2.3.

Measurements were taken with an eyepiece micrometer (20 units = 1 mm).

Abbreviations used: deltg = dorsal external laterotergite (connexivum); mtg = abdominal median tergite; pe-angles = posteroexterior angles (of deltg); vltg = ventral laterotergite. When citing the text on the labels of a pin attached to the specimens / separates the lines and // different labels.

Taxonomy

Subfamily Mezirinae Oshanin 1908

Osellaptera gen. n.

urn:lsid:zoobank.org:act:3B994BCD-645A-4233-96F4-B7CA4CCA2BCD
http://species-id.net/wiki/Osellaptera

Type species: *Osellaptera setifera* sp. n.

Diagnosis. Although superficially resembling the habitus of *Mystilocoris pubescens* Usinger & Matsuda, 1959 from Colombia, the new species cannot be placed in any of the apterous or micropterous Neotropical Mezirinae genera; here therefore *Osellaptera* gen. n. is proposed. It is distinguished from *Mystilocoris pubescens* (the only species of this genus) by its micropterous condition (apterous im *Mystilocoris*), more slender antennae, head as long as wide (about 1.5× wider in *Mystilocoris*), different structure and fusion of thorax and abdomen, and position of spiracles II-IV ventral, V sublateral and hardly visible from above, VI and VI sublateral on a prominent tubercle and visible, VIII lateral (II-VI ventral, VII sublateral and visible, VIII lateral), and the shape of the pygophore.

Description. Small sized micropterous Mezirinae; body oval, laterally constricted at metanotum, attenuated posteriorly, surface of body with deep punctures and long pubescence on carinate structures; legs and antennae beset with long setae; colouration cinnamoneous, legs and antennae are lighter.

Head. Triangular as wide as long, clypeus narrow reaching ½ of antennal segment I; antenniferous lobes short; antennae slender twice as long as width of head, segment I longest, II+III shorter, IV shortest; eyes stalked; postocular lobes converging to constricted neck.

Pronotum. Distinctly wider than long, lateral margins converging anteriorly with a vertically reflexed triangular expansion, disk with 2 ovate callosities depressed between them.

Mesonotum. Strongly transverse, median elevated ridge fused to that of metanotum and mtg I+II; lateral sclerites callous delimited laterally by flap-like structures these regarded as reduced remnants of wingpads.

Metanotum. Fused to mtg I+II, lateral sclerites oval and callous; surface of mtg I+II punctured delimited posteriorly by carinae expanding laterally from median ridge.

Abdomen. The median ridge of thorax continues along the tergal plate of mtg III-VI and highest on mtg IV; lateral sclerites with subrectangular punctured depressions; deltg II+III fused, anteriorly constricted, reaching mesonotum; lateral margins of deltg II-VI reflexed, those of deltg II-IV laterally expanded and pilose.

Venter. Metathoracic scent gland canal curved anteriorly and upward, not visible from above; spiracles II-IV ventral, V sublateral and barely visible from above, VI and VII sublateral on a prominent tubercle and fairly visible, VIII lateral and visible from above.

Legs. Long and slender, claws with thin pulvilli.

Etymology. It is a pleasure to dedicate this conspicuous new flat bug genus to my friend Giuseppe Osella (Verona), appreciating his long time friendship and generosity donating to me Aradidae from his collection trips, and recognizing his important contributions to various matters of coleopterology.

Osellaptera setifera **sp. n.**

urn:lsid:zoobank.org:act:53337094-CD36-4238-A232-E4386BA21613
http://species-id.net/wiki/Osellaptera_setifera
Fig. 1

Holotype male labelled: Ecuador, Cotopaxi / Otonga (foresta nublada) / 2000m 23–30 VII 2004 / G. Osella leg. This specimen is designated as holotype and labelled accordingly.

Description. Holotype male, micropterous body surface deeply punctured interrupted with smooth carinae bearing dense pilosity; colouration cinnamomeous, appendages lighter with long dense erect setae curved on apices.

Figures 1–2. 1 *Osellaptera setifera* gen. n., sp. n., holotype male dorsal view **2** *Kormilevia ecuadoriana* sp. n., holotype female dorsal view.

Head. As wide as long (26/26); pilose clypeus produced and narrowly rounded anteriorly reaching 1/3 of antennal segment I; genae thin and adherent as long as clypeus; antenniferous lobes short, apex recurved apically; antennae twice as long as width of head (52/26), segment I club-shaped and longest, II and III shorter and cylindrical thickened apically, IV shortest, clavate with pilose apex; length of antennal segments I/II/III/IV = 18/12/14/8; eyes stalked directed anterolaterally; postocular lobes sinuately converging to constricted neck; vertex with a median elevation laterally separated from smooth oval callosities by deep grooves; rostrum arising from a slit-like atrium, shorter than head, rostral groove with carinate borders.

Pronotum. About 2.8× as wide as long (31/11); lateral margins converging anteriorly with a vertically reflexed triangular expansion, disk with 2 ovate callosities deeply depressed between them, anterolateral angles slightly produced and rounded; anterior margin concave, ring like; posterior margin convex.

Mesonotum. Strongly transverse, 3.35× as wide across wingpads as long, consisting of a median ridge fused to that of metanotum and mtg I+II and of lateral oval callosities delimited by an inclined pilose carina followed by flap-like wingpads produced over lateral margins of abdomen.

Metanotum. Fused to mtg I+II these visible as transverse punctured depressions, posteriorly delimited by curved pilose carinae which are connected to median ridge, lateral sclerites of metanotum punctured and callous, posteriorly sloping to mtg I without a separating suture.

Abdomen. Tergal plate of mtg III-VI medially elevated and connected anteriorly to thoracic ridge, highest on mtg IV, lateral sclerites with subrectangular punctured depressions; triangular deltg II+III fused, produced and constricted anteriorly, reaching lateral margin of mesonotum; deltg II-IV laterally expanded, their pe-angles produced and beset with long setae; tergite VII with 2 (1+1) sublateral smooth callosities, strongly medially raised for the reception of the large pygophore, this pyriform projecting posteriorly; paratergites VIII small, much shorter than pygophore, surface with short yellowish pilosity; the cleft visible between tergite VII and anterior margin of pygophore shows triangular apices of parameres; the single male was not dissected for furtherstudy of the latter.

Venter. Metathoracic scent gland canal curved anteriorly and upward, not visible from above; spiracles II-IV ventral, V sublateral and barely visible from above, VI and VII sublateral on a prominent tubercle and fairly visible, VIII lateral and visible from above.

Legs. Long and slender, claws hook-like with thin pulvilli, with protibial comb.

Measurements. Length 5.4mm (incl. cleft pygophore); width of abdomen at apex of deltg II 2.1mm; across tergite III 2.6mm, across tergite VII 2.3mm; length / width of pygophore 0.45/0.75mm; length of antennae 2.6mm.

Etymology. The name refers to the dense setae covering legs and antennae and most body parts.

Genus *Kormilevia* Usinger & Matsuda 1959

http://species-id.net/wiki/Kormilevia

Remarks. The micropterous genus *Kormilevia* Usinger & Matsuda, 1959 was erected for *setifera* Usinger & Matsuda, 1959 from Brazil. These authors recognized that species described as *Acaricoris dureti* Kormilev, 1953a from Argentina, or as *Pictinus plaumanni* Kormilev, 1953b and *Pictinus montrouzieri* Kormilev, 1953b, both from Brazil, belong to *Kormilevia* and were transferred there giving a key to the 4 then known species. They were however uncertain about the taxonomic position of *Acaricoris teresopolitanus* Wygodzinsky, 1948 and did not include this in the key. Kormilev 1963 described the next species *aberrans* sp. n. from Colombia and 1964 *gerali* sp. n. from Brazil, and presents a key to 6 species including *teresopolitana* but omitting his *aberrans*.

As the comparative notes of Kormilev's descriptions are partly insufficient, the important structures of the mesonotum are not described or illustrated (e.g., *aberrans*, *gerali*) and the position of spiracles used in Kormilev's 1964 key are contradictory to the descriptions (*plaumanni*, *montrouzieri*), a comparison of taxa is uncertain and needs a revision based on the types. Here all available data from the literature were assembled and a tentative new key for all 8 taxa is presented below. For *plaumanni* and *montrouzieri* original material was available for study (ex. coll. Plaumann).

All *Kormilevia* species are micropterous, although not always recognized as such, sharing small nonfunctional wingpads that enable only a very limited range of distribution. It can be assumed that they are therefore endemic to the region of origin. Because of biogeographical considerations – the closest record to the Ecuadorian locality is that of *aberrans* from Bogota, Colombia, which lies about 800km north – and distinct characters, *Kormilevia ecuatoriana* sp. n. is described here although only a single female is available.

Key to species of *Kormilevia*

1 (2) Spiracles II-VI ventral, remote from lateral margin, VII+VIII lateral and visible from above; only female holotype known (described as A*caricoris*), 4.8mm, Fig. 7 (Brazil) .... ***eresopolitana* (Wygodzinsky) 1948**

2 (1) Spiracles II-IV ventral, V-VI sublateral or lateral and barely visible from above, VII-VIII lateral **3**

3 (4) Antennae long, about 2.6× as long as width of head, antennal segment IV as long a.............II, only female holotype known, of larger size, 5.3mm, Fig. 2 (Ecuador, Cotopaxi) .... ***ecuatoriana* sp. n.**

4 (3) Antennae shorter, 2.03-2.28× as long as width of head, antennal segment IV longer than II, of smaller size (except *aberrans* =4.55–5.3mm) **5**

5 (6) Eyes as long as distance from anterior margin of eye to apex of antenniferous lobes, holotype male 3.65mm, paratype female 4.0mm, Fig. 8 (Brazil, Est. do Rio) .... ***etifera* Usinger & Matsuda 1959**

6 (9) Eyes large, longer than distance from anterior margin of eye to apex of antenniferous lobes **7**

7 (8) Length of antennae 2.28× as long as width of head, head about as long as wide,smaller species, only male holotype known, 3.5mm, Fig. 6 (Argentinia, Iguazu) .... ***dureti* (Kormilev) 1953**

8 (7) Antennae 2.12× as long as width of head, head distinctly wider than long, larger species, holotype male 4.55mm, paratype female 5.32mm (Colombia, Bogota) .... ***aberrans* Kormilev 1963**

9 (6) Eyes smaller, shorter than antenniferous lobes **10**

10(11) Spiracles II-IV ventral, in both sexes, V sublateral and barely visible from above, VI-VIII lateral and distinctly visible from above, holotype male 4.0mm, paratype female 4.5mm (Brazil, Sta.Catarina) .... ***gerali* Kormilev 1964**

11(10) Spiracles II-IV ventral, in females V sublateral and barely visible from above, VI-VIII lateral and visible, in male V-VIII lateral and visible from above **12**

12(13) Scutellum like mesonotum with a median V-shaped posteriorly raised ridge and a median groove at base, male pygophore posteriorly obtuse, holotype male 3.9mm, paratype female 4.25mm, Figs 3, 4 (Brazil, Sta.Catarina) .... ***montrouzieri* (Kormilev) 1953**

13(12) Scutellum like mesonotum with a parallel ridge reaching from base to apex with an indistinct median suture, male pygophore posteriorly conical, holotype male 3.9mm, paratype female 4.4mm, Fig. 5 (Brazil, Sta.Catarina)....... .... ***plaumanni* (Kormilev) 1953**

***Kormilevia ecuadoriana* sp. n.**

urn:lsid:zoobank.org:act:35441D85-FADC-4EB8-8EAF-EBE72B208B46
http://species-id.net/wiki/Kormilevia_ecuadoriana
Fig. 2

Holotype female labelled: Ecuador 2008 / legg. Baviera, Belló / Osella & Poliano // ECU-Cotopaxi / Otonga – Galapagos / m 1620, 5 VIII 2008 / S 00°23.962' / W 58°56.720'. The specimen is designated as holotype and labelled accordingly. CEHI.

Diagnosis. The new species differs from all 7 species assigned to date to the genus *Kormilevia* Usinger & Matsuda, 1959 catalogued by Kormilev and Froeschner 1987 and can be recognized by the long antennae and other characters mentioned in the key.

Description. Small sized micropterous Mezirinae; body oval, abdomen dilated posteriorly, surface of body granulate and rugose, lateral margins with short setae; antennae and legs beset with fine setigerous tubercles. Colouration of body reddish brown, pronotum except oval callosities, smooth part of scutellum, apodemal impressions of tergal plate and anterolateral angles of deltg II-VII and apices of tergites VII-X yellowish; antennae yellowish, apical half of segment I, apex of II and III and basal half of IV darker brown, legs yellowish, femora and tibiae brown on apical half.

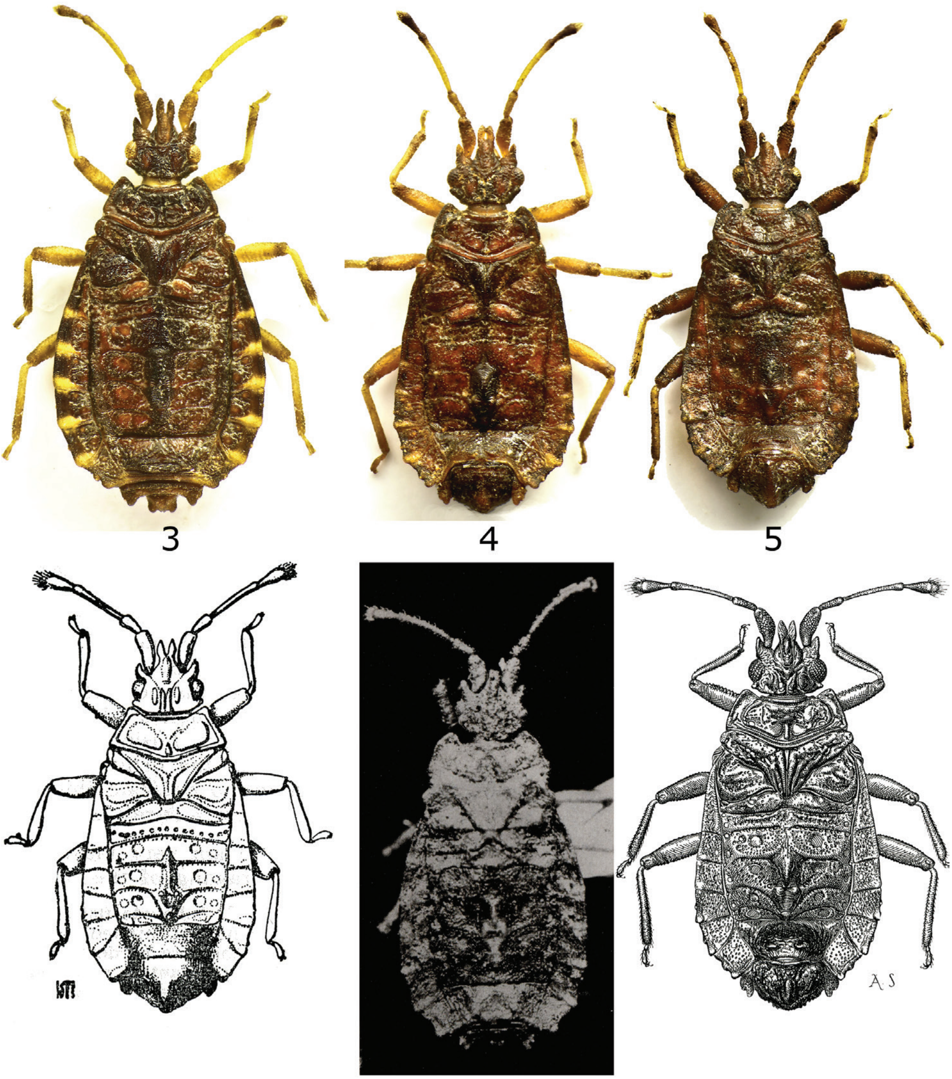
Head. Slightly longer than width across eyes (20/17.5); clypeus conical; genae thin and adherent, as long as clypeus, reaching about 1/3 of antennal segment I; antenniferous lobes short with acute apex; antennae 2.62× as long as width of head (46/17.5), segment I thickest, II and IV thinner and shortest, dilated apically, III thinnest and longest, cylindrical, IV with pilose apex; length of antennal segments I/II/III/IV = 13/8/17/8; eyes granular inserted in head, their length shorter than antenniferous lobes (9/10); postocular lobes notched behind eyes followed by a round lateral tubercle not reaching outer margin of eyes, then straight, converging to constricted collar; vertex with irregular rugosities separated laterally by a deep groove from oval callosities; rostrum arising from a slit-like atrium, shorter than head.

Pronotum. More than twice as wide as long (31/12); sinuate lateral margins emarginate and carinate converging anteriorly, anterolateral angles narrowly rounded, produced over anterior margin; posterior margin carinate, slightly convex; disk smooth depressed at middle, flanked by 2 (+1) oval granulate callosities.

Mesonotum. Consisting of a triangular scutellum-like plate with smooth surface and anterior and lateral margins carinate and a median granulate carina, anterolaterally delimited by small rounded wing pads, lateral polygonal sclerites with a median oval granulate callosity; metathoracic scent gland visible from above posterior to wing pads.

Metanotum. Transverse, surface rugose with 2(1+1) submedian ovate callosities, depressed between them; posterior margin nearly straight, separated from fused tergites I+II by a distinct suture. Tergites I+II fused, posterior margin delimited by a bisinuate suture, raised medially.

Abdomen. Tergal plate flat, consisting of mediotergites III-VI laterally with large oval depressions, medially elevated on tergites IV and V; deltg II-VII slightly reflexed, their lateral margin subparallel at middle attenuated anteriorly and posteriorly, their



Figures 3-8. *Kormilevia* species. **3** *Kormilevia montrouzieri* female from Sta. Catarina, Brazil **4** *Kormilevia montrouzieri* male from same locality **5** *Kormilevia plaumanni* male from Sta. Catarina, Brazil **6** *Kormilevia dureti*, male holotype (from Kormilev 1953) **7** *Kormilevia teresopolitana*, female holotype (from Wygodzinsky 1948) **8** *Kormilevia setifera*, holotype male (from Usinger & Matsuda 1959).

surface longitudinally carinate on outer half; deltg II triangular not fused to deltg III, deltg II-VII separated by sutures; pe-angles of deltg VI slightly rounded, of deltg VII produced posteriorly over straight posterior margin of tergite VII; tergite VIII bilobate, visible tergites IX and X tricuspidate.

Venter. Spiracles II-IV ventral, V sublateral but barely visible from above, VI-VIII lateral and visible from above.

Legs. Long and straight, femora moderately incrassate medially, tarsi two-segmented, claws with pulvilli and a long median setiform parempodium.

Measurements. Length 5.3mm; width of mesonotum across wing pads 1.75mm; scutellum length / width 0.6/1.45mm; width of abdomen across tergites IV and V 2.85mm.

Etymology. Named after Ecuador, the country of origin.

Subfamily Carventinae Usinger, 1950

Cotopaxicoris gen. n.

urn:lsid:zoobank.org:act:02E9A006-655E-4EAF-A28D-D9A8D482740F
http://species-id.net/wiki/Cotopaxicoris

Type species: *Cotopaxicoris cruciatus* sp. n.

Diagnosis. The combination of characters: general habitus, long antennae, stalked eyes, pro-and mesonotum separated by sutures, metanotum fused to mtg I+II and to abdominal tergal plate, long pilosity on body, and appendages and the micropterous condition. This combination of characters is not shared by any apterous or micropterous Carventinae recorded from mainland South and Mesoamerica (*Aparilocoris* Kormilev, 1983; *Dihybogaster* Kormilev, 1953b; *Glyptocoris* Harris & Drake, 1944; *Kolpodaptera* Usinger & Matsuda, 1959; *Peggicoris* Drake, 1956, *Reeceicus* Drake, 1956). It stands also apart and shows no resemblances to genera described from the Caribbean Islands.

Description. Micropterous; body subrectangular strongly attenuated anteriorly; surface of head and body with deep punctures, the elevated structures and lateral margins of head and body as well as of legs and antennae beset with fringe-like yellowish setae; colouration light brown, head darker, tibiae lighter.

Head. Distinctly wider than long, clypeus short, genae adherent shorter than clypeus; antenniferous lobes short diverging anteriorly; antennae about 2.5× as long as width of head; segment I longest, those following shorter and thinner; eyes stalked; postocular lobes converging posteriorly; rostrum arising from an open atrium as long as head.

Pronotum. Subrectangular about 3× as wide as long; lateral margins with rounded reflexed carinate paranota, posteriorly delimited by a notch followed by a laterally produced knob-like process; surface of disk with a median carina and rugose lateral sclerites; posterior margin carinate and convex, separated by a distinct suture from mesonotum.

Mesonotum. Strongly transverse, about 4× as wide as long; surface with a median ridge which continues throughout thorax and abdomen, laterally flanked by oval smooth depressions followed by rugose sclerites, these delimited laterally by basally elevated flap-like structures representing reduced wingpads; suture separating meso- and metanotum recognizeable lateral of median ridge, where it is marked only by a thin indistinct suture.

Metanotum. Fused to mtg I+II and tergal plate; continuous median ridge widened posteriorly then forming a cross-like ridge on mtg I+II; lateral sclerites with rugose callosities, depressed anteriorly; surface of mtg I+II deeply punctured.

Abdomen. Tergal plate fused to mtg I+II, median ridge narrower on mtg III continuing and raised posteriorly, highest on mtg IV-V; surface laterally with oval punctured depressions; deltg II+III fused, laterally expanded, an inclined carina marking posteror margin of deltg II; pe-angles of deltg V and VII roundly expanded.

Venter. Spiracles I-IV ventral remote from lateral margin, V and VI sublateral but visible from above, VII-VIII lateral and visible.

Legs. Long and slender, tarsi with long thin pulvilli.

Etymology. Named after the Cotopaxi region, the second highest mountain in Ecuador, where this interesting new taxon was collected.

Cotopaxicoris cruciatus **sp. n.**

urn:lsid:zoobank.org:act:272A0E55-EC1E-48D9-BEAC-04EC9102047C
http://species-id.net/wiki/Cotopaxicoris_cruciatus
Fig. 9

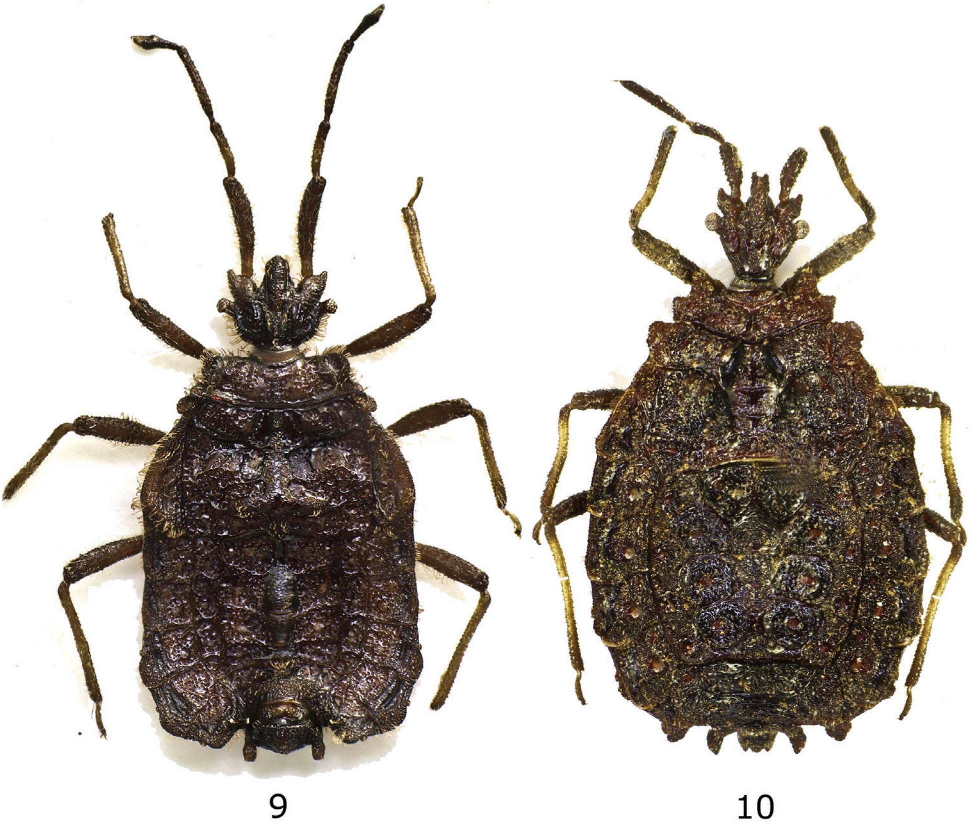
Holotype male labelled: Ecuador (Cotopaxi) 2008 / legg. Baviera, Belló / Osella & Pogliano // Vaglio bosque / nublado e\o sotto / legno e\o tronchi. CEHI. This specimen is designated as holotype and labelled accordingly.

Description. Holotype male, micropterous; body surface deeply punctured with fringe-like pilosity on lateral margins of head, body, and carinate elevations, legs and antennae with fine erect setae; colouration light brown with darker head and lighter tibiae.

Head. Wider than long (27/24); clypeus short subparallel, genae adherent not reaching apex of clypeus; antenniferous lobes diverging anteriorly, apices narrowly rounded; antennae 2.48× as long as width of head (67/27); segment I longest and thickest, moderately incrassate along apical 2/3, II and III shorter and thinner, cylindrical, IV shortest spindle-shaped with pilose apex; length of antennal segments I/II/III/IV = 23/13/19/12; eyes stalked directed anterolaterally; postocular lobes roundly converging toward constricted neck densely beset with long erect setae with curved apices; vertex medially elevated with two rows of setae, laterally with 2(1+1) large oval rugose callosities; rostrum arising from a slit-like atrium, as long as head, lateral margins of rostral groove carinate.

Pronotum. Subrectangular, 3× as wide across rounded lateral margins as long (33.5/11); lateral margins with rounded reflexed carinate paranota, posteriorly delimited by a notch followed posterolaterally by a laterally produced knob-like process; surface of disk with median carina and rugose lateral sclerites; posterior margin carinate and convex, separated from mesonotum by distinct suture.

Mesonotum. Strongly transverse, 4.5× as wide across wingpads as long at middle (45/10); consisting of two transverse laterally rounded sclerites lateral of median moderately elevated ridge, surface of sclerites with an oval smooth depression adjacent



Figures 9–10. 9 *Cotopaxicoris cruciatus* gen. n., sp. n., holotype male dorsal view **10** *Onorecoris piceus* gen. n., sp. n., holotype female dorsal view.

to median posteriorly widening ridge followed by rugose callosities; all margins carinate, anterolateral angles triangularly raised to level of adjacent knob-like process of pronotum, posterolaterally produced into oval flap-like expansions, these representing reduced wingpads; suture separating meso- and metanotum only developed lateral of median ridge, upon which the transverse fusion line is indistinct and barely discernible.

Metanotum. Fused to mtg I+II and tergal plate; continuous median ridge widened posteriorly then forming a cross-like elevated ridge on mtg I+II; lateral sclerites with rugose callosities, depressed anteriorly; surface of mtg I+II deeply punctured.

Abdomen. Tergal plate of abdominal mtg III-VI fused to mtg I+II, the median ridge narrower on mtg III continuing, widening and raised posteriorly, highest on abdominal scent gland at posterior margin of mtg IV-V; with oval punctured depressions laterally; lateral margins subparallel at deltg III+IV, dilated at deltg II, V and VI; deltg II+III fused, laterally expanded, an inclined carina marks the posteror margin of deltg II; pe-angles of deltg V and VII rounded expanded; tergite VII medially raised for reception of globose pygophore, this wider than long with a conical median elevation; paratergites VIII cylindrical produced over pygophore; the single male was not dissected for the study of parameres.

Venter. Spiracles I-IV ventral, remote from lateral margin, V and VI sublateral but visible from above, VII-VIII lateral and visible.

Legs. Long and slender, femora moderately incrassate, tibiae straight, tarsi with long thin pulvilli.

Measurements. Length 5.8mm; width of abdomen across tergite III 3.1mm, IV 3.15mm, V 3.2mm; width/length of pygophore 0.75/0.3mm; length of antennae 3.35mm.

Etymology. Refers to the cross-like elevated ridge on the thorax.

Onorecoris **gen. n.**

urn:lsid:zoobank.org:act:FD590891-3410-449E-9961-33FC189561CC
http://species-id.net/wiki/Onorecoris

Type species: *Onorecoris piceus* sp. n.

Diagnosis. As in *Cotopaxicoris,* the assemblage of characters: general habitus, antennae twice as long as width of head, stalked eyes, a pentagonal fused median scerite on meso- and metanotum are not shared by apterous Carventinae recorded from South and Mesoamerica as reported for *Cotopaxicoris* description. Therefore, a new genus *Onorecoris* gen. n. is erected for *O. piceus* sp. n.

Description. Apterous female; body oval attenuated anteriorly, surface of head and body rugose and tuberculate, legs and antennae beset with stiff hairs bearing tubercles; colouration piceous, tibiae yellowish except base and apex.

Head. Slightly longer than width across eyes; clypeus narrow, flanked by anteriorly produced genae reaching about ½ of antennal segment I; antenniferous lobes wide, apex narrowly rounded; antennae about twice as long as width of head, antennal segment III longest, I and II shorter, IV fusiform; eyes slightly stalked; postocular lobes converging uniformly to narrow neck region; rostrum arising from slit-like atrium, shorter than head.

Pronotum. About 3× as wide as long, lateral margins angulate at humeri then triangularly projecting anteriorly, produced over anterior margin; disk with median carina flanked by rugose callosities; posterior margin separated from mesonotum by a deep furrow.

Mesonotum. With median posteriorly widening and moderately elevated pentagonal ridge and lateral subrectangular sclerites with rugose surface, their lateral margins rounded, produced laterally; separated from metanotum along lateral sclerites by deep grooves, median ridge fused and continuing on metanotum and mtg I+II where its structure disappears.

Metanotum. Lateral sclerites separated from continuous median ridge by deep depressions, their surface deeply punctured and callous, posteriorly completely fused to mtg I+II; lateral margins with a small round expansion.

Abdomen. Tergal plate roundly elevated at middle, highest on mtg IV-V, lateral parts with oval punctured depressions these laterally delimited by carinate structures; lateral margins rounded with partly visible rims of dorsally reflexed vltg II-VII these increase posteriorly; pe-angles of deltg II-VII with a distinct dorsal tubercle; deltg II-VII separated by sutures, triangular deltg II anteriorly reaching to metanotum .

Venter. Surface rugose and punctured, spiracles II-IV ventral, V sublateral and visible from above, VI and VII on sublateral tubercles of reflexed vltg VI and VII and visible from above, VIII dorsolateral.

Legs. Long and slender, tibiae medially curved, claws with thin pulvilli.

Etymology. It is a pleasure to dedicate this interesting new flat bug genus to my friend Giovanni Onore (Quito), versatile and successful entomologist in Ecuador who made the species available for study.

***Onorecoris piceus* sp. n.**
urn:lsid:zoobank.org:act:411698E8-6CA4-4023-81BF-20E4C2E085CB
http://species-id.net/wiki/Onorecoris_piceus
Fig. 10

Holotype female labelled: Ecuador, Loja 7 Uritujinga 2800m / 19 Dec. 1997 G.Onore. CEHI. The specimen is damaged by a pinhole on the abdomen and lacks the right antennal segments II-IV. It was cleaned and remounted by the author. This specimen is designated as holotype and labelled accordingly.

Description. Medium-sized apterous Carventinae, body broadly ovate, attenuated anteriorly; surface rather flat with rugosities and punctures; colouration piceous.

Head. Longer than wide (23/22.5, incl. neck 25/22.5); clypeus narrow, raised with a round tubercle subapically; genae thin, produced over apex of clypeus reaching about ½ of antennal segment I, antenniferous lobes diverging laterally, apex with a round tubercle; antennae 2.09× as long as width of head (47/22.5), segment I thickened on anterior ¾ densely beset with tubercles bearing stiff hairs, II shortest, III longest, IV fusiform with pilose apex; length of antennal segments I/II/III/IV = 12.5/8/18/8.5; eyes slightly stalked; postocular lobes uniformly converging to constricted neck; vertex with a median ridge, this posterolaterally with 2(1+1) elevated round tubercles, separated from lateral oval callosities by deep grooves.

Pronotum. Strongly transverse, more than 3× as wide as long (35/11); lateral margins angularly produced on humeri then triangularly projecting anteriorly, longer than collar; disk with a V-shaped median sclerite anteriorly followed posteriorly by small median triangular ridge separated from oval callosities by deep grooves; posterior margin convex, transverse suture separates the mesonotum.

Mesonotum. Distinctly wider than long (45/10), consisting of a median posteriorly widening and moderately elevated pentagonal ridge and lateral subrectangular sclerites with rugose surface, their lateral margins rounded, produced laterally; separated from metanotum along lateral sclerites by deep grooves, median ridge fused, continuing on metanotum and mtg I+II where its structure is obliterated.

Metanotum. About 3.5× as wide as length including fused mtg I+II (52/15); lateral sclerites separated from continuous median ridge by deep depressions, their surface deeply punctured and callous, posteriorly completely fused to mtg I+II; lateral margins with a small round expansion.

Abdomen. Lateral and anterior margins of tergal plate convex, posterior margin straight; its surface rather flat with moderately rounded elevation on mtg IV-V, highest at scent gland scar IV-V; lateral parts with oval punctured depressions on mtg IV-VI, those of mtg III larger, directed anteriorly, their lateral margins delimited by carinae, these enlarged on anterolateral angles; deltg II-VII separated by sutures, triangular deltg II anteriorly reaching metanotum; pe-angles of deltg II-VII slightly reflexed, rounded, with larger dorsal, granulate tubercle; dorsally reflexed margins of vltg II-VII partly visible from above as lateral rims which increase in size from deltg II-VI forming triangular tubercle on deltg VII; tergite VII with a median elevated ridge, tergite VIII bilobate, visible apices of tergites IX and X tricuspidate, as long as posteriorly produced paratergites VIII.

Venter. Spiracles II-IV ventral, V sublateral and visible from above, VI and VII on sublateral tubercles of reflexed vltg VI and VII and visible from above, VIII dorsolateral¸sternites separated by transverse sutures, surface rugose and punctured,

Legs. Long and slender, femora cylindrical, tibiae medially curved, tarsi bisegmented, claws with thin pulvilli.

Measurements. Length 6.1mm; width of abdomen across tergite III and IV 3.65mm, V 3.5mm; width of tergite VIII 1.05mm; width /length of tergal plate 2.3/2.1mm; length of antennae 2.35mm.

Etymology. The epithet refers to the piceous colouration of this unusual specimen.

Acknowledgments

I am very grateful to my friends Giuseppe Osella (Verona, Italy) and Giovanni Onore (Quito, Ecuador) who generously made available these specimens for examination and description. I also thank Stefan Heim (Innsbruck, Austria) for the photos and Alexi Popov and his editorial team (Blagoevgrad, Bulgaria) for the invitation to contribute to this volume and the two anonymous reviewers for their suggestions and linguistical improvement of the text.

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RESEARCH ARTICLE

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The Auchenorrhyncha fauna of peat bogs in the Austrian part of the Bohemian Forest (Insecta, Hemiptera)

Werner E. Holzinger[1], Lydia Schlosser[2]

[1] *Ökoteam – Institute for Animal Ecology and Landscape Planning, Bergmanngasse 22, 8010 Graz, Austria*

Corresponding author: *Werner Holzinger* (holzinger@oekoteam.at)

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Abstract

The first overview on the Auchenorrhyncha fauna of peat bogs of the Austrian Bohemian Forest is presented. Seven oligotrophic peat bog sites were studied in 2011 by suction sampler (“G-Vac”) and 93 Auchenorrhyncha species (with 7465 adult specimens) were recorded. Eleven species (about 18 % of the individuals) are tyrphobiontic or tyrphophilous. The relative species abundance plot is not very steep; the six most abundant species represent 50 % of the individuals. The most common species is *Conomelus anceps* (17 % of the individuals). Compared to the whole Austrian Auchenorrhyncha fauna, the fauna of peat bogs comprises distinctly more univoltine species and more species hibernating in nymphal stage. Densities of adult Auchenorrhyncha in peat bogs are low in spring (about 10–60 individuals per m^2) and high in July, with up to 180 (±50) individuals per m^2. Disturbed peat bogs have higher species numbers and higher Auchenorrhyncha densities in total, but lower numbers and densities in peat bog specialists.

Zusammenfassung

Diese Studie gibt erstmals einen Überblick über die Zikadenfauna der Moore des österreichischen Anteils des Böhmerwaldes. Sieben Moorflächen wurden 2011 mittels Saugfang quantitativ untersucht. Insgesamt konnten 93 Zikadenarten (in 7465 adulten Individuen) festgestellt werden. Elf Arten (ca. 18 % der Individuen) sind tyrphobiont oder tyrphophil. Die Gesamtdominanzkurve ist nicht sehr steil; die sechs häufigsten Arten repräsentieren 50 % aller Individuen, die häufigste Art ist *Conomelus anceps* (17 % der Individuen).

Vergleicht man die Zikadenfauna der Moore mit der Zikadenfauna Österreichs, so weist erstere deutlich mehr univoltine Arten und mehr Larvalüberwinterer auf. Phänologisch betrachtet sind die Dichten adulter Zikaden in Mooren im Frühling niedrig (ca. 10–60 Individuen pro m²) und im Juli hoch (bis 180 ± 50 Individuen pro m²). Gestörte Moorlebensräume haben höhere Artenzahlen und höhere Zikadendichten, aber die Artenzahl und Individuendichte der Moorspezialisten ist deutlich geringer als in ungestörten Mooren.

Keywords

Auchenorrhyncha, Fulgoromorpha, Cicadomorpha, peat bogs, wetland, species composition, Bohemian Forest, Austria

Introduction

Peat bogs are characterized by very wet, acidic and oligotrophic conditions, and their soil is of organic origin. They are among the most threatened habitats in Central Europe, due to dewatering, peat mineralization, land reclamation, afforestation, nutrient contamination and recently by climate change. Within the last century, over 90 % of all peat bogs in Austria were devastated or completely destroyed (Niedermair et al. 2010).

Auchenorrhyncha are among the most abundant animal groups in peatlands. The majority of species is stenoecious, specialized on both habitat conditions and host plants (Nickel et al. 2002, Nickel 2003; see Table 3). With a few exceptions (Leising 1977, Holzinger 1995, 2000, Holzinger and Novotny 1998) the Auchenorrhyncha fauna of Austrian peat bogs is poorly studied, and the hopper fauna of the granite and gneiss highlands of the Austrian Bohemian Forest is completely unknown. Here we present the first overview on the peat bog fauna of this area and give some data on the Auchenorrhyncha communities of Central European peat bogs (see also Schlosser 2012, Schlosser and Holzinger 2012).

Methods and materials

Seven typical oligotrophic peat bog sites of the Bohemian Forest were studied in 2011. Quantitative samples were taken monthly (from May until September) by a suction sampler (“G-Vac”, see Stewart 2002). Each sample was taken by walking slowly through the sampling site and performing 100 “touchdowns” with the suction sampler nozzle (Ø 12 cm). Thus one sample represents the fauna of 1.1 m². Three samples per date and site were taken, thus the data set contains a total of (7 sites × 5 dates × 3 samples =) 105 samples.

Study sites

The study sites are located in the very north of Upper Austria, close to the German and Czech border. They are shown in Fig. 1 and characterized in Table 1 and 2.

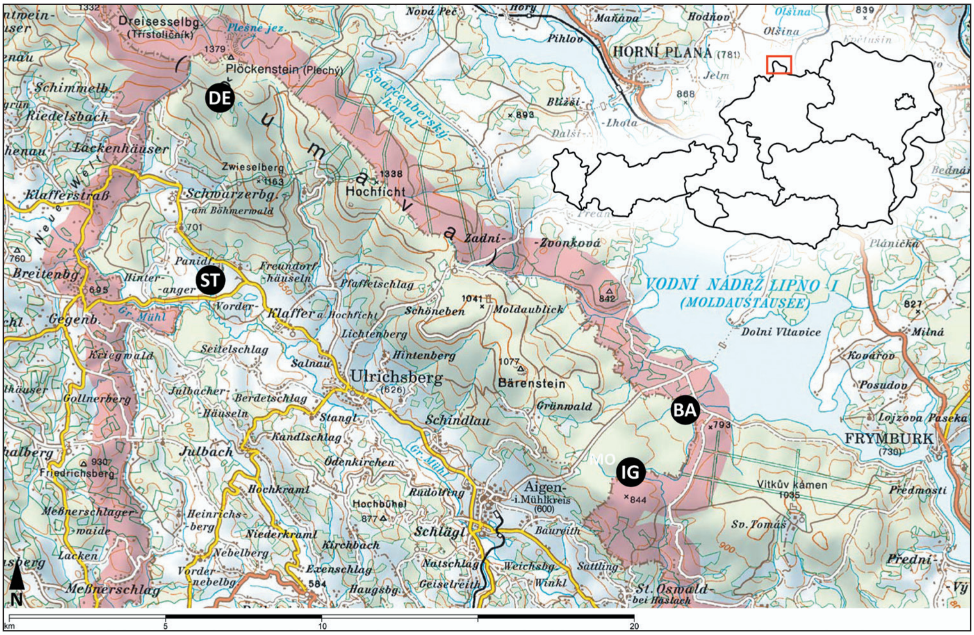

Figure 1. Location of the sampling sites in the Bohemian Forest (Upper Austria), overview. Samling sites: DE = Deutsches Haidl, ST = Stadlau, BA = Bayrische Au, IG = Moor am Iglbach. Map source: AMAP 3D.

Table 1. Study sites, coordinates and sampling dates on these sites (according to the Upper Austrian environmental lawyer, unpublished).

Code	Site name	Coordinates	Altitude	Area (ha)	Site description	Sampling dates
BA	Bayrische Au	48°40'49"N; 14°03'32"E	720 m	33.8	oligotrophic peat bog of national importance (Steiner 1992)	13.5., 22.6., 27.7., 22.8., 24.9.2011
ST-1	Stadlau 1	48°42'29"N; 13°51'12"E	610 m	7.1	dewatered, partially eroded and heavily nutrient contaminated remnants of a formerly large peat bog area	17.5., 20.6., 25.7., 21.8., 23.9.2011
ST-2	Stadlau 2	48°42'23"N; 13°51'18"E	610 m			
ST-3	Stadlau 3	48°42'32"N; 13°51'15"E	610 m			
IG-1	Iglbach-Moor 1	48°39'10"N; 14°01'44"E	800 m	3.9	drained peat bog complex, oligotrophic to mesotrophic, partially still very wet	19.5., 22.6., 26.7., 20.8., 24.9.2011
IG-2	Iglbach-Moor 2	48°39'09"N; 14°01'30"E	800 m			
DE	Deutsches Haidl	48°45'43"N; 13°51'13"E	1242 m	2.8	acidic oligotrophic peat bog of international importance (Steiner 1992); sphagnum moss–spruce forest with a large central area covered by *Carex limosa* and *Sphagnum majus*	18.5., 25.6., 27.7., 22.8., 25.9.2011

Table 2. Vegetation and management of the study sites (according to the Upper Austrian environmental lawyer, unpublished).

Code	Site name	Vegetation	Site management
BA	Bayrische Au	Patchy mixture of *Phalaridetum arundinaceae*, *Caricetum rostratae*, *Caricetum gracilis*, *Caricetum nigrae*, *Sphagnetum magellanici*	parts of the peat bog formerly used for peat-ditching; no management today
ST-1	Stadlau 1	Molinion, *Sphagnetum magellanici*	some years grazed (cattle) but not in 2011
ST-2	Stadlau 2	*Caricetum nigrae*, *Caricetum rostratae*, Junco-Molinietum	some years grazed (cattle) but not in 2011
ST-3	Stadlau 3	Junco-Molinietum	mowing once a year (July), grazed (cattle)
IG-1	Iglbach-Moor 1	*Caricetum rostratae*	no management
IG-2	Iglbach-Moor 2	*Caricetum rostratae*	no management
DE	Deutsches Haidl	*Caricetum limosae*, *Sphagnetum magellanici*, Sphagno girgensohnii-Piceetum	no management

Results and discussion

A total number of 93 Auchenorrhyncha species (7465 adult specimens) were collected and identified (Tables 3 and 4). The most abundant species is *Conomelus anceps* representing almost 17 per cent of the total number of specimens, followed by *Jassargus pseudocellaris* (5.5 %), *Muellerianella extrusa* (9.2 %), *Sorhoanus xanthoneurus* (7.6 %) and *Macustus grisescens* (5.2 %). The relative species abundance plot (Fig. 2) is not very steep; the six most abundant species represent only 50 % of the total individuals, and the 75 % mark is reached at species number 14.

Eleven species are peat bog specialists, i.e. tyrphobiontic or tyrphophilous, according to Nickel et al. (2002). Compared to other wetland areas in Central Europe (see

Table 3. Overview on Auchenorrhyncha collected in seven peat bogs in the Austrian part of the Bohemian Forest. Abbreviations: BA = Bayrische Au, ST = Stadlau, IG = Moor am Iglbach, DE = Deutsches Haidl.

	BA	ST-1	ST-2	ST-3	IG-1	IG-2	DE	Total
Total number of adult specimens	1389	735	667	1724	891	1446	613	7465
Total number of taxa	31	29	30	50	44	47	19	93
Number of tyrphobiontic and tyrphophilous individuals	50	80	155	26	154	290	580	1333
Number of tyrphobiontic and tyrphophilous species	5	5	4	5	7	5	3	11
Percentage of peat bog specialists (individuals)	3.6	10.8	23.2	1.5	17.2	20.0	94.6	17.9
Percentage of peat bog specialists (species)	16.1	17.2	13.3	10.0	15.9	10.6	15.8	11.8

Table 4. Auchenorrhyncha species of peat bogs in the Austrian part of the Bohemian Forest. The species are grouped into ecological types after Holzinger (2009), except for tyrphobiontic and tyrphophilous species identified after Nickel et al. (2002). Within one type, species are sorted in descending number. Abbreviations: BA = Bayrische Au, ST = Stadlau, IG = Moor am Iglbach, DE = Deutsches Haidl; ind. = individuals; rel. abd. = relative abundance; RL A = threat status according to the Austrian Red List (Holzinger 2009): LC = least concern, DD = data deficient, NT = near threatened, VU = vulnerable, EN = endangered, CR = critically endangered.

No.	Species	Total number of specimens/percentage of total abundance of sampling site							Total ind.	rel. abd. (%)	RL A
		BA	ST-1	ST-2	ST-3	IG-1	IG-2	DE			
Tyrphobiontic species											
1	*Sorhoanus xanthoneurus* (Fieber, 1869)					1 0,1		567 92,5	568	7.6	CR
2	*Kelisia vittipennis* (J. Sahlberg, 1868)	1 0,1	18 2,4	87 13		24 2,7	150 10,4		280	3.8	VU
3	*Stroggylocephalus livens* (Zetterstedt, 1840)	6 0,4							6	0.1	CR
4	*Cixius similis* Kirschbaum, 1868							1 0,2	1	<0.1	VU
Tyrphophilous species											
5	*Sorhoanus assimilis* (Fallén, 1806)	16 1,2	48 6,5	55 8,2	1 0,1	33 3,7	25 1,7	12 2	190	2.5	VU
6	*Paradelphacodes paludosa* (Flor, 1861)	15 1,1	1 0,1	6 0,9	2 0,1	61 6,8	74 5,1		159	2.1	EN
7	*Oncodelphax pullula* (Boheman, 1852)	12 0,9	9 1,2	7 1		17 1,9	15 1		60	0.8	EN
8	*Cicadula saturata* (Edwards, 1915)		4 0,5			11 1,2	26 1,8		40	0.5	
9	*Macrosteles ossiannilssoni* Lindberg, 1954				15 0,9				15	0.2	NT
10	*Kelisia ribauti* Wagner, 1938 „boreomontan"				1 0,1	7 0,8			8	0.1	EN
11	*Kelisia ribauti* Wagner, 1938 „mediterran"				7 0,4				7	0.1	EN
Hygrophilous grassland species											
12	*Conomelus anceps* (Germar, 1821)	847 61	16 2,2	177 26,5	22 1,3	17 1,9	156 10,8	2 0,3	1237	16.6	LC
13	*Muellerianella extrusa* (Scott, 1871)	115 8,3	193 26,3	71 10,6	40 2,3	35 3,9	233 16,1	1 0,2	688	9.2	DD
14	*Macustus grisescens* (Zetterstedt, 1828)	62 4,5	113 15,4	27 4	1 0,1	89 10	88 6,1	8 1,3	388	5.2	LC
15	*Forcipata citrinella* (Zetterstedt, 1828)				206 11,9				206	2.8	NT
16	*Megamelus notula* (Germar, 1830)	15 1,1	12 1,6	1 0,1	33 1,9	31 3,5	98 6,8		190	2.5	NT
17	*Kelisia praecox* Haupt, 1935		7 1	8 1,2		134 15	4 0,3		153	2	VU

No.	Species	Total number of specimens/percentage of total abundance of sampling site							Total ind.	rel. abd. (%)	RL A
		BA	ST-1	ST-2	ST-3	IG-1	IG-2	DE			
18	*Cicadula quadrinotata* (Fabricius, 1794)	7 0,5		4 0,6	48 2,8	19 2,1	22 1,5		101	1.3	LC
19	*Kelisia pallidula* (Boheman, 1847)			24 3,6			58 4		82	1.1	EN
20	*Jassargus sursumflexus* (Then, 1902)	26 1,9	33 4,5	1 0,1	2 0,1		1 0,1		63	0.8	LC
21	*Muellerianella brevipennis* (Boheman, 1847)	5 0,4	2 0,3	2 0,3	15 0,9	12 1,3	21 1,5	1 0,2	58	0.8	LC
22	*Xanthodelphax straminea* (Stål, 1858)	6 0,4		1 0,1		11 1,2	12 0,8		30	0.4	VU
23	*Macrosteles viridigriseus* (Edwards, 1922)				15 0,9				15	0.2	LC
24	*Stenocranus major* (Kirschbaum, 1868)	9 0,6							9	0.1	LC
25	*Cicadula albingensis* Wagner, 1940		7 1						7	0.1	LC
26	*Erzaleus metrius* (Flor, 1861)	5 0,4							5	0.1	LC
27	*Athysanus quadrum* Boheman, 1845						2 0,1		2	<0.1	EN
28	*Streptanus sordidus* (Zetterstedt, 1828)					2 0,2			2	<0.1	LC
29	*Struebingianella lugubrina* (Boheman, 1847)	1 0,1							1	<0.1	VU
Mesophilic grassland species											
30	*Jassargus pseudocellaris* (Flor, 1861)				410 23,8	1 0,1			411	5.5	LC
31	*Cicadella viridis* (Linnaeus, 1758)	44 3,2	65 8,8	37 5,5	3 0,2	93 10,4	155 10,7	1 0,2	398	5.3	LC
32	*Neophilaenus lineatus* (Linnaeus, 1758)	45 3,2	70 9,5	90 13,5		91 10,2	26 1,8		322	4.3	LC
33	*Delphacodes venosus* (Germar, 1830)	59 4,2	34 4,6	38 5,7	1 0,1	40 4,5	110 7,6	1 0,2	283	3.8	NT
34	*Arthaldeus pascuellus* (Fallén, 1826)	52 3,7			97 5,6	53 5,9	41 2,8		243	3.3	LC
35	*Dicranotropis divergens* Kirschbaum, 1868				110 6,4				110	1.5	LC
36	*Psammotettix confinis* (Dahlbom, 1850)				79 4,6	3 0,3	1 0,1	1 0,2	84	1.1	LC
37	*Acanthodelphax spinosa* (Fieber, 1866)		1 0,1	2 0,3	58 3,4	12 1,3	6 0,4	1 0,2	80	1.1	LC
38	*Anaceratagallia ribauti* (Ossiannilsson, 1938)				64 3,7				64	0.9	LC
39	*Anoscopus albifrons* (Linnaeus, 1758)		4 0,5		44 2,6	4 0,4	5 0,3		57	0.8	LC

No.	Species	Total number of specimens/percentage of total abundance of sampling site							Total ind.	rel. abd. (%)	RL A
		BA	ST-1	ST-2	ST-3	IG-1	IG-2	DE			
40	*Criomorphus albomarginatus* Curtis, 1833		12 1,6	3 0,4		18 2	11 0,8		44	0.6	LC
41	*Anoscopus flavostriatus* (Donovan, 1799)	2 0,1			9 0,5	13 1,5	15 1		39	0.5	LC
42	*Aphrodes diminuta* Ribaut, 1952		1 0,1	1 0,1	9 0,5	5 0,6	23 1,6		39	0.5	DD
43	*Psammotettix cephalotes* (Herrich-Schäffer, 1834)				27 1,6			1 0,2	28	0.4	NT
44	*Javesella forcipata* (Boheman, 1847)		27 3,7		1 0,1				28	0.4	LC
45	*Javesella dubia* (Kirschbaum, 1868)				26 1,5				26	0.4	LC
46	*Errastunus ocellaris* (Fallén, 1806)	19 1,4			5 0,3				24	0.3	LC
47	*Agallia brachyptera* (Boheman, 1847)		3 0,4	6 0,9	12 0,7				21	0.3	LC
48	*Eupteryx notata* Curtis, 1937				18 1				18	0.2	LC
49	*Athysanus argentarius* Metcalf, 1955	5 0,4	3 0,4	3 0,4		1 0,1	1 0,1		13	0.2	LC
50	*Graphocraerus ventralis* (Fallén, 1806)				13 0,8				13	0.2	LC
51	*Rhopalopyx adumbrata* (C. Sahlberg, 1842)			2 0,3		10 1,1	1 0,1		13	0.2	LC
52	*Anoscopus serratulae* (Fabricius, 1775)				7 0,4				7	0.1	LC
53	*Elymana sulphurella* (Zetterstedt, 1828)				4 0,2				4	0.1	LC
54	*Euscelis incisus* (Kirschbaum, 1858)				4 0,2				4	0.1	LC
55	*Xanthodelphax flaveola* (Flor, 1861)					4 0,4			4	<0.1	EN
56	*Cicadula persimilis* (Edwards, 1920)						3 0,2		3	<0.1	LC
57	*Megophthalmus scanicus* (Fallén, 1806)					3 0,3			3	<0.1	LC
58	*Cercopis vulnerata* Rossi, 1807	1 0,1				1 0,1			2	<0.1	LC
59	*Dicranotropis hamata* (Boheman, 1847)				1 0,1		1 0,1		2	<0.1	LC
60	*Diplocolenus bohemani* (Zetterstedt, 1840)						2 0,1		2	<0.1	LC
61	*Philaenus spumarius* (Linnaeus, 1758)				1 0,1		1 0,1		2	<0.1	LC

No.	**Species**	**Total number of specimens/percentage of total abundance of sampling site**							**Total ind.**	**rel. abd. (%)**	**RL A**
		BA	**ST-1**	**ST-2**	**ST-3**	**IG-1**	**IG-2**	**DE**			
Eurytopic species											
62	*Deltocephalus pulicaris* (Fallén, 1806)	1 0,1	1 0,1		194 11,3	4 0,4	5 0,3		205	2.7	LC
63	*Macrosteles laevis* (Ribaut, 1927)				39 2,3				39	0.5	LC
64	*Javesella pellucida* (Fabricius, 1794)	1 0,1			23 1,3	1 0,1	2 0,1		27	0.4	LC
65	*Laodelphax striatella* (Fallén, 1826)				3 0,2		1 0,1	1 0,2	5	0.1	LC
Mesophilic boundary species											
66	*Macrosteles septemnotatus* (Fallén, 1806)		37 5	4 0,6					41	0.5	LC
67	*Stiroma bicarinata* (Herrich-Schäffer, 1835)				2 0,1	1 0,1	19 1,3		22	0.3	LC
68	*Endria nebulosa* (Ball, 1900)					3 0,3	5 0,3		8	0.1	
69	*Hardya tenuis* (Germar, 1821)	1 0,1				4 0,4	1 0,1		6	0.1	LC
70	*Balclutha calamagrostis* Ossiannilsson, 1961	1 0,1		1 0,1					2	<0.1	LC
71	*Aphrophora alni* (Fallén, 1805)			1 0,1					1	<0.1	LC
72	*Evacanthus interruptus* (Linnaeus, 1758)						1 0,1		1	<0.1	LC
73	*Hyledelphax elegantula* (Boheman, 1847)						1 0,1		1	<0.1	LC
74	*Javesella discolor* (Boheman, 1847)						1 0,1		1	<0.1	LC
Montane grassland species											
75	*Verdanus abdominalis* (Fabricius, 1803)				27 1,6	2 0,2	6 0,4		35	0.5	LC
76	*Planaphrodes bifasciata* (Linnaeus, 1758)				12 0,7				12	0.2	LC
77	*Jassargus alpinus* (Then, 1896)							4 0,7	4	0.1	LC
78	*Erythria manderstjernii* (Kirschbaum, 1868)							3 0,5	3	<0.1	LC
79	*Neophilaenus exclamationis* (Thunberg, 1784)						1 0,1		1	<0.1	LC
Silting zone species											
80	*Stroggylocephalus agrestis* (Fallén, 1806)			3 0,4		6 0,7	12 0,8		21	0.3	EN
81	*Cosmotettix costalis* (Fallén, 1826)		3 0,4	3 0,4					6	0.1	EN

No.	Species	Total number of specimens/percentage of total abundance of sampling site							Total ind.	rel. abd. (%)	RL A
		BA	**ST-1**	**ST-2**	**ST-3**	**IG-1**	**IG-2**	**DE**			
82	*Limotettix striola* (Fallén, 1806)	1 0,1							1	<0.1	VU
Xerothermophilic grassland species											
83	*Eupelix cuspidata* (Fabricius, 1775)		1 0,1	1 0,1		4 0,4			6	0.1	NT
84	*Doratura stylata* (Boheman, 1847)				2 0,1				2	<0.1	LC
85	*Delphacinus mesomelas* (Boheman, 1850)				1 0,1				1	<0.1	VU
86	*Streptanus marginatus* (Kirschbaum, 1858)						1 0,1		1	<0.1	DD
Hygrophilous forest species											
87	*Planaphrodes nigrita* (Kirschbaum, 1868)					5 0,6			5	0.1	LC
88	*Macropsis cerea* (Germar, 1837)						2 0,1		2	<0.1	LC
89	*Doliotettix lunulatus* (Zetterstedt, 1840)					1 0,1			1	<0.1	
Mesophilic forest species											
90	*Fagocyba cruenta* (Herrich-Schäffer, 1838)							4 0,7	4	0.1	LC
91	*Hesium domino* (Reuter, 1880)				3 0,2				3	<0.1	LC
92	*Ulopa carneae* Wagner, 1955							1 0,2	1	<0.1	EN
Riparian species											
93	*Paraliburnia adela* (Flor, 1861)	8 0,6							8	0.1	EN

e.g. Schiemenz 1971, 1975, 1976, 1977, Remane and Reimer 1989, Andrew and Rushton 1993, Holzinger and Novotny 1998, Szwedo et al. 1998, Nickel 2002, Nickel and Gärtner 2009, Walter and Nickel 2009, Swierczewski and Blaszczyk 2011), this is a very average number. Peat bog specialists represent 18 % of the total number of individuals collected. The majority of the individuals are hygrophilous and mesophilic grassland species (Figs 3, 5).

Seven species could be found on all sites, among them one peat bog specialist (*Sorhoanus assimilis*). 18 species occur in at least five of the seven sites, among them three more peat bog specialists (*Kelisia vittipennis, Paradelphacodes paludosa, Oncodelphax pullula*). Almost half of the species (44) were recorded only on one site (among them four peat bog specialists).

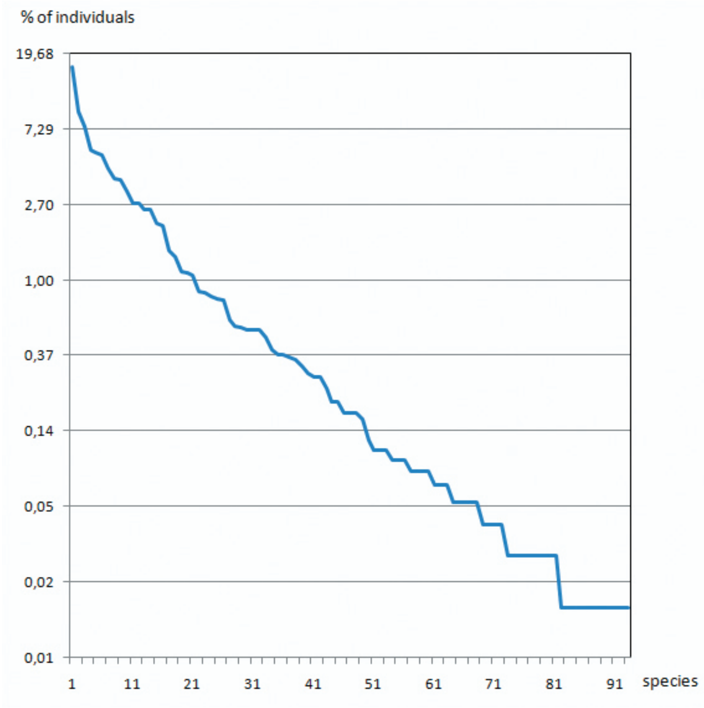

Figure 2. Species abundance ranking. The species are ordered by their relative abundance (descending).

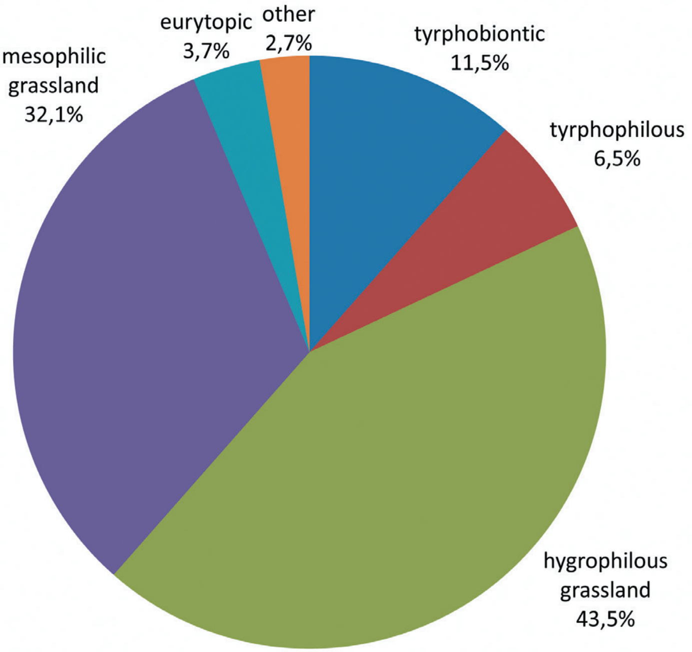

Figure 3. Auchenorrhyncha communities of the Austrian Bohemian Forest peat bogs: Presence of the ecological types (after Holzinger 2009) [percentage of total specimens].

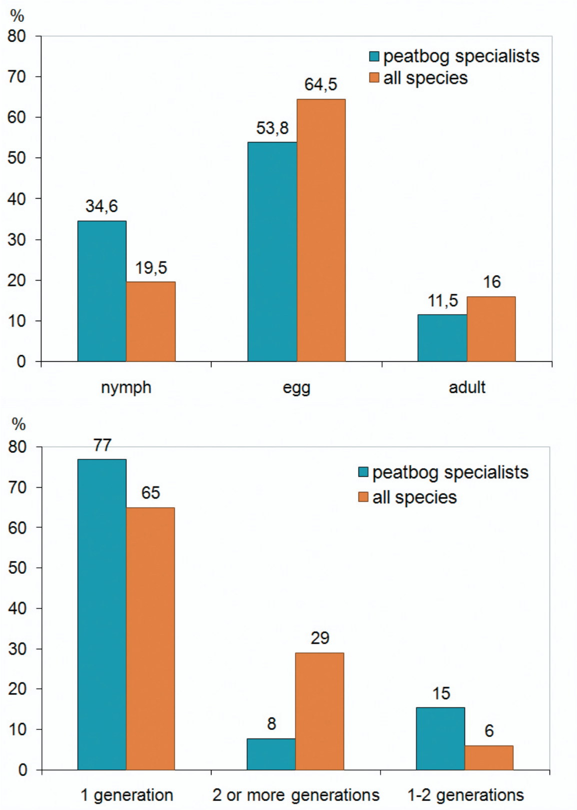

Figure 4. Percentage of the hibernation stages (left) and of generation numbers (right) of Auchenorrhyncha species recorded in Bohemian Forest peat bogs compared to those of the whole Austrian Auchenorrhyncha fauna (data from Holzinger 2009).

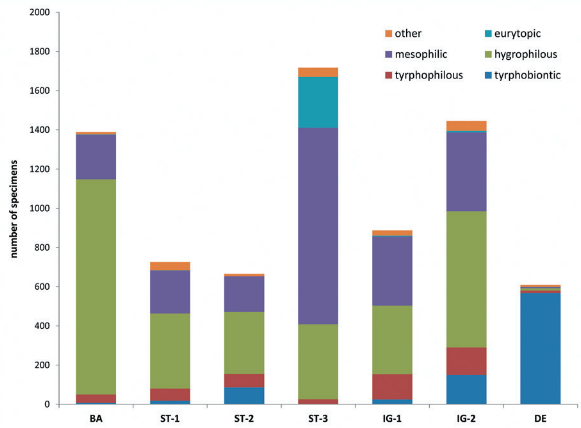

Figure 5. Total number of Auchenorrhyncha collected at the seven peat bog sites. Colours = ecological types (after Holzinger 2009). Abbreviations: BA = Bayrische Au, ST = Stadlau, IG = Moor am Iglbach, DE = Deutsches Haidl. ST-3 is the site with highest human impact (grazing, mowing, dehydratation); DE is a peat bog in much higher elevation than all other sites.

Species composition

The Auchenorrhyncha communities of the peat bogs show higher proportions of univoltine species than the total fauna of Austria. The number of species hibernating in nymphal stages is also higher in peat bogs than in the total fauna of Austria (Fig. 4). This might be caused by comparatively unsuitable conditions (low temperature, high humidity) for Auchenorrhyncha development in these habitats.

The vast majority of the Central European Auchenorrhyncha species is mono- or oligophagous, specialised on one or few host plant species or genera (see Holzinger 2009 for the fauna of Austria). Interestingly, the tyrphophilous and tyrphobiontic Auchenorrhyncha species feeding on *Calamagrostis canescens* and *Molinia caerulea* in Germany (see Nickel 2003) could not be found within this study (whereas the non-tyrphophilous monophagous species are present). These species are missing or very rare in the southern parts of Central Europe and might not (or no longer?) exist in the peat bogs of the Austrian part of the Bohemian Forest (Fig. 6).

Saisonality and densities

The densities of adult Auchenorrhyncha in peat bogs are low in spring (about 10–60 individuals per m²), increase towards July up to 180 (±50) individuals per m² and

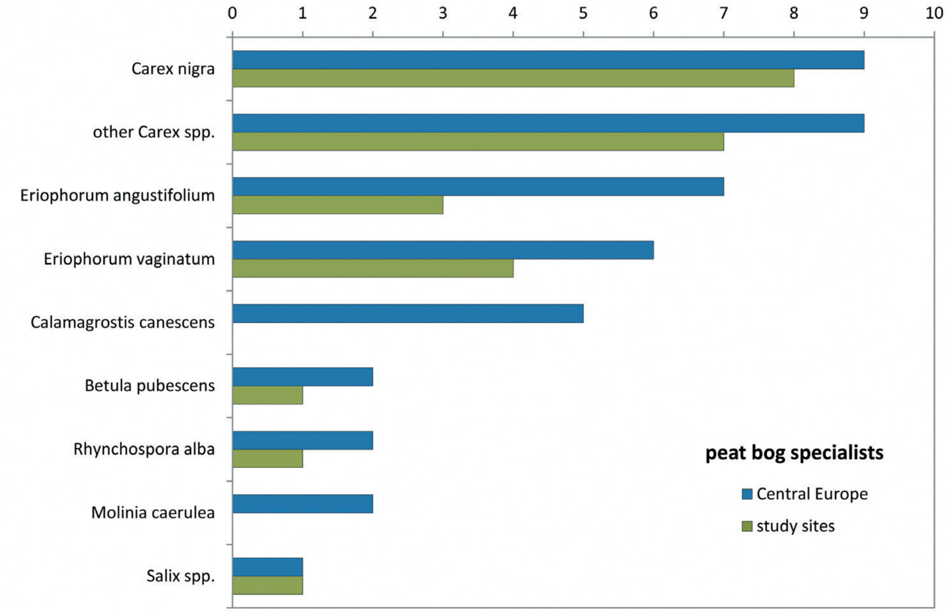

Figure 6. Number of tyrphobiontic and tyrphophilous species specialised on wetland plant species (data from Nickel 2003). Most plant species are utilised by their Auchenorrhyncha hosts also in the study sites, only *Calamagrostis canescens* and *Molinia caerulea* lack their mono-/oligophagous tyrphophilous “species set”.

slowly decreases afterwards (Fig. 7). Disturbed sites have higher species numbers and higher Auchenorrhyncha densities in total but lower numbers and densities in peat bog specialists. The highest proportion of peat bog specialists (almost 95 %) was found in the undisturbed site „Deutsches Haidl" (Fig. 5).

These Auchenorrhyncha densities of peat bogs are similar to those of other Central European grassland habitats (pastures and meadows: about 50–200 adult specimens/m^2; alpine meadows: about 50–100 specimens/m^2; ÖKOTEAM unpublished data).[1]

Figure 7. Seasonal mean numbers of Auchenorrhyncha species (left) and adult hopper specimens (=individuals/m^2; right) in the peat bogs of the Austrian part of the Bohemian Forest.

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[1] Other studies with much higher numbers usually include nymphal stages (e.g. Nickel and Hildebrandt 2003, Morris et al. 2005).

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RESEARCH ARTICLE

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True bugs (Hemiptera, Heteroptera) as psyllid predators (Hemiptera, Psylloidea)

Dušanka Jerinić-Prodanović[1], Ljiljana Protić[2]

1 *University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Zemun, Serbia* **2** *Natural History Museum, Njegoševa 51, 11000 Belgrade, Serbia*

Corresponding author: *Dušanka Jerinić-Prodanović* (dusanka@agrif.bg.ac.rs)

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Abstract

Data on natural enemies of psyllids are rare and can usually be found in papers about economically significant species. During an investigation of psyllid fauna in Serbia, natural enemies were investigated, too. True bugs were the most numerous among them. From 28 psyllid species, 21 species of true bugs from families Anthocoridae and Miridae were reared. Seven species of Anthocoridae were identified: *Anthocoris amplicollis* (Horváth, 1839), *A. confusus* Reuter, 1884, *A. nemoralis* (Fabricius, 1794), *A. nemorum* (Linnaeus, 1761), *Orius majusculus* Reuter, 1884, *O. minutus* (Linnaeus, 1758) and *O. niger* Wolff, 1811. The following 14 species of Miridae were identified: *Atractotomus mali* Meyer-Dür, 1843, *Campylomma verbasci* (Meyer-Dür, 1843), *Deraeocoris flavilinea* (A. Costa, 1862), *D. ruber* (Linnaeus, 1758), *D. lutescens* (Schilling, 1836), *Heterocordylus genistae* (Scopoli, 1763), *Hypseloecus visci* (Puton, 1888), *Malacocoris chlorizans* Panzer, 1794, *Miris striatus* (Linnaeus, 1758), *Orthotylus marginalis* Reuter, 1884, *Psallus assimilis* Stichel, 1956, *Ps. quercus* Kirschbaum, 1856, *Ps. flavellus* Stichel, 1933 and *Pseudoloxops coccinea* (Meyer-Dür, 1843). The aim of the research was to provide list of true bugs recorded as predators of psyllids in order to preserve their diversity and significance, especially on cultivated plants.

Keywords

Psylloidea, Heteroptera, predators, natural enemies, Serbia

Introduction

Predators of psyllids (Psylloidea) have been poorly known. So far, detailed researches were carried out only on the predators of economically significant species, such as pear psyllids *Cacopsylla pyri* (Linnaeus, 1758), *C. pyricola* (Foerster, 1848) and *C. pyrisuga* (Foerster, 1848); apple psyllid *C. mali* (Schmidberger, 1836) and eucalyptus psyllids from the subfamily Spondyliaspidinae (Jonsson 1983, Herard 1985, 1986, Santas 1987, Erler 2004, Horton et al. 2004, Sigsgaard et al. 2006, Jauset et al. 2006, Luiz de Queiroz et al. 2012). There are too few data on predators of other psyllid species. Hodkinson and Flint (1971) investigated predators of ash psyllid, *Psyllopsis fraxini* (Linnaeus, 1758), in England, and Harizanova et al. (2012), predatory complex of *Acizzia jamatonica* (Kuwayama, 1908) in Bulgaria. In these papers, the most represented are psyllid predators from the order Hemiptera (suborder Heteroptera) followed by Coleoptera, Neuroptera, Diptera, Dermaptera and Acari. Within the Heteroptera, the most numerous in species families are Anthocoridae, Miridae and Nabidae. A polyphagous species, *Anthocoris nemoralis* (Fabricius, 1794), was most frequently found, with a preference for the species from superfamily Psylloidea (Jonsson 1983, Herard 1986). *Anthocoris nemoralis* (Anthocoridae) was introduced from Europe to North America (British Columbia) in 1963 in order to control *C. pyricola*, where its establishment was successful. Besides giving satisfactory effects, this species also spread in the new environment suppressing autochthonous species *Anthocoris antevolens* White, 1879 and *A. melanocerus* Reuter, 1884, which are most common anthocorid predators in orchards (Herard 1986, Horton et al. 2004).

Data on psyllid predators in Serbia relate only to the predators of pear psyllids (Pavićević 1977, Grbić et al. 1989, Jerinić-Prodanović et al. 2010).

Pavićević (1977) found a large number of predatory species, among which two were from family Anthocoridae. Grbić et al. (1989) recorded four species of Heteroptera: *Anthocoris nemoralis* and *Orius* sp. (both Anthocoridae), *Pilophorus clavatus* (Linnaeus, 1767) (Miridae) and *Nabis pseudoferus* Remane, 1949 (Nabidae), while Jerinić-Prodanović et al. (2010) reported seven species: *Anthocoris nemoralis* (Fabricius, 1794), *A. nemorum* (Linnaeus, 1761), *Orius* (*Heterorius*) *minutus* (Linnaeus, 1758) and *Orius* (*Orius*) *niger* Wolff, 1811 from the family Anthocoridae and *Campylomma verbasci* (Meyer-Dür, 1843), *Deraeocoris* (*Deraeocoris*) *ruber* (Linnaeus, 1758) and *Deraeocoris* (*Knightocapsus*) *lutescens* (Schilling, 1836) from the family Miridae.

There is no data on other predatory psyllid species in Serbia.

Methods

Insect material was collected from 419 localities within the whole territory of the Republic of Serbia. Investigations were carried out in the period from 2005 to 2010, in field conditions and in the laboratory of the Faculty of Agriculture in Zemun, University of Belgrade. Locality mapping was carried out in World UTM (Universal Transverse Mercator) cartographic projection. Determination of coordinates of investigated localities in the field was carried out using GPS devices Geoexplorer 3 (Trimble) and E-trex Vista Hcx (Garmin), with an accuracy of 3 to 5 meters.

Adults of predatory true bugs were collected from psyllid colonies by an aspirator and their larvae were collected together with plant material and psyllids and further reared to adults in laboratory conditions in Petri dishes.

The species identification of Heteroptera was based on Wagner (1970–1971, 1975), Péricart (1972) and Kerzhner and Josifov (1999).

A part of the material is deposited in the first author's collection in the Faculty of Agriculture, University of Belgrade, and another part, in the second author's collection in Natural History Museum, Belgrade.

Results and discussion

We collected and reared 21 true bug species predating on 28 psyllid species (Table 1) from 44 localities (Fig. 1 and Table 2). The identified true bugs belong to families Anthocoridae and Miridae.

Anthocoridae

1) *Anthocoris amplicollis* (Horváth, 1839)

Trophic status. Zoophagous.

Distribution. Europe.

Prey. ***Psylla buxi*** **(Linnaeus, 1758)**, from *Buxus sempervirens*, Nova Galenika, 13.VI.2009, reared 3♂♂, 2♀♀.

A. amplicollis was already reported in Serbia (Protić and Stojanović 2003) but the above mentioned record is the first one in Serbia as a psyllid predator. In Switzerland, it was registered by Wyniger and Burckhardt (2003) in galls of *Psyllopsis fraxini.* According to available literature data, *A. amplicollis* has not been published as a predator of *P. buxi*.

2) *Anthocoris confusus* Reuter, 1884

Trophic status. Zoophagous.

Distribution. Palaearctic.

Prey. ***Psylla buxi***, from *Buxus semprevirens*, Sokobanja, 25.IX.2009, reared 1♀.

Registered as a psyllid predator on conifers (Wyniger and Burckhardt 2003) and aphids (Herard 1986). In the present paper, reported for the first time as a psyllid predator in Serbia.

Table 1. List of preys (Psylloidea) and their predators (Heteroptera) and host plants in Serbia.

Preys (Psylloidea)	Predators (Heteroptera)																				
	Anthocoridae							Miridae													
	Ant amp	Ant con	Ant nea	Ant neu	Ori maj	Ori min	Ori nig	Atr mal	Cam ver	Der fla	Der lut	Der rub	Het gen	Hyp vis	Mal chl	Mir str	Ort mar	Psa ass	Psa fla	Psa que	Pse coc
Baeopelma foersteri						Aln glu															
Cacopsylla affinis				Cra mon				Cra mon													
Cacopsylla bidens			Pyr com	Pyr com			Pyr com		Pyr com	Pyr com											
Cacopsylla melanoneura				Cra mon		Mal dom	Mal dom	Mal dom, Cra mon	Mal dom				Mal dom, Cra mon			Cra mon					
Cacopsylla peregrina				Cra mon				Cra mon								Cra mon					
Cacopsylla picta						Mal dom		Mal dom													
Cacopsylla pulchra				Sal pur																	
Cacopsylla pyri			Pyr com	Pyr com		Pyr com	Pyr com		Pyr com		Pyr com	Pyr com									
Cacopsylla pyricola									Pyr com												
Cacopsylla pyrisuga			Pyr com	Pyr com					Pyr com												
Cacopsylla rhamnicola						Rha cat					Rha cat						Rha cat				
Cacopsylla visci			Vis alb	Vis alb										Vis alb							

Preys (Psylloidea)	**Predators (Heteroptera)**																				
	Anthocoridae							**Miridae**												
	Ant amp	**Ant con**	**Ant nea**	**Ant neu**	**Ori maj**	**Ori min**	**Ori nig**	**Atr mal**	**Cam ver**	**Der fla**	**Der lut**	**Der rub**	**Het gen**	**Hyp vis**	**Mal chl**	**Mir str**	**Ort mar**	**Psa ass**	**Psa fla**	**Psa que**	**Pse coc**
Camarotoscena speciosa			Pop nig			Pop nig					Pop nig										
Craspedolepta sp.							Art vul														
Homotoma ficus						Fic car				Fic car					Fic car						
Livia junci							Jun bul														
Psylla buxi	Bux sem	Bux sem		Bux sem																	
Psyllopsis discrepans			Fra spp		Fra spp	Fra orn				Fra ang								Fra spp	Fra spp	Fra orn, Fra spp	
Psyllopsis fraxini			Fra spp																		
Psyllopsis fraxinicola			Fra spp	Fra ang		Fra spp	Fra orn				Fra ang							Fra spp			Fra spp
Psyllopsis machinosa			Fra spp		Fra spp	Fra orn				Fra ang										Fra spp	
Psyllopsis meliphila			Fra spp																		
Psyllopsis repens			Fra spp			Fra orn															
Trichochermes walkeri							Rha cat														
Trioza chenopodii							Atr tat				Atr obl										

Preys (Psylloidea)	Predators (Heteroptera)																			
	Anthocoridae							Miridae												
	Ant amp	Ant con	Ant nea	Ant neu	Ori maj	Ori min	Ori nig	Atr mal	Cam ver	Der fla	Der lut	Der rub	Het gen	Hyp vis	Mal chl	Mir str	Ort mar	Psa ass	Psa fla	Psa que	Pse coc
Trioza mesembrina						Cha hir															
Trioza rhamni						Rha cat				Rha cat											
Trioza urticae			Urt dio				Urt dio														

Abbreviations

Predators. **Anthocoridae**: Ant amp, *Anthocoris amplicollis*; Ant con, *Anthocoris confusus*; Ant nea, *Anthocoris nemoralis*; Ant neu, *Anthocoris nemorum*; Ori maj, *Orius majusculus*; Ori min, *Orius minutus*; Ori nig, *Orius niger*; **Miridae**: Atr mal, *Atractotomus mali*; Cam ver, *Campylomma verbasci*; Der fla, *Deraeocoris flavilinea*; Der lut, *Deraeocoris lutescens*; Der rub, *Deraeocoris ruber*; Het gen, *Heterocordylus genistae*; Hyp vis, *Hypseloecus visci*; Mal chl, *Malacocoris chlorizans*; Mir str, *Miris striatus*; Ort mar, *Orthotylus marginalis*; Psa ass, *Psallus assimilis*; Psa fla, *Psallus flavellus*; Psa que, *Psallus quercus*; Pse coc, *Pseudoloxops coccinea*.

Host plants: Aln glu, *Alnus glutinosa*; Art vul, *Artemisia vulgaris*; Atr obl, *Atriplex oblongifolia*; Atr tat, *Atriplex tatarica*; Bux sem, *Buxus sempervirens*; Cha hir, *Chaerophyllum hirsutum*; Cra mon, *Crataegus monogyna*; Fic car, *Ficus carica*; Fra ang, *Fraxinus angustifolia*; Fra orn, *Fraxinus ornus*; Fra spp, *Fraxinus* spp.; Jun bul, *Juncus bulbosus*; Mal dom, *Malus domestica*; Pop nig, *Populus nigra*; Pyr com, *Pyrus communis*; Rha cat, *Rhamnus cathartica*; Sal pur, *Salix purpurea*; Vis alb, *Viscum album*; Urt dio, *Urtica dioica*.

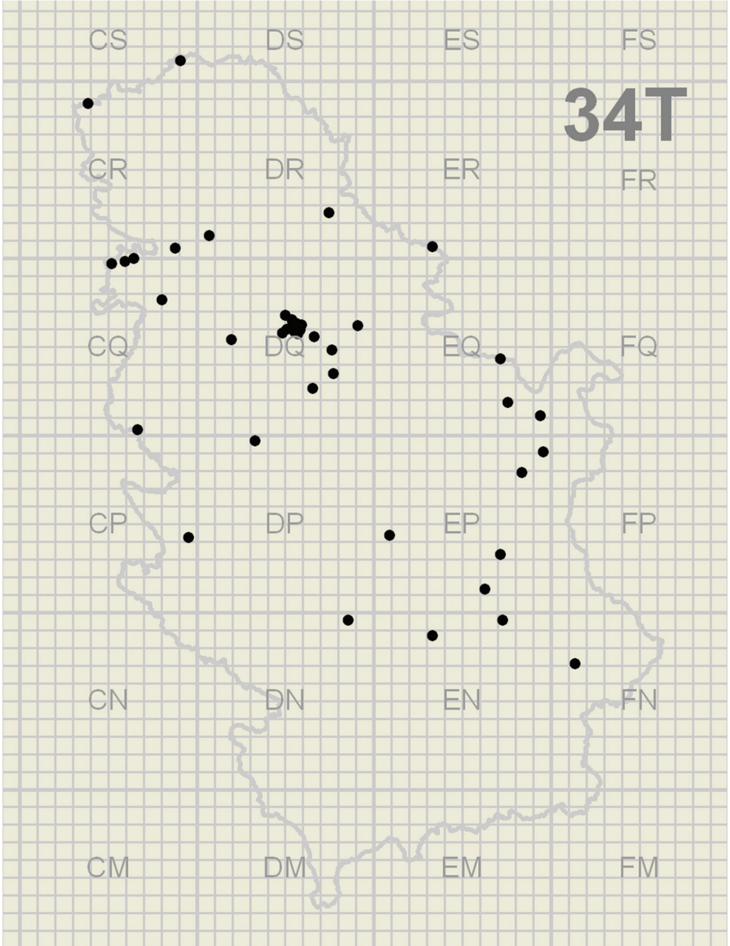

Figure 1. Localities in Serbia where true bug predators of psyllids were collected.

3) *Anthocoris nemoralis* (Fabricius, 1794)

Trophic status. Zoophagous.

Distribution. Euro-Mediterranean.

Preys. ***Cacopsylla bidens* (Šulc, 1907)**, from *Pyrus communis*, Beograd–Karaburma, 19.V.2006, reared 2♀♀ 'ex larva'25.V.2006. ***Cacopsylla pyri***, from *Pyrus communis*, Nemenikuće, 15.VI.2006, reared 1♂ 'ex larva'22.VI.2006; Radmilovac, 2.IX.2005, reared 1♂; 12.VI.2006, reared 1♂ 'ex larva'25.VI.2006; 26.X.2006, collected 1♂; 7.VI.2007, reared 1♂, 1♀ 'ex larva'11.VI.2007, 20.VI.2007, collected 1 larva and 1♂; 26.X.2008, reared 1♂ 'ex larva'3.XI.2008. ***Cacopsylla pyrisuga***, from *Pyrus communis*, Zemunski kej, 28.V.2007, collected 1♀. ***Cacopsylla visci* (Curtis, 1835)**, from *Viscum album*, Beograd–Bulevar Aleksandra Karađorđevića, 25.III.2007, reared 2♂♂, 1♀ 'ex larva'12.IV.2007; 23.IV.2007, reared 2♂♂, 5♀♀

'ex larva'3.V.2007. ***Camarotoscena speciosa* (Flor, 1861)**, from *Populus nigra*, Radmilovac, 22.V.2000, reared 1♂ 'ex larva'25.V.2000; Zemun–Nova Galenika, 25.VIII.2008, collected 1♀; 1.IX.2008, reared 3♀♀ 'ex larva'9.IX.2008; 10.IX.2008, collected 1♀, 1♂; 17.IX.2008, collected 1♀, 1♂; 24.IX.2008, reared 2♂♂, 2♀♀ 'ex larva'1.X.2008; 27.VII.2010, collected 1♂, 1♀, 18.X.2010, collected 1♂, 1♀. ***Psyllopsis discrepans* (Flor, 1861)**, from *Fraxinus* sp., Beograd–Autokomanda, 10.V.2007, reared 1♀; Brestovačka Banja, 25.V.2007, reared 5♂♂, 4♀♀ 'ex larva'8.VI.2007; Ilinci, 24.V.2008, collected 1♂; Majdanpek, 25.V.2007, reared 1♂, 1♀ 'ex larva'3.VI.2007, Milošev konak, 21.VI.2007, 1♂. ***Psyllopsis fraxini***, from *Fraxinus* sp., Veliko Središte, 30.V.2006, reared 2♀♀. ***Psyllopsis fraxinicola* (Foerster, 1848)**, from *Fraxinus* sp., Beograd–Autokomanda, 10.V.2007, reared 1♀; Beograd–Kalemegdan, 24.V.2007, collected 1♂; Brestovačka Banja, 25.V.2007, reared 5♂♂, 4♀♀ 'ex larva'8.VI.2007; Majdanpek, 25.V.2007, reared 1♂, 1♀ 'ex larva'3.VI.2007; Veliko Središte, 4.VI.2006, reared 2♀♀ 'ex larva'19.VI.2006. ***Psyllopsis machinosa* Loginova, 1963**, from *Fraxinus* sp., Beograd–Autokomanda, 10.V. 2007, reared 1♀. ***Psyllopsis meliphila* Löw, 1881**, from *Fraxinus* sp., Nemenikuće, 15.VI.2006, collected 1♂. ***Psyllopsis repens* Loginova, 1963**, from *Fraxinus* sp., Beograd–Autokomanda, 14.X.2008, reared 1♀. ***Trioza urticae* (Linnaeus, 1758)**, from *Urtica dioica*, Ilinci, 24.VI.2007, collected 2♀♀ .

A. nemoralis is an important component of the natural enemy community in pear and apple orchards where it provides biological control against arthropod pests, particularly psyllids (Horton et al. 2004). Investigating the predator–prey complex of *C. pyri* in a pear orchard in France, Herard (1986) found that *A. nemoralis* was the most efficient enemy against this pest. *A. nemoralis* is mentioned in many papers as a permanent member of biocomplexes of pear psyllids in Europe (Wheeler 2000b, Erler 2004, Sigsgaard et al. 2006). In Turkey, *A. nemoralis* was an equally present and efficient predator of pear psyllid *C. pyri*, both in treated and untreated orchards, but still insufficient for its full control (Erler 2004). In Spain, Jauset et al. (2006) determined *A. nemoralis* as a very efficient predator of *C. pyri*, both in treated and untreated pear orchards. Now, there is a mass production of *A. nemoralis* in companies specialized for biological control of harmful insects (Sigsgaard et al. 2006). The same authors reported that *A. nemoralis* mostly prefers *C. pyri* to aphids, and that it prefers laying eggs on pear to apple. *A. nemoralis* is a polyphagous predatory species having psyllids as a usual prey.

It is distributed in Europe and the Mediterranean. From Europe it was introduced into North America in 1963 in order to control pear psyllid *C. pyricola*, giving satisfactory results (Horton et al. 2004). This species has adapted to this region so well that it has suppressed autochthonous predatory species *A. antevolens* and *A. melanocerus* (Herard 1986, Horton et al. 2004). In Serbia, in a pear orchard, Pavićević (1977), Grbić et al. (1989) and Jerinić-Prodanović (2010) note a permanent presence of *A. nemoralis*, both during vegetation and winter period together with an overwintering adult of *C. pyri*. *A. nemoralis* was also reported as a predator of *Psyllopsis repens* in Serbia (Malenovský and Jerinić-Prodanović 2011).

Table 2. Geographical coordinates of inspected localities.

No	Locality	Latitude	Longitude	Altitude
1	Bački breg	45°55'21"N	18°55'24"E	90
2	Bavanište	44°48'42"N	20°53'10"E	80
3	Beloljin	43°14'03"N	21°24'26"E	290
4	Beograd–Autokomanda	44°47'20"N	20°28'20"E	100
5	Beograd–Banjica	44°45'18"N	20°28'58"E	190
6	Beograd–Block 45	44°47'36"N	20°22'47"E	75
7	Beograd–Bulevar Aleksandra Karadjordjevića	44°46'50"N	20°27'31"E	175
8	Beograd–Hotel Jugoslavija	44°49'36"N	20°25'22"E	75
9	Beograd–Hram Svetog Save	44°47'53"N	20°28'03"E	120
10	Beograd–Kalemegdan	44°49'19"N	20°26'52"E	110
11	Beograd–Karaburma	44°48'48"N	20°29'15"E	110
12	Beograd–Milošev konak	44°46'38"N	20°25'36"E	80
13	Beograd–Voždovac	44°47'17"N	20°28'28"E	85
14	Brestovačka Banja	44°03'36"N	22°02'36"E	360
15	Dobra	44°38'23"N	21°54'06"E	85
16	Draževac	43°28'08"N	21°46'37"E	205
17	Galovica	44°46'22"N	20°21'04"E	75
18	Grocka	44°41'21"N	20°42'02"E	125
19	Ilinci	45°06'41"N	19°07'16"E	80
20	Izvor	43°04'58"N	22°23'57"E	290
21	Kelebija	46°08'59"N	19°35'10"E	125
22	Kopaonik–Srebrenac	43°19'02"N	20°50'08"E	1740
23	Klokočevac	44°20'53"N	22°10'45"E	140
24	Koruška	45°11'46"N	19°34'23"E	110
25	Lipovača	45°08'24"N	19°16'53"E	165
26	Luka	44°09'46"N	22°11'56"E	340
27	Majdanpek	44°25'10"N	21°57'10"E	520
28	Nemenikuće	44°29'38"N	20°34'00"E	280
29	Niš	43°18'35"N	21°53'50"E	200
30	Novi Sad–Detelinara	45°15'50"N	19°48'56"E	80
31	Obedska bara	44°44'10"N	19°59'15"E	80
32	Oparić	43°44'40"N	21°06'38"E	310
33	Radenković	44°56'01"N	19°29'05"E	80
34	Radmilovac	44°45'15"N	20°34'39"E	160
35	Sokobanja	43°38'41"N	21°53'11"E	350
36	Sutjeska	45°23'02"N	20°41'53"E	75
37	Šid	45°07'31"N	19°12'58"E	105
38	Umčari	44°34'10"N	20°43'00"E	160
39	Uzovnica	44°16'12"N	19°19'47"E	170
40	Veliko Središte	45°12'54"N	21°25'30"E	120
41	Vrujci	44°13'26"N	20°09'53"E	170
42	Zemun–Nova Galenika	44°51'41"N	20°22'11"E	90
43	Zemunski kej	44°50'29"N	20°25'06"E	75
44	Zlatibor–Kraljevske Vode	43°43'39"N	19°42'06"E	950

4) ***Anthocoris nemorum* (Linnaeus, 1761)**

Trophic status. Zoophagous.

Distribution. Eurosiberian.

Preys. ***Cacopsylla affinis* (Löw, 1880)**, from *Crataegus monogyna*, Ilinci, 27.IV.2008, reared 1♂ ‘ex larva'14.V. 2008. ***Cacopsylla bidens***, from *Pyrus communis*, Nemenikuće, 15.VI.2006, reared 1♀. ***Cacopsylla melanoneura* (Foerster, 1848)**, from *Crataegus monogyna*, Ilinci, 27.IV.2008, reared 1♂ ‘ex larva'14.V.2008; Klokočevac, 10.V.2008, collected 1♀. ***Cacopsylla peregrina* (Foerster, 1848)**, from *Crataegus monogyna*, Ilinci, 27.IV.2008, reared 1♂ ‘ex larva'14.V.2008. ***Cacopsylla pulchra* (Zetterstedt, 1838)**, from *Salix purpurea*, Zlatibor–Kraljevske Vode, 30.IV.2007, collected 1♀ and 1 larva. ***Cacopsylla pyri***, from *Pyrus communis*, Novi Sad–Detelinara, 23.V.2008, reared 2♂♂, 3♀♀ ‘ex larva'4.VI.2008; 14.VI.2008, reared 3♂♂ ‘ex larva'17.VI.2008. ***Cacopsylla pyrisuga***, from *Pyrus communis*, Grocka, 10.V.2008, reared 1♀ ‘ex larva'23.V.2008. ***Cacopsylla visci***, from *Viscum album*, Beograd–Bulevar Aleksandra Karađorđevića, 23.IV.2007, reared 1♂ ‘ex larva'3.V.2007. ***Psylla buxi***, from *Buxus sempervirens*, Vrujci, 1.VI.2009, collected 2♂♂, 1♀; Šid, 3.V.2008, collected 2♀♀; Zemun–Nova Galenika, 4.V.2008, reared 2♂♂, 3♀♀ ‘ex larva'15.V.2008; 30.VII.2008, collected 1♀; 14.VI.2009, collected 2 specimens. ***Psyllopsis fraxinicola***, from *Fraxinus angustifolia*, Beograd–Hram Svetog Save, 14.IV.2008, reared 1♂ and 1 larva.

A. nemorum is noted as a predator of many insect species, in the first place Hemiptera, Diptera, eggs of Lepidoptera and mites (Herard 1986, Wheeler 2000b, Sigsgaard et al. 2006), already registered as a predator of both *C. pyri* and *Ps. fraxini* (Herard 1986). It is also largely reported as an efficient predator of apple psyllid *Cacopsylla mali* in Norway (Jonsson 1983). In England, Hodkinson and Flint (1971) determined *A. nemorum* as a predator of *Psyllopsis fraxini* collected from ash, while in Germany Novak and Achtziger (1995) registered it as a predator of hawthorn psyllids *Cacopsylla melanoneura* and *C. peregrina*. Sigsgaard et al. (2006) note *A. nemorum* as a more polyphagous species than *A. nemoralis*. They also determined in experimental conditions that *A. nemorum* prefers aphids to psyllids, and has a preference for laying eggs on apple rather than on pear.

A. nemorum is an Eurosiberian species, introduced to North America in order to control *C. pyricola* just like *A. nemoralis*, but without satisfactory results (Herard 1986).

A. nemorum is reported here for the first time as a predator of psyllids in Serbia.

5) ***Orius* (*Heterorius*) *majusculus* Reuter, 1884**

Trophic status. Zoophagous.

Distribution. Euro-Atlantic.

Preys. ***Psyllopsis discrepans*** and ***Psyllopsis machinosa***, from *Fraxinus* spp., Beograd–Autokomanda, 6.V.2009, collected 1♂.

O. majusculus was registered as a predator of psyllids (Herard 1986). It is noted as a predator of aphids, such as *Diuraphis noxia* and *Schizaphis graminum* in Russia, mites in France, whiteflies in greenhouses in Italy and pear psyllid *Cacopsylla pyri* in France (Péricart 1972, Herard 1986).

The present paper reports *O. majusculus* as a psyllid predator for the first time in Serbia and *Psyllopsis discrepans* and *Ps. machinosa* for the first time as a prey of *O. majusculus.*

6) *Orius* (*Heterorius*) *minutus* (Linnaeus, 1758)

Fig. 2

Trophic status. Zoophagous.

Distribution. Palaearctic.

Preys. ***Baeopelma foersteri*** **(Flor, 1861)**, from *Alnus glutinosa*, Radenković, 3.VI.2006, collected 1♀. ***Cacopsylla melanoneura***, from *Malus domestica*, Beograd–Hotel Jugoslavija, 26.V.2005, reared 1♂; Ilinci, 2.V.2010, reared 1♂, 2♀♀ ‘ex larva'10.V.2010. ***Cacopsylla picta*** **(Foerster, 1848)**, from *Malus domestica*, Beograd–Hotel Jugoslavija, 26.V.2005, reared 1♂. ***Cacopsylla pyri***, from *Pyrus communis*, Radmilovac, 10.VII.2006, reared 1♂, 2♀♀ ‘ex larva'20.VII.2006; 26.VII.2006, collected 1♂; 4.IX.2006, collected 1♂. ***Cacopsylla rhamnicola*** **(Scott, 1876)**, from *Rhamnus cathartica*, Kelebija, 25.V.2005, reared 1♀ ‘ex larva'6.VI.2005. ***Camarotoscena speciosa***, from *Populus nigra*, Zemun–Nova Galenika, 1.IX.2008, reared 1♂ ‘ex larva'9. IX.2008; 24.IX.2008, reared 1♂ ‘ex larva'1.X.2008. ***Homotoma ficus*** **(Linnaeus, 1758)**, from *Ficus carica*, Beograd–Banjica, 23.IX.2008, collected 2♂♂, 3♀♀, feeding on eggs. ***Psyllopsis discrepans***, from *Fraxinus ornus*, Ilinci, 21.V.2005, collected 1♂. ***Psyllopsis discrepans*** and ***Psyllopsis repens***, from *Fraxinus ornus*, Beograd–Autokomanda, 7.IX.2008, reared 5♂♂, 4♀♀ ‘ex larva'11.IX.2008; 21.IX.2008, collected 3♂♂; 23.IX.2008, collected 1♂; 7.X.2008, collected 1♂, 1♀; 14.X.2008, collected 1♀; 21.X.2008, collected 1♀. ***Psyllopsis fraxinicola***, from *Fraxinus* sp., Vrujci, 1.VII.2009, 1♀. ***Psyllopsis machinosa***, from *Fraxinus ornus*, Beograd–Autokomanda, 6.V.2009, reared 1♀ ‘ex larva'10.V.2009. ***Psyllopsis repens***, from *Fraxinus ornus*, Beograd–Autokomanda, 21.VIII.2010, reared 1♀. ***Trioza mesembrina*** **Burckhardt, 1986**, from *Chaerophyllum hirsutum*, Kopaonik–Srebrenac, 7.VIII.2008, reared 1♂. ***Trioza rhamni*** **(Schrank, 1801)**, from *Rhamnus cathartica*, Kelebija, 25.V.2005, reared 1♀ ‘ex larva'6.VI.2005; Ilinci, 2.V.2009, 1♂.

O. minutus is an extremely polyphagous species distributed in Europe, Siberia, China and Mediterranean region. Many authors determined it as a predator of harmful insect species from a number of orders (Thysanoptera, Diptera, Lepidoptera, Coleoptera and Hemiptera Homoptera). Already reported as a psyllid predator (Herard 1986). In France, Herard (1986) determined *O. minutus* as a predator of pear psyllids, primarily *C. pyri*, and hawthorn psyllids. Also in Slovenia, Vrabl and Matis (1977) register it as a predator of *C. pyri* and *C. pyrisuga*. In Serbia, Pavićević (1977) and Jerinić-Prodanović et al. (2010) determined *O. minutus* as a predator of *C. pyri* in

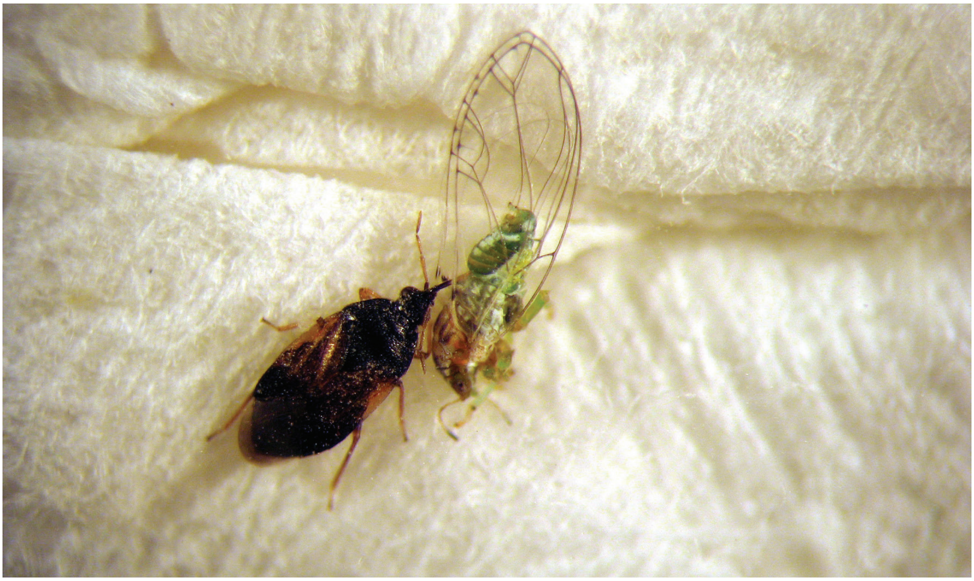

Figure 2. *Orius minutus* feeding on *Trioza rhamni.*

pear orchards. Malenovský and Jerinić-Prodanović (2011) also found it as a predator of *Ps. repens*. In Croatia, Arčanin and Balarin (1972) recognized the significance of *O. minutus* in the reduction of the mite *Panonychus ulmi*.

7) ***Orius*** **(*Orius*)** ***niger*** **Wolff, 1811**

Trophic status. Zoophagous.

Distribution. Palaearctic.

Preys. ***Cacopsylla bidens***, from *Pyrus communis*, Ilinci, 13.X.2008, collected 1♂. ***Cacopsylla melanoneura***, from *Malus domestica*, Lipovača, 29.IV.2006, collected 1♂. ***Cacopsylla pyri***, from *Pyrus communis*, Radmilovac, 26.VI.2006, reared 1♂ 'ex larva'30.VI.2006; 10.VII.2006, reared 1♀ 'ex larva'20.VII.2006. ***Craspedolepta* sp.**, from *Artemisia vulgaris*, Sutjeska, 2.X.2009, reared 1♂ and 4♀♀. ***Psyllopsis fraxinicola***, from *Fraxinus ornus*, Vrujci, 30.VI.2009, collected 1 specimen. ***Livia junci* (Schrank, 1789)**, from *Juncus bulbosus*, Beograd–Block 45, 10.VIII.2005, reared 1♂ 'ex larva'16.VIII.2005. ***Trichochermes walkeri* (Foerster, 1848)**, from *Rhamnus cathartica*, Ilinci, 14.IX.2008, 2♂♂, 2♀♀. ***Trioza chenopodii* Reuter, 1876**, from *Atriplex tatarica*, Ilinci, 20.VIII.2006, 1♂ 'ex larva'23.VIII.2006. ***Trioza urticae***, from *Urtica dioica*, Bački breg, 7.VI.2005, reared 1♂; Ilinci, 14.V.2005, reared 1♂, 1♀ 'ex larva'27.V.2005; Luka, 25.V.2007, reared 1♂.

O. niger is widespread in Western Palaearctic, very rare in the Mediterranean region, also reported from China. It is a very polyphagous species, preying on aphids, psyllids, whiteflies, thrips, larvae of noctuids, mites (Péricart 1972, Herard 1986, Protić 1993).

In south France, Herard (1986) determined *Orius niger* on pears as a predator of *Cacopsylla pyri*, but also collected it in a large number from *Trioza urticae* from nettle, which was surrounding the pear orchards. In Croatia, *O. niger* was determined along with *O. minutus* on *Panonychus ulmi* in an apple orchard (Arčanin and Balarin 1972).

In Serbia, Grbić et al. (1989), investigating pear psyllid predators, reported *Orius* spp., so we are not able to compare our results with theirs. In the same paper, authors mentioned the presence of other *Orius* species frequently during summer and autumn which is in accordance with our investigations.

Miridae

8) *Atractotomus mali* Meyer-Dür, 1843

Trophic status. Phytozoophagous.

Distribution. Palaearctic.

Preys. ***Cacopsylla affinis***, from *Crataegus monogyna*, Koruška, 1.V.2008, reared 1♀ 'ex larva'8.V.2008. ***Cacopsylla melanoneura***, from *Crataegus monogyna*, Beograd–Hotel Jugoslavija, 22.IV.2008, reared 2♂♂, 1♀ 'ex larva'30.IV.2008; 18.V.2008, reared 1♀ 'ex larva'23.V.2008; Dobra, 10.V.2008, reared 1♂, 1♀ 'ex larva'21.V.2008; Draževac, 20.IV.2008, reared 1♂, 1♀ 2.V.2008; Koruška, 1.V.2008, reared 1♀ 'ex larva'8.V.2008. ***Cacopsylla melanoneura***, from *Malus domestica*, Ilinci, 24.V.2008, reared 1♀ 'ex larva'30.V.2008; Oparić, 4.V.2008, reared 2♂ 'ex larva'19.V.2008; Ilinci, 2.V.2010, reared 1♀. ***Cacopsylla peregrina***, from *Crataegus monogyna*, Beograd–Hotel Jugoslavija, 22.IV.2008, reared 2♂♂, 1♀ 'ex larva'30.IV.2008; Dobra, 10.V.2008, reared 1♂, 1♀ 'ex larva'21.V.2008; Koruška, 1.V.2008, reared 1♀ 'ex larva'8.V.2008. ***Cacopsylla picta***, from *Malus domestica*, Ilinci, 24.V.2008, 1♀ 'ex larva'30.V.2008.

A. mali has been reported so far as a predator of mites, aphids, thrips, psyllids, butterfly larvae and pupae (Wheeler 2000b). It was registered as a predator of apple psyllid *Cacopsylla mali* in Norway (Jonsson 1983) and of pear psyllid *C. pyri* in Greece (Santas 1987). In Germany, Novak and Achtziger (1995) registered it as a predator of hawthorn psyllids *Cacopsylla* spp.

First record of *A. mali* as a predator of *C. picta*. The above mentioned data are the first ones for *A. mali* as a psyllid predator in Serbia.

9) *Campylomma verbasci* (Meyer-Dür, 1843)

Trophic status. Zoophytophagous.

Distribution. Holarctic.

Preys. ***Cacopsylla bidens***, from *Pyrus communis*, Ilinci, 24.V.2008, reared 1♂ 'ex larva'29.V.2008; Bavanište, 25.V.2006, reared 1♂, 1♀ 'ex larva'30.V.2006. ***Cacopsylla pyri***, ***Cacopsylla pyricola*** and ***Cacopsylla pyrisuga***, from *Pyrus communis*, Bavanište, 25.V.2006, 1♂, 1♀ 'ex larva'30.V. 2006. ***Cacopsylla melanoneura***, from *Malus domestica*, Ilinci, 2.V.2010, reared 2♂♂.

C. verbasci is a zoophytophagous species preying on apple aphids, pear psyllids, codling moth, thrips and mites (Wheeler 2000b). Its most common prey among insects are *Aphis pomi* and *Cacopsylla mali*, and among mites *Panonychus ulmi* and *Tetranychus urticae* (Hagen et al. 1999, Wheeler 2000b, Bradley 2007).

However, if there is a lack of prey, it can feed on apple fruits, rarely pear, causing the harm to their aesthetic value. Therefore, *C. verbasci* is a significant fruit pest in Canada (Hagen et al. 1999, Wheeler 2000a, Bradley 2007). Erler (2004) reported the presence of *C. verbasci* as a predator of *C. pyri* in treated and untreated pear orchards in Turkey, and Harizanova et al. (2012) mentioned it on *Acizzia jamatonica* in Bulgaria.

Already known in Serbia (Protić 1993) but in our investigations registered for the first time as a predator of psyllids in this country.

10) *Deraeocoris* (*Deraeocoris*) *flavilinea* (A. Costa, 1862)

Trophic status. Zoophytophagous.

Distribution. Western and Central Europe.

Preys. ***Cacopsylla bidens***, from *Pyrus communis*, Beograd–Karaburma, 4.V.2006, reared 1♀ 'ex larva'18.V.2006. ***Homotoma ficus***, from *Ficus carica*, Beograd–Banjica, 21.V.2009, collected 1♂, 2♀♀. ***Trioza rhamni***, from *Rhamnus cathartica*, Beograd–Hotel Jugoslavija, 26.V.2005, reared 1♂ 'ex larva'29.V.2005. ***Psyllopsis discrepans*** and ***Psyllopsis machinosa***, from *Fraxinus angustifolia*, Beograd–Autokomanda, 21.V.2009, 1♂, 1♀.

D. flavilinea is reported so far as a predator of psyllids (Jerinić-Prodanović and Protić 2011, Simov et al. 2012). Until 1980's, it was known only from Sicily, from where it has spread to Central Europe where it is now considered as an invasive species (Rabitsch 2008). As a predator of psyllids, it has been known in Serbia since 2011 (Jerinić-Prodanović and Protić 2011).

11) *Deraeocoris* (*Deraeocoris*) *ruber* (Linnaeus, 1758)

Trophic status. Zoophytophagous.

Distribution. Holarctic.

Prey. ***Cacopsylla pyri***, from *Pyrus communis*, Radmilovac, 10.VII.2006, reared 1♀.

A very polyphagous zoophytophagous species. A Holarctic species occurring in large quantities in the south of Europe.

Already mentioned as a predator of *C. pyri* (Herard 1986). It also preys on younger caterpillar instars of some butterflies, mites and various other small insects in apple orchards, on *Rubus* spp. and *Urtica* spp. as well as on aphids on *Corylus* spp. (Herard 1986).

Reported as a predator of *A. jamatonica* (Harizanova et al. 2012) in Bulgaria and *C. pyri* in Serbia (Jerinić-Prodanović et al. 2010).

12) ***Deraeocoris (Knightocapsus) lutescens*** **(Schilling, 1836)**

Trophic status. Zoophagous.

Distribution. Euro-Mediterranean.

Preys. ***Cacopsylla pyri***, from *Pyrus communis*, Izvor, 14.IV.2009, 1♂. ***Cacopsylla rhamnicola***, from *Rhamnus cathartica*, Obedska bara, 4.VI.2005, reared 1♂ 'ex larva'18.VI.2005. ***Camarotoscena speciosa***, from *Populus nigra*, Zemun–Nova Galenika, 18.X.2010, collected 1♀. ***Psyllopsis fraxinicola***, from *Fraxinus angustifolia*, Zemun–Nova Galenika, 1.IX.2006, collected 1♀. ***Trioza chenopodii***, from *Atriplex oblongifolia*, Galovica, 18.VII.2003, reared 1♂.

D. lutescens is a Mediterranean species, distributed also in small numbers in Central Europe. Known mainly as an egg predator of pear psyllid *C. pyri* and hawthorn psyllid *C. crataegi* (Herard 1986). It is also reported as a predator of aphids and mite *Panonychus ulmi* in apple orchards in Croatia (Arčanin and Balarin 1972) and in pear orchards as a predator of *C. pyri* in France and Turkey (Herard 1986, Erler 2004).

D. lutescens has been already registered in Serbia (Protić 1993) but here is reported for the first time as a predator of psyllids in this country.

13) ***Heterocordylus (Heterodactylus) genistae*** **(Scopoli, 1763)**

Trophic status. Phytozoophagous.

Distribution. Europe.

Prey. ***Cacopsylla melanoneura***, from *Malus domestica*, Beloljin, 4.V.2008, collected 1♂; Ilinci, 20.V.2006, reared 1♂ 'ex larva'25.V.2006; Uzovnica, 29.IV.2007, collected 1 specimen.

H. genistae is mentioned in the literature as a beneficial insect being a predator of psyllids both in larval and adult stage. It is registered as a predator of various other insects (Protić 1993, 1998).

In the present paper, we report *H. genistae* for the first time as a predator of psyllids in Serbia.

14) ***Hypseloecus visci*** **(Puton, 1888)**

Trophic status. Zoophagous.

Distribution. Europe.

Prey. ***Cacopsylla visci***, from *Viscum album*, Beograd–Bulevar Aleksandra Karađorđevića, 25.III.2007, reared 4♀♀ 'ex larva'16.IV.2007.

An exclusively zoophagous species.

Already known from Serbia as a psyllid predator (Jerinić-Prodanović and Protić 2011).

15) *Malacocoris chlorizans* Panzer, 1794

Trophic status. Zoophagous.

Distribution. Eurasia.

Prey. ***Homotoma ficus***, from *Ficus carica*, Beograd–Hotel Jugoslavija, 16.V.2007, collected 1♂, 1♀; Beograd–Voždovac, 26.V.2007, collected 5♂♂, 1♀; Zemunski kej, 15.V.2008, collected 1 larva.

A general predator on aphids, psyllids, eggs and larvae of leaf miner moths (Wheeler 2000b, Wyniger and Burckhardt 2003). In Croatia, it is registered as a predator of *Panonychus ulmi* in apple orchards by Arčanin and Balarin (1972).

Malacocoris chlorizans has been already registered in Serbia (Protić 1998) but in the present paper is reported for the first time as a predator of psyllids in this country.

16) *Miris striatus* (Linnaeus, 1758)

Trophic status. Zoophagous.

Distribution. Europe, Central Asia.

Preys. ***Cacopsylla melanoneura*** and ***Cacopsylla peregrina***, from *Crataegus monogyna*, Dobra, 10.V.2008, reared 1♀ ‘ex larva'21.V.2008.

Already reported from Serbia (Protić 1993, 1998). The above mentioned record is the first one of *M. striatus* as a predator of psyllids.

17) *Orthotylus* (*Orthotylus*) *marginalis* Reuter, 1884

Trophic status. Zoophytophagous.

Distribution. Eurosiberian.

Prey. ***Cacopsylla rhamnicola***, from *Rhamnus cathartica*, Beograd–Hotel Jugoslavija, 15.V.2008, reared 1♀ ‘ex larva'19.V.2008.

O. marginalis is registered as a predator of aphids and psyllids (Wheeler 2000b). In Finland and Russia, it was mentioned as a predator of *C. mali* (Jonsson 1983).

Registered in Serbia (Protić 2011) but here reported for the first time as a psyllid predator.

18) *Psallus* (*Hylopsallus*) *assimilis* Stichel, 1956

Trophic status. Phytozoophagous.

Distribution. Europe.

Preys. ***Psyllopsis discrepans***, from *Fraxinus* sp., Ilinci, 21.V.2005, reared 2♂♂, 2♀♀; Umčari, 25.V.2007, reared 1♀. ***Psyllopsis fraxinicola*** and ***Psyllopsis discrepans***, from *Fraxinus* sp., Beograd–Autokomanda, 10.V.2007, reared 5♂♂, 8♀♀ ‘ex larva'16.V.2007.

Figure 3. Larva of *Psallus flavellus* feeding on *Psyllopsis fraxinicola.*

Already known as a predator of various insect species, inlcuding psyllids.

Previously registered in Serbia (Protić 1998) but in the present paper reported for the first time as a psyllid predator in this country.

19) *Psallus* (*Psallus*) *flavellus* Stichel, 1933

Fig. 3

Trophic status. Phytozoophagous.

Distribution. Europe.

Preys. ***Psyllopsis* spp.**, from *Fraxinus* sp., Beograd–Autokomanda, 8.V.2010, reared 3♂♂, 1♀. ***Psyllopsis discrepans***, from *Fraxinus* sp., Beograd–Autokomanda, 13.V.2010, reared 2♂♂, 1♀.

Previously registered in Serbia (Protić 2011). Reported here for the first time as a psyllid predator.

20) *Psallus* (*Phylidea*) *quercus* Kirschbaum, 1856

Trophic status. Phytozoophagous.

Distribution. Europe, Asia.

Preys. ***Psyllopsis discrepans***, from *Fraxinus ornus*, Ilinci, 24.V. 2008, collected 1♀; 17.V. 2009, 1♂, 2♀♀. ***Psyllopsis discrepans*** and ***Ps. machinosa***, from *Fraxinus* sp., Beograd–Autokomanda, 6.V.2009, reared 4♀♀ 'ex larva'10.V.2009; 21.V.2009, reared 1♂, 3♀♀.

So far known as a predator of aphids, psyllids, thrips, spiders and eggs of various insects (Protić 1998).

Registered in Serbia (Protić 2011) but here reported for the first time as a psyllid predator in this country.

21) *Pseudoloxops coccinea* Meyer-Dür, 1843

Trophic status. Zoophagous.

Distribution. Euro-Mediterranean.

Preys. ***Psyllopsis fraxinicola***, from *Fraxinus* sp., Niš, 27.V.2008, collected 1♂. ***Psyllopsis* sp.**, *Fraxinus* sp., Beograd–Autokomanda 8.V.2010, reared 1♂ 'ex larva'21.V.2010.

Registered in Serbia (Protić 1999). Reported for the first time as a predator of psyllids.

Conclusions

From 28 psyllid species and 19 host plants, we reared or collected 21 species of true bugs belonging to the families Anthocoridae and Miridae. According to available literature data, 12 of the recorded species are zoophagous, while the other nine have mixed nutrition.

Miris striatus, *Pseudoloxops coccinea* and *Psallus flavellus* (Miridae) have not been registered as psyllid predators so far. Sixteen species of true bugs are recorded here for the first time as psyllid predators in Serbia (*Anthocoris amplicollis*, *A. nemorum*, *A. confusus*, *Orius majusculus*, *O. niger*, *Atractotomus mali*, *Campylomma verbasci*, *Deraeocoris lutescens*, *Heterocordylus genistae*, *Malacocoris chlorizans*, *Orthotylus marginalis*, *Psallus assimilis*, *Ps. quercus*, *Ps. flavellus*, *Miris striatus* and *Pseudoloxops coccinea*).

From the family Anthocoridae, we identified seven species: *Anthocoris amplicollis*, *A. confusus*, *A. nemoralis*, *A. nemorum*, *Orius majusculus*, *O. minutus* and *O. niger*. The most polyphagous among them was *O. minutus*, found on 13 species of psyllids: *Baeopelma foersteri*, *Cacopsylla melanoneura*, *C. picta*, *C. pyri*, *C. rhamnicola*, *Camarotoscena speciosa*, *Homotoma ficus*, *Psyllopsis discrepans*, *Ps. fraxinicola*, *Ps. machinosa*, *Ps. repens*, *Trioza mesembrina* and *T. rhamni*.

From the family Miridae, we reared or collected 14 species: *Atractotomus mali*, *Campylomma verbasci*, *Deraeocoris flavilinea*, *D. ruber*, *D. lutescens*, *Heterocordylus genistae*, *Hypseloecus visci*, *Malacocoris chlorizans*, *Miris striatus*, *Orthotylus marginalis*, *Psallus assimilis*, *P. flavellus*, *P. quercus* and *Pseudoloxops coccinea*. Among them, the most polyphagous were *C. verbasci*, *D. flavillinea* and *D. lutescens*, each registered on five psyllid species.

Most of predatory true bugs are registered on deciduous perennial plants. We found the highest number of predatory true bugs on psyllids which overwinter on host plant and have more than one generation per year, e.g. *Cacopsylla pyri*, *Psyllopsis fraxinicola* and *Ps. discrepans*. On each of them, seven predatory true bugs were registered. Species from the genus *Psallus* were registered as predators only of psyllid genus *Psyllopsis.*

Further investigations are necessary for the preservation of known beneficial predatory true bugs and finding of new ones, potentially usable for biological control on economically significant psyllid species.

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RESEARCH ARTICLE

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Redescription of *Urartucoris ermolenkoi* (Hemiptera, Heteroptera, Coreidae) and a revised key to the genera of Pseudophloeini of the Western Palaearctic Region

Petr Kment[1], Meral Fent[2], George Japoshvili[3]

[1] *Department of Entomology, National Museum, 14800 Prague 4, Czech Republic* [2] *Department of Biology, Faculty of Science, Trakya University, 22030 Edirne, Turkey* [3] *Entomology and Biocontrol Research Centre, Agricultural University of Georgia, Tbilisi, Georgia*

Corresponding author: *Petr Kment* (sigara@post.cz); *Meral Fent* (m_fent@hotmail.com); *George Japoshvili* (giorgij70@yahoo.com)

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Abstract

Urartucoris ermolenkoi P. V. Putshkov, 1979 (Hemiptera: Heteroptera: Coreidae: Pseudophloeinae) is recorded from Turkey for the first time. Redescriptions of the genus and species are provided, the male of *U. ermolenkoi* being described for the first time, and intraspecific variability of the species is discussed. Adults of *U. ermolenkoi* were collected from mid April to end of July and in mid September by means of pitfall traps. First data on the habitat of the species are provided: it is epigeic, inhabiting sparse forests and shrublands at higher elevations (ca. 1400–1600 m a.s.l.) in arid regions of central Anatolia. A revised key to the genera of the West Palaearctic Pseudophloeini is provided. Translations of the original descriptions from Russian are given in Appendix.

Keywords

Heteroptera, Coreidae, Pseudophloeinae, key, morphology, ecology, distribution, Turkey, Palaearctic Region

Introduction

The subfamily Pseudophloeinae Stål, 1868 is represented in the Palaearctic Region (*sensu* Aukema and Rieger 2006) by two tribes, the mostly tropical Clavigrallini Stål, 1873 with 3 genera and 9 species distributed in the southern border areas – Arabian Peninsula, Iran, Afghanistan, central and southern China, Taiwan, and Japan, and

Pseudophloeini with 17 genera and 42 species distributed throughout the region (Dolling 2006, Aukema et al. 2012). Moulet (1995) monographed the Coreoidea and Pyrrhocoroidea fauna of the Euro-Mediterranean region, keying 10 genera and 26 species of Pseudophloeini: *Anoplocerus* Kiritshenko, 1926 (3 species), *Arenocoris* Hahn, 1834 (4 species), *Bathysolen* Fieber, 1860 (2 species), *Bothrostethus* Fieber, 1860 (1 species), *Ceraleptus* A. Costa, 1847 (4 species), *Loxocnemis* Fieber, 1860 (1 species), *Coriomeris* Westwood, 1842 (9 species), *Nemocoris* R. F. Sahlberg, 1848 (1 species), *Strobilotoma* Fieber, 1860 (1 species), and *Ulmicola* Kirkaldy, 1909 (1 species). However, some eastern-Mediterranean genera and species were omitted from this work, as follows:

i) The genus *Microtelocerus* Reuter, 1900 contains two species, *M. testaceus* Reuter, 1900 (described from Tajikistan) and *M. linnavuorii* Dolling, 1979 (described from Sinai, Egypt). Dolling (2006) listed *M. linnavuorii* also from Libya (as a new record) and *M. testaceus* also from Iran without further details (no record was listed by Hoberlandt (1989) or Ghahari et al. (2012)). Records of *M. testaceus* from Sinai (Egypt) by Priesner and Wagner (1961) and El Hamouly et al. (2010) almost certainly pertain to *M. linnavuorii*.

ii) The monotypic genus *Urartucoris* P. V. Putshkov, 1979 contains *U. ermolenkoi* P. V. Putshkov, 1979 described based on two females from the Nakhchivan Autonomous Republic of Azerbaijan (Putshkov 1979).

iii) Moulet (1995) keyed 4 species of *Ceraleptus* and did not deal with *C. sartus* Kiritshenko, 1912 which is a Central Asian species also recorded from the Asian part of Turkey (Wagner 1959: 106).

iv) Moulet (1995) also omitted three species of *Coriomeris* inhabiting Transcaucasia and the Near East: *C. armeniacus* Tshernova, 1978 (Armenia, Asian Turkey, Azerbaijan, Iran), *C. pallidus* Reuter, 1900 (south European Territory of Russia, Asian Turkey, Lebanon, Syria, Iran, Central Asia up to northwestern China and Afghanistan), and *C. validicornis* Jakovlev, 1904 (Armenia, Asian Turkey, Azerbaijan, Georgia, Iran) (Tshernova 1978, Dolling 2006).

The knowledge on the Coreidae fauna of Turkey was recently improved by several faunistic surveys, especially those by Dursun and Fent (2009), Yıldırım et al. (2011), and Dursun (2011), including references to further minor studies. Finally, the Turkish fauna was summarized in form of a checklist by Dursun (2011), listing 17 genera and 31 species, of which 8 genera and 24 species belong to Pseudophloeinae. An additional species, *Gonocerus patellatus* Kiritshenko, 1916 (Coreinae), was recorded from Anatolia by Yıldırım et al. (2011).

Specimens of an additional genus and species so far unrecorded from Turkey, *Urartucoris ermolenkoi*, were recently obtained by the third author. This species has never been recorded after its original description, and its male sex has remained unknown so far. In this contribution we redescribe the genus and species, provide the first description and illustrations of the male of *U. ermolenkoi*, and give the first information on its habitat preference. An updated key to the West Palaearctic genera of Pseudophloeini is presented as well.

The examined material of *U. ermolenkoi* was collected during the ongoing systematic studies on insect diversity of the Gölcük Natural Park, which has already been a subject of several papers, including i.a. records of two genera and 25 species new to Turkish fauna and among them five species of Encyrtidae (Hymenoptera: Chalcidoidea) described as new to science (Fent and Japoshvili 2012, Japoshvili 2011, Japoshvili and Anlas 2011, Japoshvili and Çelik 2010, Japoshvili and Ljubomirov 2011, Japoshvili and Toyganözü 2011, Japoshvili et al. 2009, 2010, 2011). Concerning Heteroptera, Fent and Japoshvili (2012) identified 66 species of true bugs from 13 families, the family Coreidae being represented by 9 species (7 in the tribe Pseudophloeini).

Material and methods

The Gölcük Natural Park (GNP) (Fig. 1) is situated in Isparta Province (Mediterranean Region of Turkey) in an arid region located 8 km southwest of the city Isparta. With its diverse vegetation and wildlife, geomorphological structure, and aesthetically pleasing landscape, GNP is one of the most important areas of the Lakes District in Turkey (Fig. 17). This area of 5,925 ha was proclaimed a natural park but its condition is deteriorating because it has no master plan and only minimal management (Gül et al. 2005). Area of the GNP has a rather complex geology, composed of alternating sedimentary (Akdağ limestone, conglomerates, flysch), magmatic (harzburgite, serpentinite), and volcanic rocks (trachy-andesites, tight tuffs, ash, and pumice tuff stones). Isparta Province itself is located at the border between the Irano-Anatolian and Mediterranean basin biodiversity hotspots, and this is reflected in the flora of the GNP as well: 22 (9.7 %) species endemic for Irano-Anatolian hotspot and 17 (7.5 %) endemic for Mediterranean basin hotspot are represented in this region (Fakir 1998, Fakir and Dutkuner 1999); 25 species (11 %) are endemic for Turkey (Fakir 1998). The studies performed around Gölcük Lake showed that 227 plant taxa from 136 genera within 47 families existed there, and among them red pine (*Pinus brutia* Ten.), black pine (*Pinus nigra* Arnold. ssp. *pallasiana* (Lamb.), oaks (*Quercus* spp.), cedar (*Cedrus libani* A. Rich.), pseudoacacia (*Robinia pseudoacacia* L.) and some other shrubs are characteristic for the Gölcük Natural Park (Fakir and Dutkuner 1999, Karatepe et al. 2005).

Dry-mounted specimens were measured under a stereomicroscope using an ocular micrometer. The following measurements were examined: body length (from apex of clypeus to apex of membrane), head length (from apex of clypeus to the anterior pronotal margin), head width (maximum width across eyes), interocular width (between inner margins of eyes), lengths of antennomeres (maximum lengths), pronotum length (medially in most exposed view), pronotum width (maximum width between humeral angles), scutellum length (medially from base to apex), scutellum width (maximum width at base), and abdomen width (maximum width).

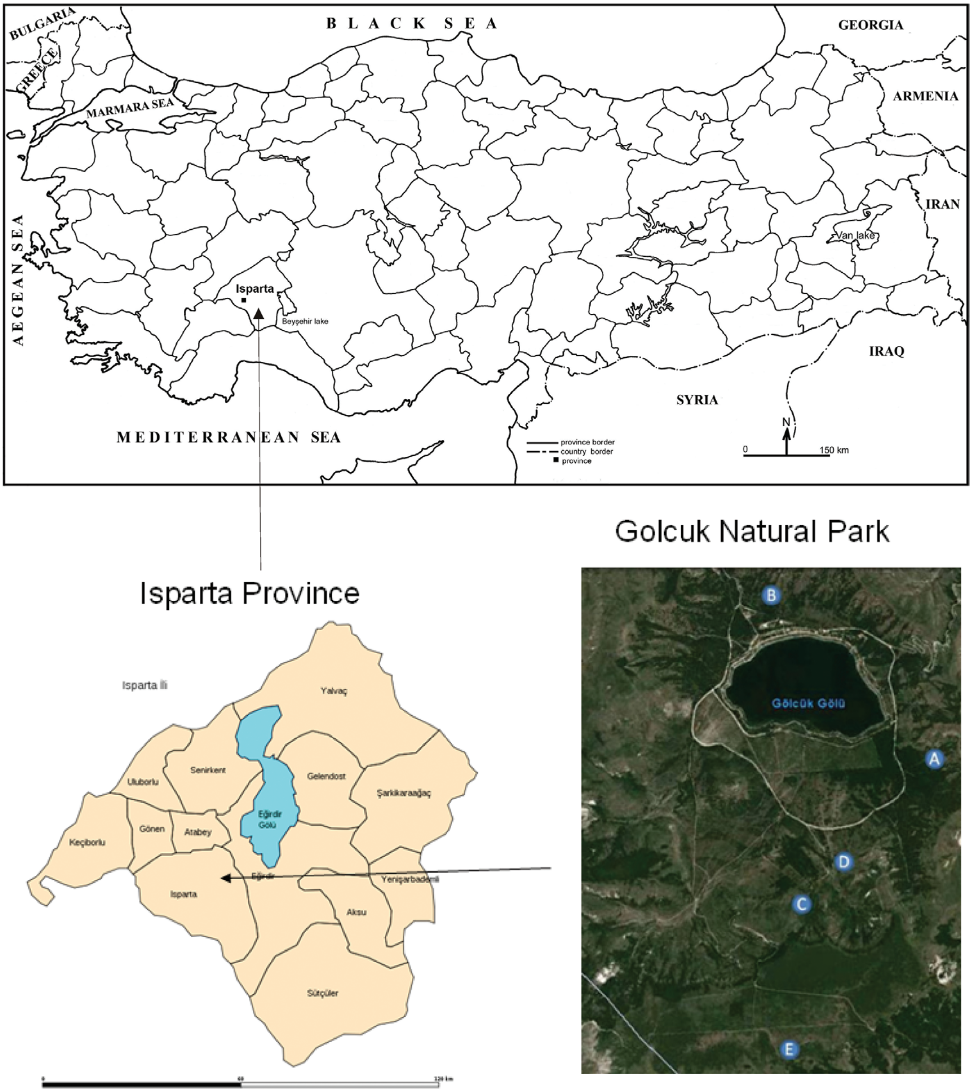


Figure 1. Location of the Gölcük Natural Park within Turkey and position of the collection sites of *Urartucoris ermolenkoi* P. V. Putshkov, 1979 within the Natural Park.

All line drawings (using camera lucida) and the dissections of genitalia were made under a Leica MZ75 stereomicroscope. For the study of genitalia, a male specimen was softened in distilled water, and the pygophore was removed under stereomicroscope using a fine forceps, then put into concentrated KOH solution and heated until the solution started to boil. After maceration the pygophore was washed in distilled water and dissected under stereomicroscope. The dissected phallus is preserved in a plastic microvial with glycerol attached to the same pin as the specimen. The morphological terminology follows mostly Tsai et al. (2011).

Results

Urartucoris P. V. Putshkov, 1979

http://species-id.net/wiki/Urartucoris

Urartucoris P. V. Putshkov, 1979: 62 (original description). Type species: *Urartucoris ermolenkoi* P. V. Putshkov, 1979, by original designation.

Urartucoris: Dolling (1986): 206–207 (taxonomic relationships, distribution), Dolling (2006): 55 (catalogue).

Redescription. *Structure.* *Head* porrect, robust, about as long as wide across eyes, strongly gibbose dorsally, anterior portion of head (anteriad of antenniferous tubercles) long (Fig. 2). Clypeus anteriorly surpassing mandibular plates. Antenniferous tubercles large, apically produced into long, inward-curved projection embracing base of antennal segment I. Compound eyes small, globular, protruding from head outline by most of their width (Fig. 2). Ocelli situated on small tubercles slightly posteriad of posterior margin of compound eyes, directed dorsolaterad; each ocellus closer to eye than to each other. Antennal segments ordered from longest to shortest: II > IV > III ≥ I. Antennal segment I robust, obovate, narrowing in basal one quarter of its length, slightly curved towards base, its apex surpassing apex of clypeus anteriorly; antennal segments II–IV much more slender, II and III almost cylindrical, slightly widening towards apex, IV spindle-shaped, with constricted base (Fig. 2). Bucculae short, covering approximately anterior half of labial segment I, surpassing labial segment I ventrally, ventral margin rounded, anteriorly reaching apex of clypeus (Fig. 4). Labial segments ordered from longest to shortest: I > II > IV > III; apex of segment I not reaching posterior margin of head, apex of segment II reaching anterior margin of procoxae, and apex of segment IV reaching anterior margin of mesocoxae (Figs 3, 4).

Pronotum trapezoid, anterior margin slightly concave, lateral and posterior margin nearly straight (Fig. 2). Pronotum highest at line connecting humeral angles, sloping anteriorly towards head (Fig. 4). Pronotal disk flat, slightly sloping towards lateral and posterior margin. Anterior margin of pronotum raised, forming sharp collar (most prominent laterally) (Figs 2, 3), constricted posteriorly by deep transverse groove continuing to propleura; anterolateral angles of pronotum such as in *Ceraleptus* not developed. Lateral margins of pronotum and humeral angles rounded, unarmed, not protruding (Fig. 2).

Scutellum triangular, slightly wider than long, flat, only anterolateral angles with small depressions, apex acutangulate (Fig. 2).

Thoracic venter. Mesosternum depressed between mesocoxae. Metasternum anteriorly convex, narrowing posteriad, metacoxae situated close to each other (Fig. 3). Metapleuron posterolaterally rounded, not protruding (Fig. 3). Ostiole of metathoracic scent glands shifted somewhat laterad, situated between meso- and metacetabulum, laterally accompanied with a short peritreme; vestibular scar well visible; evaporatorium very small, narrowly surrounding vestibular scar, ostiole, and peritreme.

Legs. All femora oval in cross-section. Profemur widest in midlength, mesofemur approximately in its apical third (Fig. 3), both unarmed. Metafemur clavate, widest subapically (Fig. 3), its ventral surface with two parallel rows of more than ten spines and small denticles getting bigger from base to apex, two to four of the spines being large, the spines in rows being situated in nearly equal distances; surface between both rows flat, smooth. Tibiae somewhat flattened laterally, slightly widening from base to apex, unarmed. Tarsomeres ordered from longest to shortest: I > III > II, tarsomere I being slightly longer than II and III combined (Fig. 3).

Wings. Corium widest approximately at midlength, narrowing both anteriad and posteriad, costal margin of corium therefore slightly convex medially; posterolateral angle of corium acutangulate (Fig. 2). Membrane apically rounded, reaching apex of abdomen (♂; Fig. 2) or slightly shorter (♀). Hind wings developed.

Abdomen widest slightly behind its midlength (Fig. 3). Corium exposed, directed dorsolaterad, its outer margin smooth, posterolateral angles of laterotergites not protruding (Fig. 3), except for obtusangulate posterolateral angles of laterotergite VII in females. Abdominal venter regularly convex.

Male genitalia. Pygophore (Figs 5–9) black, lateral angles slightly brownish, insinuated anterolaterally, posterolateral angles distinctly produced, lobe-like, surrounding parameres laterally; infolding of ventral rim large, with a pair of depressions harbouring basal portion of parameres (Fig. 7). Paramere sockets not visible in dorsal view, covered by posterolateral angles of pygophore (Figs 6–7). Paramere (Figs 10–13) clavate in posterior (outer) and anterior (inner) view, slightly S-shaped in lateral view; posterior surface (Fig. 13) of head of paramere flattened, pale brown, bearing sparse and stout setae arising from large punctures; rest of paramere body blackish; inner surface (Fig. 11) produced into two ridges holding acute angle, distal ridge higher, apically rounded, proximal one lower and angulate; surface between the ridges and between proximal ridge and base of the paramere concave, rest of anterior surface convex. Phallus (Figs 14–16) with sclerotized vesica with two coils and a single pair of long endophallic reservoir outgrowths.

Differential diagnosis. *Urartucoris* differs from all Palaearctic Pseudophloeini in very long antennal segment II, sharp and well delimited pronotal collar, and presence of two nearly identical rows of denticles and spines on metafemora, the spines in the rows being situated in nearly equal distances. It resembles the genus *Ceraleptus* (especially *Ceraleptus gracilicornis* (Herrich-Schaeffer, 1835)) in the close position of the metacoxae but it differs from it, besides the above mentioned generic characters, in the robust antennae and the body being covered by stiff spinules (Putshkov 1979). See also the Key below. Also Dolling (1986) suggested close relationship between *Urartucoris*, *Ceraleptus*, and *Microtelocerus*, but without listing a single shared character.

Etymology. Originally, etymology of the name was not specified. The name consists of the name Urartu, which was an ancient Armenian kingdom (ca. 860–585 B.C.) spread out between Asia Minor, Caucasus and Mesopotamia, with center around the Van Lake (today in eastern Turkey), and the ending *-coris*, used for true bug. The name is masculine.

Urartucoris ermolenkoi **P. V. Putshkov, 1979**

http://species-id.net/wiki/Urartucoris_ermolenkoi
Figs 2–16

Urartucoris ermolenkoi P. V. Putshkov, 1979: 63–64. Type material: Holotype: ♀, Azerbaijan: 'Nakhichevanskaya ASSR: 6 km N of Bilav village, 1700 m, 22 V 1966 (V. M. Ermolenko)' (coll. Institute of Zoology, Ukrainian Academy of Sciences, Kiev); paratype: 1 ♀, Azerbaijan, Nakhchivan: '0.5 km E of Ak-Dar village, 2000 m, 19 VII 1977 (P. V. Puchkov)' (coll. Zoological Institute, Russian Academy of Sciences, St. Petersburg).

Urartucoris ermolenkoi: Dolling (2005): 55 (catalogue), Putshkov and Putshkov (2012): 95 (type depository).

Material examined. TURKEY: Isparta province: Gölcük (site A), 17.iv.2008, 1 ♂, M. Kaya lgt.; (sites A,B), 17.iv.2008, 3 ♂♂, M. Kaya lgt.; (site D), 24.iv.2008, 1 ♂ 1 ♀, G. Japoshvili lgt.; (site C), 15.v.2008, 1 ♀, M. Kaya lgt.; (site E), 10.vii.2008, 1 ♂ 1 ♀, G. Japoshvili lgt.; (site B), 24.vii.2008, 1 ♀, G. Japoshvili lgt.; (site E), 11.ix.2008, 1 ♂ 1 ♀, G. Japoshvili lgt. (coll. Trakya University, Edirne, Turkey, except 1 ♂ 1 ♀ in coll. National Museum, Praha, Czech Republic).

Location of the collecting sites: A – N37°43'33.81", E30°30'26.22", 1472 m alt.; B – N37°44'13.12", E30°29'22.95", 1420 m alt.; C – N37°42'49.02", E30°29'48.93", 1485 m alt.; D – N37°43'03.00", E30°29'56.90", 1443 m alt.; E – N37°42'09.05", E30°29'43.97", 1621 m alt.

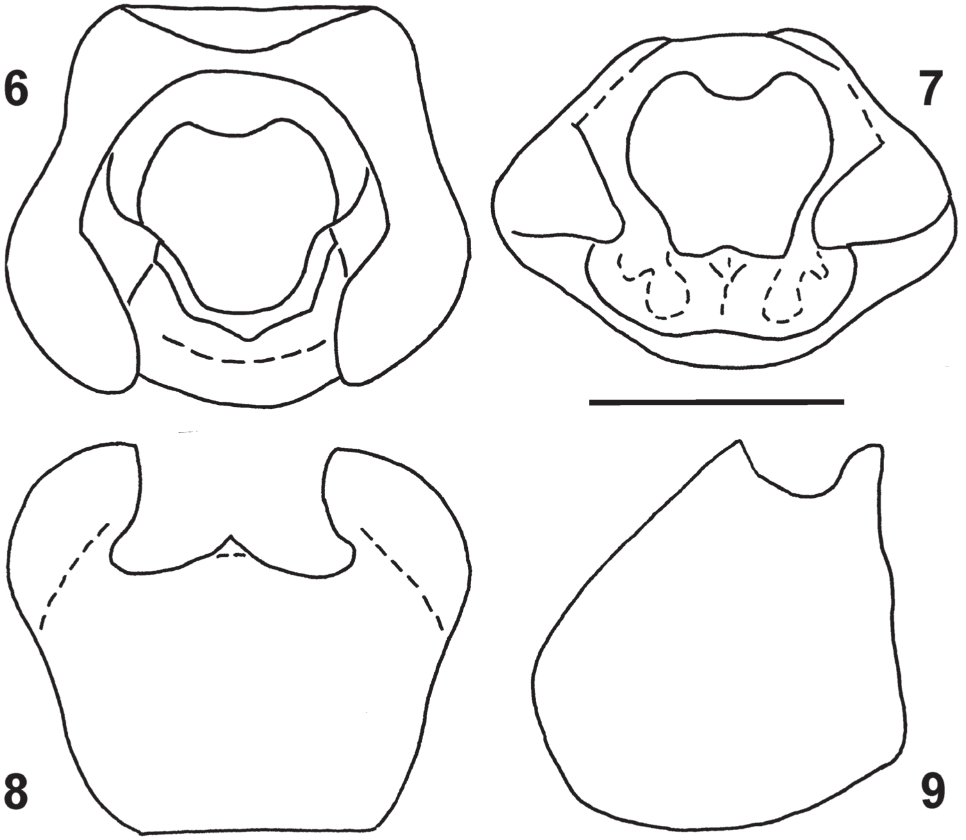
Redescription. ***Colouration*** (Figs 2–5). Body dorsally dark brown, except three ochraceous stripes dorsally on head, one in midline, running from base of head towards base of clypeus, and two lateral ones, running from base of head along inner margin of eye towards base of antenniferous tubercle; elongate ivory spot on apex of scutellum; and rather irregular whitish spots posterolaterally on laterotergites. Membrane brownish, with small round pale spots; veins dark brown. Antennae and labium black. Head ventrally brown. Thorax ventrally dark brown, pleura to various extent covered with smaller to larger, irregular, sometimes confluent ochraceous spots, especially on metapleuron. Profemora, metatibiae and metatarsi blackish brown. Meso- and metafemora blackish brown with irregular ochraceous spots, especially on dorsal surface. Pro- and mesotibiae ochraceous, basally and apically infuscated with dark brown, pro- and mesotarsi dark brown. Abdomen ventrally pale with nearly continuous wide blackish stripes laterally and at mid-distance between lateral margin and midline, sternites III–VII with narrow, black, nearly continuous to interrupted stripe along midline.

Measurements. Males (mm; n = 8): Body length 9.4–10.3; head: length 1.7–1.8, width across eyes 1.7–1.8, interocular width 1.0–1.3; pronotum: length 1.9–2.1, width across pronotal collar 1.6–1.8, width across humeral angles 2.9–3.3; scutellum: length 1.1–1.3, width 1.4–1.6; abdomen: maximum width (slightly behind its midlength) 4.0–4.2; length of antennal segments: I – 0.9–1.1, II – 1.2–1.5, III – 0.9–1.1, IV – 1.0–1.2; profemur: length 1.8–2.2; protibia: length 1.7–2.0; mesofemur: length 2.1–2.5; mesotibia: length 2.0–2.3; metafemur: length 2.7–3.6; metatibia: length 3.0–3.5.

Figures 2–5. *Urartucoris ermolenkoi* P. V. Putshkov, 1979, male (10.2 mm). **2–4** habitus (**2** dorsal view **3** ventral view **4** lateral view) **5** intact pygophore in posterior view. (Photos P. Kment).

Females (mm; n = 4): Body length 10.5–11.0; head: length 1.7–1.9, width across eyes 1.8–2.0, interocular width 1.2–1.25; pronotum: length 2.0–2.1, width across pronotal collar 1.7–1.9, width across humeral angles 3.1–3.4; scutellum: length 1.2–1.4, width 1.5–1.7; abdomen: maximum width (slightly behind its midlength) 4.2–4.6; length of antennal segments: I – 0.9–1.1, II – 1.3–1.4, III – 1.1 (n = 1), IV – 1.2 (n = 1); profemur: length 2.0–2.3; protibia: length 1.9–2.2; mesofemur: length 2.3–2.6; mesotibia: length 2.1–2.3; metafemur: length 3.1–3.8; metatibia: length 3.0–3.4.

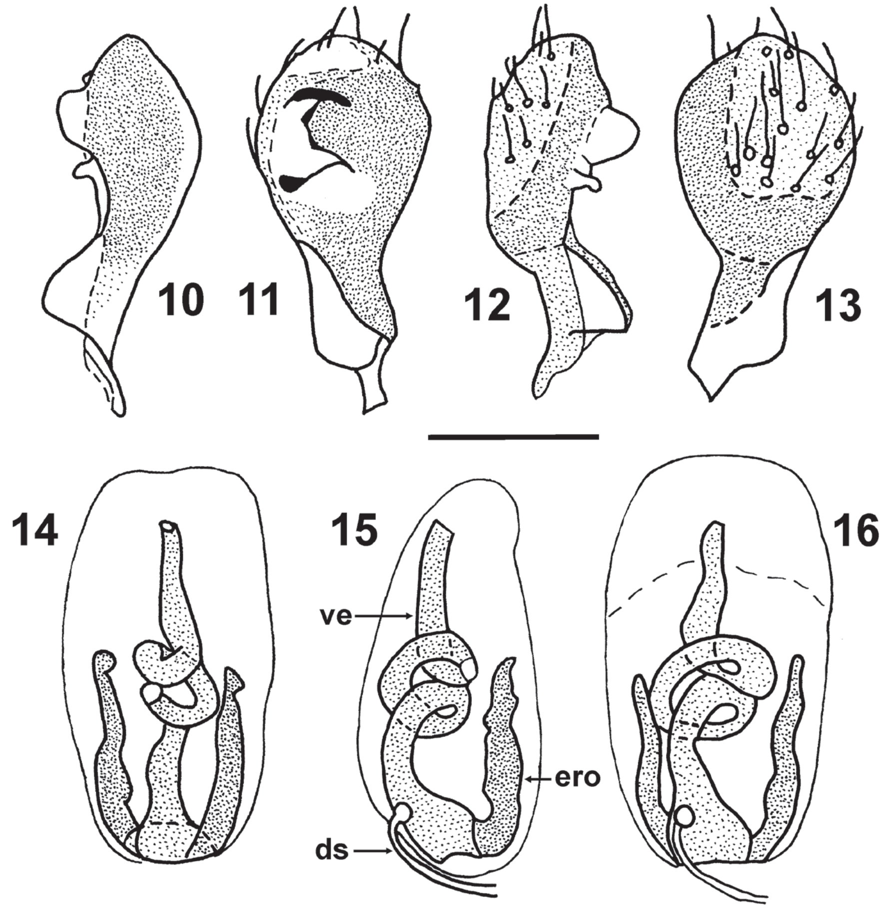
Pilosity and vestiture. Body dorsum (except membrane), antennae and legs covered with long, stiff, semi-erect to erect, brown to black spinules, arising from apices of small tubercles (best visible in lateral view); tubercles largest on vertex and anterior portion of pronotum, those on posterior portion of pronotum, scutellum, and coriaceous part of hemelytra smaller. Spinules on tibiae nearly as long as half of diameter of tibia, those on



Figures 6–9. *Urartucoris ermolenkoi* P. V. Putshkov, 1979, dissected pygophore: **6** dorsal view **7** posterodorsal view **8** posterior view **9** lateral view. Scale bar: 1 mm.

femora nearly as long as the large spinules on pronotum. Body venter with double pilosity: Long, stiff, semi-erect to erect, dark spinules as those on body dorsum, but distinctly sparser, arising from smaller tubercles, short on pleura and ventral surface of head. Besides the dark spinules, body venter covered with intermingled, sparse, adpressed, whitish setae, slightly shorter than the spinules. Antennal segment IV covered with very short and fine adpressed pubescence among the sparse, long black spinulae. Besides the tubercles body covered with irregularly scattered, deep and dark punctures, largest on clavus.

Variability. The male resembles the female in most of the characters except for slightly smaller body (9.4–10.3 mm) than in females (10.5–11.2 mm), membrane reaching apex of abdomen (slightly shorter in females) and shape of last abdominal segments. We found also some differences in colouration, but this may represent rather intraspecific variability than sexual dimorphism: Peritreme yellowish, only slightly infuscated on its lateral edge (♂); peritreme black (♀). Abdominal sternites III–VII with narrow, black, nearly continuous stripe along midline (♂); sternite III medially with large blackish spot, the black longitudinal stripe in ventral midline being interrupted,



Figures 10–16. *Urartucoris ermolenkoi* P. V. Putshkov, 1979. **10–13** paramere (**10, 12** lateral views **11** anterior view **13** posterior view). **14–16** phallus (not inflated, articulatory apparatus lost) **14** dorsal view **15** lateral view **16** ventral view). Lettering: **ero** endophallic reservoir outgrowths, **ds** ductus seminis, **ve** vesica. Scale bar: 0.5 mm.

ventrites IV–VI medially with only smaller black spots posteriorly (♀). The extent of ochraceous colouration on thoracic pleura is certainly variable among specimens.

The Turkish specimens fit well the original description except for a few details. The mesofemora of the Turkish specimens are unarmed, while Putshkov (1979) mentioned mesofemora with two small spines. There are also slight differences in colouration. According to Putshkov (1979), the Nakhchivan specimens differed, e.g., in antennae dark brown with antennal segment I black; anterior portion of pronotum paler than its posterior portion, darkened near lateral margins and along midline; meso- and metafemora pale, apically darkened, especially dorsally; and abdomen ventrally pale with isolated dark spots, forming two interrupted stripes in lateral midlines (halfway between connexivum and ventral midline of abdomen). The Turkish females are either slightly smaller or approximately as large as the Nakhchivan specimens.

Etymology. Originally, etymology of the name was not specified. Most probably, the species was dedicated to Valeriy Mikhaylovich Ermolenko (1920–2006), an Ukrainian expert in Hymenoptera: Symphyta and collector of the holotype.

Phenology. Adults were collected from mid April to end of July and in mid September (Putshkov 1979, this paper).

Habitat. All the specimens of *Urartucoris ermolenkoi* (all adults) were collected between April and September 2008 using pitfall traps; collecting by other methods (yellow traps) yielded no specimens of this apparently epigeic species. The species was collected at five different semi-natural collecting sites in higher altitudes (1420–1621 m a.s.l.), ranging from sparse forest to mountain grassland (Figs 18–20).

– **A** Xerophilic natural plants with a reforested area with pine trees (*Pinus* sp.) and cedars (*Cedrus* sp.) planted between 1959–1969 (Şahbudak and Cengiz 2007); about 4.8% of the plants that were recorded from this site were endemic to Turkish flora. Altitude 1472 m (Fig. 18).

– **B** Main entrance to the GNP, this is an area close to the lake, with areas reforested with *Robinia pseudoacacia* planted between 1960–1965. Some natural plants like *Crataegus orientalis*, *Cotoneaster nummularia*, *Pistacia terebinthus* and other are also represented in this site which has high human activity (picnic area). Altitude 1420 m.

– **C** Mesophilous area with plantation of 50–60 years old *Populus* spp. trees, accompanied by *Crataegus orientalis*, *Cotoneaster nummularia*, *Pistacia terebinthus*, *Rosa canina*, *Pyrus*, *Juglans* and *Malus* spp. Altitude 1485 m.

– **D** Dry xerophilic sandy place with *Robinia pseudoacacia* plantations and natural shrubland with different dominant *Astragalus* spp., many of them endemic. Altitude 1443 m (Fig. 19).

– **E** Highland site, reforested in 1989 with *Cedrus* sp. and *Robinia pseudoacacia.* Altitude 1621 m (Fig. 20).

Distribution. Asian Turkey (Isparta province) (this paper, see Fig. 1), Azerbaijan: Nakhchivan (Putshkov 1979).

Revised key to the genera of the West Palaearctic Pseudophloeini

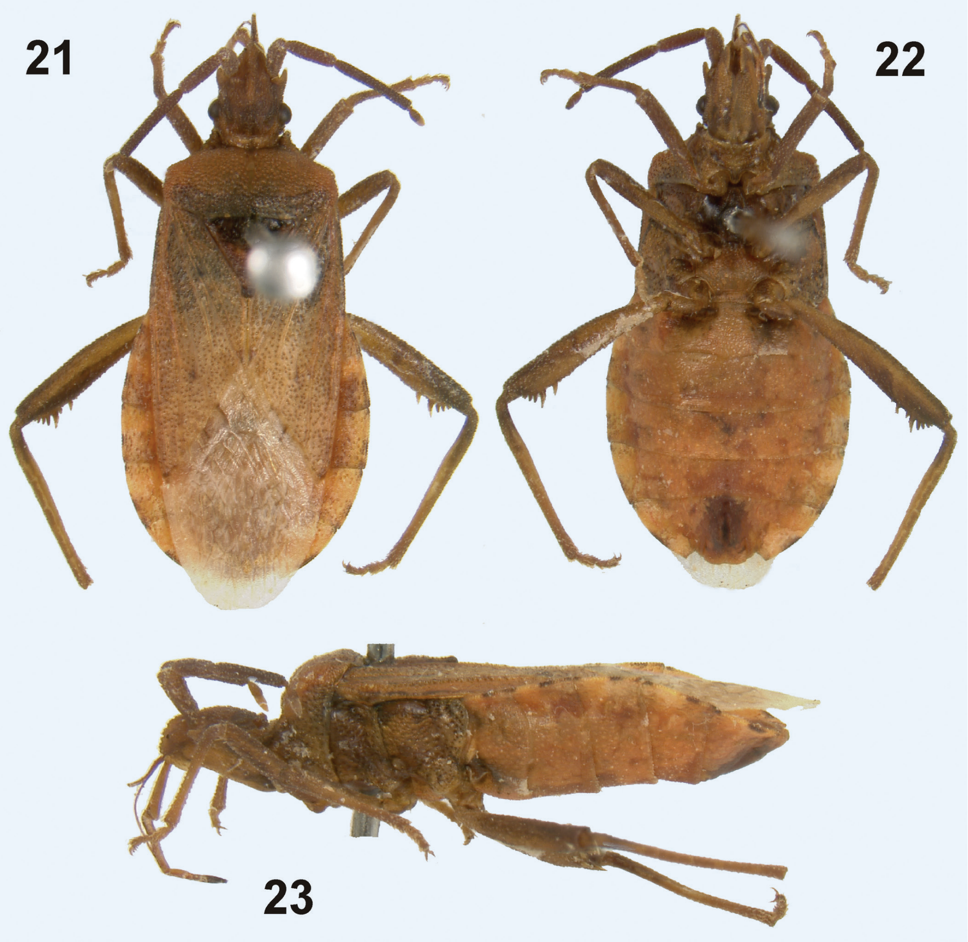
The following key is based on translation of Moulet (1995). The characters of *Microtelocerus* are based on examination of the male holotype of *M. linnavuorii* deposited in the National Museum and Gallery of Wales, Cardiff (type labels: 'Holo- / type [p, white label with red margin] // HEBREW UNIVERSITY OF JERUSALEM, ISRAEL / Department of Entomology [p] + m [hw] / LOC: [p] Gabal Sarbal 1300 [hw] / DATE: [p] 8.8.68 [hw] / COL: [p] Broza & Toren [hw, white label] // HOLOTYPE / Microtelocerus / Linnavuorii [hw] / det. [p] n. sp. M.S. [hw] / W.R. Dolling 197[p]2[hw, white label]') (see Figs 21–23), supplemented by information from Reuter (1900), Dolling (1979) and the habitus illustration by Kiritshenko (1952: 169, fig. 18). The key allows

Figures 17–18. Habitats of *Urartucoris ermolenkoi* P. V. Putshkov, 1979. **17** Landscape of the Gölcük NP **18** collecting site A. (Photos G. Japoshvili).

19

20

Figures 19–20. Microhabitats of *Urartucoris ermolenkoi* P. V. Putshkov, 1979, showing also placement of the pitfall trap **19** collecting site D **20** collecting site E. (Photos G. Japoshvili).



Figures 21–23. *Microtelocerus linnavuorii* Dolling, 1979, habitus of male holotype (**21** dorsal view **22** ventral view **23** lateral view). (Photos M. Wilson).

identification of all Pseudophloeini genera occurring in the western half of the Palaearctic Region (up to Central Asia), except Yemen where two additional genera of Afrotropical origin occur – *Mevanidea* Reuter, 1882 and *Risbecocoris* Izzard, 1949 (Dolling 2006).

1 (8) Antennal segment III more than 2 times longer than segment II **2**

2 (7) Antennal segment III much (3–4 times) longer than segment II **3**

3 (4) Posterior margin of pronotum with a spine at each side of scutellum. Head and pronotum with long setae ....***Strobilotoma* Fieber, 1860** (1 species)

4 (3) Posterior margin of pronotum without spines. Head and pronotum with short setae..**5**

5 (6) Metafemora tuberculate, generally without or at most with an inconspicuous spine apically. Lateral margins of pronotum concave medially ....***Arenocoris* Hahn, 1834** (4 species)

6 (5) Metafemora smooth with a strong apical spine. Lateral margins of pronotum straight ....***Bathysolen* Fieber, 1860** (2 species)

7 (2) Antennal segment III 2.5 times longer than segment II............................... .... ***Ulmicola* Kirkaldy, 1909** (1 species)

8 (1) Antennal segments II and III subequal, rarely antennal segment III longer (no more than 2 times) or shorter than segment II....................................**9**

9 (22) Antennal segments II and III subequal, rarely antennal segment III longer (no more than 2 times). Metafemora without two parallel rows of spines ventrally..**10**

10 (11) Posterior margin of pronotum conspicuously denticulate .... ***Coriomeris* Westwood, 1842** (12 species)

11 (10) Posterior margin of pronotum unarmed. **12**

12 (17) Antenniferous tubercles terminating in spine directed more or less distinctly forward...**13**

13 (14) Antennal segment IV distinctly longer and thicker than III. Pro- and mesofemora dentate, with one big and few small spines subapically. Head dorsally, pronotum and scutellum covered with long and dense pubescence ....***Loxocnemis* Fieber, 1860** (1 species)

14 (13) Antennal segment IV distinctly shorter and only slightly thicker than antennal segment III. Pro- and mesofemora unarmed or granulate, mesofemora with only one small spine or without a spine subapically. Head dorsally, pronotum and scutellum at most with short pubescence **15**

15 (14) Antennal segment IV less shorter (0.75–0.85 times) and thicker than antennal segment III. Profemora and mesofemora with only one small spine subapically or unarmed .... ***Anoplocerus* Kiritshenko, 1926** (3 species)

16 (15) Antennal segment IV much shorter (0.42 times) and slender than antennal segment III. Pro- and mesofemora unarmed... ....***Microtelocerus* Reuter, 1900** (1 species; Figs 21–23)

17 (12) Antenniferous tubercles obtuse or, if terminating in spine, this is curved inwards, hook-shaped. **18**

18 (19) Antennal segment I with conspicuous spine-like tubercles laterally, each with an apical seta. Humeral angles of pronotum armed with a distinct tooth. Mandibular plates reaching anterior margin of clypeus, well developed .... ***Bothrostethus* Fieber, 1860** (1 species)

19 (18) Antennal segment I without such tubercles. Humeral angles of pronotum unarmed. Mandibular plates not conspicuously developed 20

20 (21) Metafemora with group of spines apically, 2–3 of the spines larger than remaining ones ....***Ceraleptus* A. Costa, 1847** (5 species)

21 (20) Metafemora with a single spine apically ....***Nemocoris* R. F. Sahlberg, 1848** (1 species)

22 (9) Antennal segment II distinctly longer than segment III. Metafemora bearing two parallel rows of spines on their ventral surface, between which the tibia could rest............. ***Urartucoris* P. V. Putshkov, 1979** (1 species; Figs 2–4)

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Appendix

Translation of the original descriptions published in Russian (Putshkov 1979):

Urartucoris P. Putshkov, gen. n.

Type species. *Urartucoris ermolenkoi* P. Putshkov, sp. n.

Entire body completely scattered over with hard black spinules originating from small tubercles, which are less developed on ventral surface of the body. Width of head across eyes nearly equal to head length. Antennae robust, covered with hard spinules, and so are the legs. Antennal segment II distinctly longer than segment III. Pronotum slightly sloping anteriad, its anterior margin forming a collar, divided from lateral margins by deep furrow, which is best visible in dorsal view. All margins of pronotum without setae, its lateral angles rounded, without spines or processes. Metacoxae convergent. Metafemora bearing two parallel rows of spines on their posterior surface, between which the tibia can rest.

The new genus belong to the subfamily Pseudophloeinae, differing from all its Palaearctic representatives in very long antennal segment II, wide pronotal collar, and two nearly identical rows of spines on metafemora, the spines in the rows stand in nearly equal distances. It resembles the genus *Ceraleptus* (especially *Ceraleptus gracilicornis* H.-S.) in the degree of convergence of metacoxae but it differs, apart from the above mentioned generic characters, in robust antennae and body covered with hard spinules.

Urartucoris ermolenkoi **P. Putshkov, sp. n.**

(see figure)

Body dorsally blackish-brown with dense black punctures, ventrally pale brown with black spots. Body length 11–11.2 mm, body width (at level of last quarter of body) 4.5–4.8 mm. Head length 1.95–2.1 mm, head width including eyes 1.9 mm, between eyes 1.5 mm. Total length of antennae 5–5.5 mm, ratio of antennal segments 22–28 : 30–33 : 22–25 : 24–25. Lateral processes of antenniferous tubercles bent around antennal bases in form of annulus, in dorsal view it seems that antennae originate at bottom of a bowl. Tubercles on head big, bearing setae 2–3 times longer than height of tubercles. Antennae dark brown with antennal segment I black. Antennal segment I obovate, elongate, slightly curved towards base, apically 1.3–1.4 times wider than segment II. Segments II and III gradually widening (from 0.15 to 0.24 mm) towards apex, as wide as segment IV. Segment II 1.35 as long as segment III. Setae covering antennae nearly as long as width of segments II and III. Rostrum reaching mesocoxae.

Length of pronotum 2.1 mm, width across humeral angles 3.4–3.65 mm, across pronotal collar 1.9 mm, equally wide as head across eyes. Anterior portion of pronotum bearing large setiferous tubercles, the same as on the head. Anterior portion of pronotum paler than its posterior portion, darkened near lateral margins and along midline. Tubercles on the posterior portion of the pronotal disk lower, setae shorter, punctures more dense and darker. Sculpture of scutellum and the coriaceous part of hemelytra the same as on posterior surface of pronotum, except the punctures on clavus being larger.

Metacoxae convergent, as far as 2/3 of width of tibia or 1/4 of width of coxal cavity. Spines in both rows on metafemora nearly the same, regularly shortening towards base of femur. Each row including more than ten spines, two to four being large. Mesofemora with two small spines or none. Profemora completely dark, meso- and metafemora pale, apically darkened, especially dorsally. Metatibiae darker than pro- and mesotibiae. Tarsi dark, length ratio of metatarsal segments 15 : 4 : 7. Legs covered with black semierect setae, setae on tibiae nearly as long as half of the tibia width, those on femora nearly as long as the large spines.

Abdomen ventrally pale with isolated dark spots, forming two interrupted stripes in lateral midlines (half the distance between connexivum and ventral midline of abdomen). Connexivum dark with pale spots.

Material. 1 ♀ (holotype), Nakhichevanskaya ASSR: 6 km north of village Bilav, 1700 m, 22 V 1966 (V. M. Ermolenko); 1 ♀, 0.5 km east of village Ak-Dar, 2000 m, 19 VII 1977 (P. V. Putshkov). Holotype deposited in Institute of Zoology, AN USSR, and paratype in Zoological Institute AN SSSR in Leningrad.

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Taxonomic changes in some predominantly Palaearctic distributed genera of Drymini (Heteroptera, Rhyparochromidae)

Előd Kondorosy[1,†]

1 *Pannon University, Department of Animal Science, H-8360 Deák F. u. 16., Keszthely, Hungary*

† *urn:lsid:zoobank.org:author:637ACD73-2A1F-41CA-918D-1C37D1B0F341*

Corresponding author: *Előd Kondorosy* (kondorosy@georgikon.hu)

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Abstract

The history of the taxonomic research of Rhyparochromidae and especially Drymini is briefly reviewed. Two new species level synonyms are proposed: *Taphropeltus javanus* Bergroth, 1916, **syn. n.** = *T. australis* Bergroth, 1916, **syn. n.** = *Brentiscerus putoni* (Buchanan White, 1878). A monotypic new genus, *Malipatilius* **gen. n.** (type species: *Scolopostethus forticornis* Gross, 1965 from Australia) is established.

Keywords

Rhyparochromidae, Drymini, new synonyms, new genus, Palaearctic Region, Oriental Region, Australia

Introduction

The knowledge on the taxonomy of the true bugs (Hemiptera: Heteroptera) and among them the family Rhyparochromidae developed unevenly during the past more than 250 years (Fig. 1). From Linnaeus till the end of the 19th century the European fauna was most intensively studied. The fauna of the temperate and tropical Americas started to receive more attention from the second half of the century; among others, the work of C. Stål, W. L. Distant and P. R. Uhler is outstanding. The first twenty years of the

20th century was the Golden Age of the research on the Oriental fauna thanks primarily to E. Bergroth, G. Breddin and W. L. Distant). Between the first and second World Wars the research intensity decreased globally except of the Nearctic region where important works were published by H. G. Barber and others. In the 1960's–1980's the research underwent an active period, and a high number of new taxa was described especially from the Afrotropical and Australian (+ Pacific) Regions, but also from other regions; the activity of J. A. Slater and G. G. E. Scudder, furthermore A. C. Eyles, R. E. Linnavuori, M. Malipatil and T. E. Woodward was especially significant. In the last twenty years the descriptive activity slackened again.

The species occurring in more than one zoogeographical regions are included only once in Fig. 1: in the region of the type locality. Therefore the known species number in each region is more or less higher than the listed one (Palaearctic: 475:442, Oriental: 456:339, Afrotropical: 544:430, Australian: 360:305, Nearctic: 258:206, Neotropical: 393:277). These differences refer to the many common species between certain regions (especially Palaearctic and Oriental or Afrotropical; and Nearctic and Neotropical regions).

The situation in respect of the tribe Drymini is similar to the general trends of Rhyparochromidae. This tribe is of worldwide distribution but in the Western Hemisphere the species richness is much lower (and only one species reaches the Neotropical area in Middle America). A good characterization of the world distribution of the Drymini (and of the other Rhyparochromidae) was given by Slater (1986) in his excellent work but this is the only tribe which dispersion is not evaluated in Slater's interpretations.

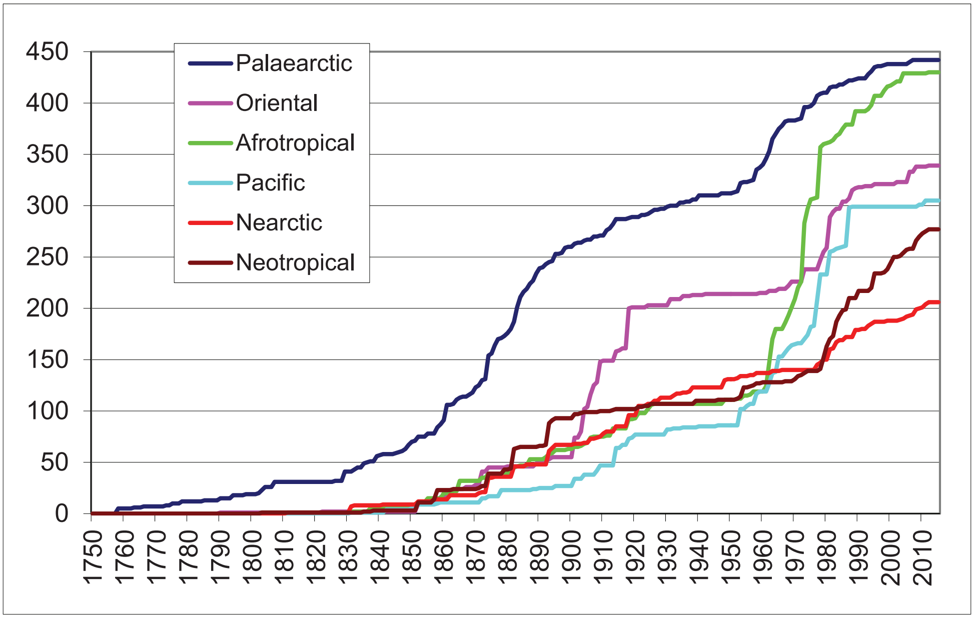

Figure 1. Number of described valid species of the family Rhyparochromidae from the main zoogeographical regions.

Members of Drymini are usually moderately vagile. This might partly explain the fact that only a few species are distributed in more than one zoogeographical area. Most of these species occur in China where they center the Oriental areas but more or less broadly extend to the neighbouring Palaearctic territories or vice versa. Therefore the species numbers described from the each region are only slightly lower than the actual number of the species known in the respective areas (Palaearctic: 83:87, Oriental: 71:79, Afrotropical: 69:72, Australian: 25:26, Nearctic: 34:36, Neotropical: 1:1).

Examining the history of the genus and species description in Drymini, the following things can be observed (Fig. 2): during the 19th century 12 genera of Drymini were described, 11 of them from the Palaearctic Region. Of the 65 discovered species 51 have Palaearctic distribution. In the first quarter of the 20th century 18 genera and 42 species were described (among them 14 genera and 30 species from southeast Asia). Before World War II the Nearctic species were most intensively studied. The knowledge of the Drymini of the Australian Region was developed extremely thanks to Gross (1965): he described 7 of the known 9 genera and 20 of the 25 species. The Afrotropical region was most intensively studied betwen 1950 and 2000; 7 of the 10 known genera and 65 of the 69 known species were described during these fifty years.

The species described before the activity of F. X. Fieber were placed in large "general" genera as *Lygaeus* Fabricius, 1794, *Pachymerus* Lepeletier et Serville, 1825, or

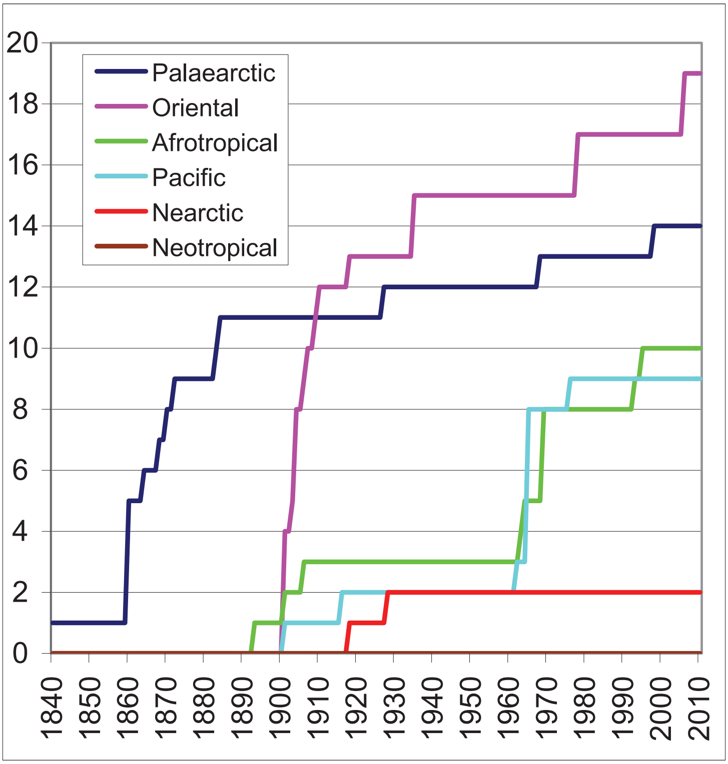

Figure 2. Number of described valid genera of the tribe Drymini from the main zoogeographical regions.

Rhyparochromus Hahn, 1826. Fieber proposed six genera in the Palaearctic Drymini. For the coming few decades the European genera were used to accommodate several new extrapalaearctic species; since most species occurring in the Nearctic Region belong to shared genera it was justified in many cases. Bergroth and Distant were the first to describe several extrapalaearctic genera in the beginning of the 20th century. As a result of their activity, the use of the Palaearctic genera became more restricted. Currently several of these have already been transferred to other genera, but some species have remained "forgotten" or are of uncertain status.

The aim of this paper is to correct some of these incorrect combinations.

Material and methods

Type and non-type specimens of Drymini of the following institutions were examined: Natural History Museum, London (BMNH); Finnish Museum of Natural History, Helsinki (FMNH); Hungarian Natural History Museum, Budapest, Hungary (HNHM); Moravian Museum, Brno, Czech Republic (MMBC); National Museum of Natural History (Naturalis), Leiden, the Nederlands (RMNH); Natural History Museum, Vienna (NHMW); Tirolese Regional Museum (Ferdinandeum), Innsbruck (TLMF); Zoological Museum, Amsterdam (ZMAN), and Natural History Museum, Berlin (MFNB).

Results

Distribution of Palaearctic genera of Drymini

As it was pointed out before, most species of Drymini are restricted to a single zoogeographical region. Similarly, most of the genera are also restricted to a single region. As an example, *Ischnocoris* Fieber, 1860, *Notochilus* Fieber, 1864, *Orsillodes* Puton, 1884, and *Thaumastopus* Fieber, 1870 are of exclusively Palaearctic distribution.

Hidakacoris Tomokuni, 1998 is currently known only from Japan, but there are some undescribed Oriental species which belong to this genus too.

All more widely distributed Palaearctic genera (13) extend to the Oriental region; 7 of them are found only in these two regions. Palaearctic genera containing species extending to Oriental areas are *Gastrodes* Westwood, 1840, *Lamproplax* Douglas & Scott, 1868, and *Trichodrymus* Lindberg, 1927. It is also frequent that an Oriental or pantropical genus has some species inhabiting marginal areas of the Palaearctic Region, most frequently China and Japan. Such genera are *Appolonius* Distant, 1901, *Mizaldus* Distant, 1901 (*Neomizaldus* Scudder, 1968, is probably a junior synonym of the latter), *Paradieuches* Distant, 1883, *Potamiaena* Distant, 1910, and *Retoka* China, 1935.

Drymus Fieber, 1860, is a genus centered in the Holarctic but also having some described and a few undescribed Oriental species.

Taphropeltus **Stål, 1872**

Taphropeltus is a predominantly Palaearctic genus which currently contains one exotic species, too (two other Palaearctic species are reaching the northern part of the Afrotropical region). The Australian *Taphropeltus australis* Bergroth, 1916, was originally included in this genus (Bergroth 1916b). Gross (1965) described *Isopeltus* Gross, 1965, and designated *T. australis* as its type species. Subsequently Slater (1976) synonymized *Isopeltus* with *Brentiscerus* Scudder, 1962 (type species: *Scolopostethus putoni* Buchanan White, 1878).

The other tropical *Taphropeltus* species is *T. javanus* Bergroth, 1916, described from Java, Indonesia (Bergroth 1916a).

Both *T. australis* and *T. javanus* show similarity to the Palaearctic members of *Taphropeltus*, but they are readily distinguished from the true *Taphropeltus* species among others by having a more strongly developed pronotal collar and three rows of claval punctures. Based on the original descriptions only, Scudder (1962) presumed that the two species are congeneric. Because no important differences between the Australian and Javanese specimens could be found which would justify considering them as representing two different species, furthermore there specimens were seen from islands between the two type localities (Bali, Flores, Sumba, New Guinea: none of them was previously known as inhabited by any *Taphropeltus* species), the two species are considered as conspecific.

Both species were described in 1916. Both of the two journal issues contain explicit information about the date of the publication: the description of *T. javanus* is dated to 12 September 1916, while the article describing *T. australis* was published during October of the same year.

Furthermore, I compared the lectotype and additional non-type specimens of *Brentiscerus putoni* (Buchanan White, 1878), which is described from New Zealand, with the mentioned species. They are virtually identical. As a conclusion, the following nomenclatural changes are required:

Brentiscerus putoni **(Buchanan White, 1878)**

http://species-id.net/wiki/Brentiscerus_putoni

Scolopostethus putoni Buchanan White, 1878: 75. Syntypes (♂, ♀): New Zealand; BMNH!

Taphropeltus javanus Bergroth, 1906a [12 Sep.]: 220. Syntype(s): [Indonesia:] Java, Mt. Tengger; lost? **syn. n.**

Taphropeltus australis Bergroth, 1906b [Oct.]: 13. Syntype(s): Australia: Victoria; lost? **syn. n.**

Type material examined. ***Scolopostethus putoni.*** **Lectotype** (designated by Scudder 1967): round label with purple margin LECTOTYPE // round label with red margin

TYPE // hw: New Zealand // Scolopostethus / putoni B.W. // Brentiscerus / putoni (Wk.) / ExDr. 77 // printed: Pres. by / Perth Museum / B. M. 1953-629. //pink hw. Scolopostethus / putoni White 1878 / G.G.E. Scudder 1965 / LECTOTPYE (female, BMNH). **Paralectotypes**: round label with blue margin PARALECTOTYPE // round label with yellow margin COTYPE // hw: New Zealand // Scolopostethus / putoni B.W. // printed: Pres. by / Perth Museum / B. M. 1953-629. (1 male, 2 females all with the same labels, BMNH).

The types of ***Taphropeltus australis*** and ***T. javanus*** are probably lost, no references mentioning them could be traced and they could not be found in FMNH where most of Bergroth's collection is deposited. Taxonomic decisions were made based by examination of non-type specimens from Australia, New Guinea and Indonesia, respectively.

Additional material examined. INDONESIA. Dammerman / O. Soemba / 700 m 249 / Kananggar / v. 1925 (1 male, RMNH); Dammerman / Idjen 1850 m / Ongop-ongop / 19. V. 1924 / No. 17 (RMNH); Banjoewangi / JAVA 1909 / MacGillavry (1 female, HNHM); INDONESIA: centr. Java / Pokalongan Reg., Bandar / 1050 m / 2.1998., leg. S. Jakl (1 female, NHMW); IDN-Bali Isl. / Bedugul reg. 1300m / Tamblingan lak.N.R. / S. Jakl lg., 3.2005 (1 female, MMBC); Sunda Exp. Rensch / W.-Flores / Rana Mêsé / 20.–30.6.1927 (1 male, MFNB); Sumba (E) / Luku-Melolo N. R. / 550 m, VII. 2005 / leg. S. Jakl (2 ex., NHMW). **PAPUA NEW GUINEA.** New Guinea / Mt. Kaindi / 2400 m / 15-16. IV. 1965 // Nr. 34 / Coll. Balogh et / Szent-Ivány (1 female, HNHM); Austr. New Guinea / Wau 1250 m / 10.-20. XI. 1972 / J. v. d. Vecht (1 male, ZMAN); Museum Leiden / Neth. New Guinea Exp. / Star Range 1260 m / Sibil / 15. VI. 1959 // Taphropeltus 3 (handwriting) (1 female, RMNH); **AUSTRALIA**. N.S.W. / Cassilis "Kuloo" / Station 710 m / 31°50'9"S, 150°8'E // 25.X.2000 / Hung. Entom. Exped. / leg. A. Podlussány, G. Hangay & I. Rozner (1 male, HNHM); N.S.W. / Karai State Forest / Kookaburra, 943 m / 31°1'4"S, 152°20'2"E // 27–28.X.2000 / Hung. Entom. Exped. / leg. A. Podlussány, G. Hangay & I. Rozner (1 female, HNHM); N.S.W., Putty / Road, Cases Courvert / 10–11.I.2006 leg. G. Hangay, I. Rozner & A. Podlussány (1 male, 2 female, HNHM); N.S.W. / Milton, 21.I.2006 / leg. A. Podlussány, G. Hangay & I. Rozner (1 female, HNHM); New South Wales / J.P. Duffels // Eucalyptus / forest // 48 km N of Singleton / 15 I 1983 (1 female, ZMAN). **NEW ZEALAND**. C. Darwin / 85–119. (1 male, BMNH); (handwriting): Kaitaia NZ / 1 VIII 23 / JG Myers // Base of prairie grass // (printed): J. G. Myers Coll. B.M. 1937-789. (1 male, BMNH).

The population of *B. putoni* in New Zealand possibly originates from Australia, where all congeners are native. There are no autochthonous Drymini species in New Zealand, only some introduced species occur, as *B. putoni*, *Grossander major* (Gross, 1965) and *Paradrymus exilirostris* Bergroth, 1916 (Malipatil 1977). Since it feeds on *Eucalyptus* seeds (Gross 1965), *B. putoni* likely was introduced with *Eucalyptus* trees.

The other species of the genus *Taphropeltus* species which are partly of extrapalaearctic distribution are *T. nervosus* (Fieber, 1861) and *T. ornatus* Linnavuori, 1978. Both of these species are morphologically rather distinct from the type species, *T. hamulatus* Thomson, 1870, and the other known Palaearctic members of the genus. It is sure that at least *T. ornatus* belongs to another genus, as it also was suggested by Péricart (1999). This problem needs further investigation.

Eremocoris **Fieber, 1860, and** ***Scolopostethus*** **Fieber, 1860**

Although the West Palaearctic species of this complex are easy to classify into one of the two genera, *Eremocoris* and *Scolopostethus* are morphologically very close to each other. Some of the described species and also certain undescribed species from the Afrotropical and Oriental Regions are morphologically transitional between *Eremocoris* and *Scolopostethus*. E.g., the African *S. maumus* Scudder, 1962, is apparently very closely related to *E. africanus* Slater, 1964. The possible synonymy of them was already suggested by Slater (1972).

Species currently placed to *Scolopostethus* live in all major zoogeographic regions, with many undescribed Oriental species. The Australian *S. forticornis* Gross, 1965, belongs to a different, so far undescribed genus which is described below as new. Each of the African *S. daulias* Linnavuori, 1978 and *S. kilimandjariensis* Scudder, 1962 represent another undescribed genus. *S. daulias* seems to be related with *Taphropeltus ornatus* Linnavuori, 1978, but their relationship needs further investigation. *S. kilimandjariensis* belongs to a new genus but its description must be done in frames of a comprehensive study on all other Afrotropical members of the *Scolopostethus–Eremocoris* complex.

Malipatilius **gen. n.**

urn:lsid:zoobank.org:act:1B42F8DE-6D15-4B14-BE9B-BD02DEAF79FC
http://species-id.net/wiki/Malipatilius

Type species. *Scolopostethus forticornis* Gross, 1965, by present designation.

Description. *Body* elongate oval, dull, extensively punctate, dorsally glabrous (Fig. 3).

Head pentagonal, with dense fine punctures. Eyes small, very prominent. Ocelli well developed, located very far from each other, near the eyes. Antenniferous tubercle curved laterally. *Antenna* very robust, subclavate.

Pronotum without anterior collar, transversal furrow deep, disk densely punctured. Anterior and posterior margins straight, lateral margin concave, explanate but not widened at transversal furrow. Anterior lobe more globose in male, lateral margin partially parallel here. *Scutellum* elevated at middle. *Fore wing.* Clavus with 3 regular rows of punctures. Corium evenly and densely punctate, nearly parallel, costal margin only slightly concave subbasally, apical margin straight. *Thoracic sternum* punctate except

Figure 3. *Malipatilius forticornis* (Gross, 1965), new combination.

submedian parts of mesosternum. *Legs* robust, fore femur strongly incrassate, especially in male, with two rows of spines and a very large spine in inner row.

Abdomen with dense decumbent pilosity, lateral portion of intersegmental suture between sternites IV–V curved anteriorly, not reaching lateral margin and sublateral furrow; trichobothrial pattern as typical in Drymini.

Included species. The genus is apparently not monotypic, because besides of the type species very probably congeneric specimens were seen at least from Java, Kalimantan and the New Hebrides.

Discussion:. The type species of *Malipatilius* gen. n. was originally placed into the genus *Scolopostethus*. The diagnostic characters of the two genera are presented in Table 1. A typical *Scolopostethus* species, *S. ornandus* Distant, 1904 is imaged for comparison on Fig. 4. *Faelicianus* Bergroth, 1918, is perhaps the sister genus of *Malipatilius* gen. n. This genus has a pale wide lateral carina on pronotum, which is broadened at transver-

Figure 4. *Scolopostethus ornandus* Distant, 1904.

Table 1. Diagnostic characters of *Malipatilius* gen. n. and *Scolopostethus.*

Character	***Malipatilius* gen. n.**	***Scolopostethus***
Eye	hind margin straight	rounded
Antennal segment I surpassing apex of head	short, less than half length of segment	longer, more than half length of segment
Length : width ratio of antennal segment III	~3.5	more than 5
Colour of pronotum	unicolorous dark (sometimes posteriorly slightly paler)	tricoloured
Lateral margin of pronotum	invariably dark	always pale on middle
Pronotal margin at transverse furrow	virtually not widened; strongly concave	distinctly widened, straight or slightly concave
Anterior pronotal lobe of male in side-view	strongly emerging, approximately as high as posterior margin	slightly emerging, nearly evenly sloping

Transversal furrow	deep	shallow
Posterior pronotal margin	straight	concave
Scutellum in side-view	convex	flat
Number of rows of punctures on clavus	3 (inner row sometimes incomplete)	3.5–4
Punctures on corium	even and dense	inner part with smooth parts
Apical margin of corium	straight	slightly S-shaped

sal impression, therefore the pronotum is evenly convex laterally. The antenna is also slender, much more than even in *Scolopostethus*. Another known genera of Drymini, e.g. the superficially similar *Salaciola* Bergroth, 1893, which sometimes has similar colour and explanate pronotal carina, are certainly not closely related.

Etymology. Patronymic, named after and dedicated to Mallik B. Malipatil, recognizing his excellent contributions to various groups of Australian Heteroptera, particularly Rhyparochromidae. Gender masculine.

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RESEARCH ARTICLE

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New data on aphid fauna (Hemiptera, Aphididae) in Algeria

Malik Laamari[1], Armelle Coeur d'Acier[2], Emmanuelle Jousselin[2]

1 *LATPPAM Laboratory, Department of Agronomy, Institute of Agronomic and Veterinary Sciences, University of Batna, Algeria* **2** *INRA, UMR CBGP (INRA/IRD/Cirad/Montpellier SupAgro), Campus International*

Corresponding author: *Malik Laamari* (laamarimalik@yahoo.fr)

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Abstract

A survey of aphids was carried out during the period 2008–2011 in different regions of Algeria by collecting and identifying aphids and their host plants. Aphids were collected from 46 host plants. Forty-six species were reported including thirty-six species which were recorded for the first time in this country and thirty species which were recorded for the first time in the Maghreb (North Africa). This study extends the number of known Algerian aphid to 156 species.

Keywords

Aphids, biodiversity, Algeria, Maghreb, North Africa

Introduction

The aphid fauna of North Africa has been poorly studied. One hundred and fifty eight species have been recorded from Morocco (Mimeur 1932, 1934, 1935a, 1935b, 1937, 1941, 1942, Blackman and Eastop 1994, 2000, 2006, Sekkat 1987). One hundred and three species are recorded from Tunisia (Bodenheimer and Swirsky 1957, Blackman and Eastop 1994, 2000, 2006, Ben Halima-Kamel 1991, 1995, Ben Halima-Kamel and Ben Hamouda 1993, 1998, 2004, 2005, Boukhris-Bouhachem et al. 1996, Boukhris-Bouhachem et al. 2007). Ninty nine species are listed from Egypt (Theobald

1922, Habib and El Kady 1961, Darwish 2009). Aphids in Libya are reprisented by seventy three species (Trotter 1912, 1914, Damiano 1961, 1962, Blackman and Eastop 1994, Ahmeid Al Nagar 2000, Ahmeid Al-Najar and Nieto Nefrya 1998). The Algerian aphid fauna is now partly known (Mimeur and Bernard 1944, Bodenheimer and Swirsky 1957, Remaudière and Leclant 1974, Dartigues 1993, Blackman and Eastop 1994, 2000, 2006, Laamari and Akkal 2002). Laamari et al. (2010) present a list of aphids and their host plants in Algeria. In this important publication, 120 aphid species are listed and commented/discussed. The bibliography of most papers concerning the aphid fauna of the country is provided.

Material and methods

The regions choosen for sample collection belonged to different bioclimatic stages. The regions of Annaba, Tarf and Algiers are located on the Mediterranean coast and are characterized by a humid and sub humid climate. Other regions (Guelma, Constantine, Setif and Oum El Bouaghi) are located on the high plateaus and high plains, where cereal crops are cultivated (semi arid climate). Khenchela, Batna and Biskra are located on the slopes north and south of the Saharan Atlas. Their natural vegetation is dominated by steppe plants. Ouargla and Ghardaia are located almost in the center of the Algerian Sahara (arid climate). Their natural vegetation is composed of desertic plants (Fig. 1).

This study, conducted between 2008 and 2011, considers only the new aphid species of Algeria and the species already mentioned but without specified host plants. Specimens were collected from wild and cultivated plants, tree and shrubs bearing aphid colonies. The aphids were preserved in 75% ethyl alcohol until their prepara-

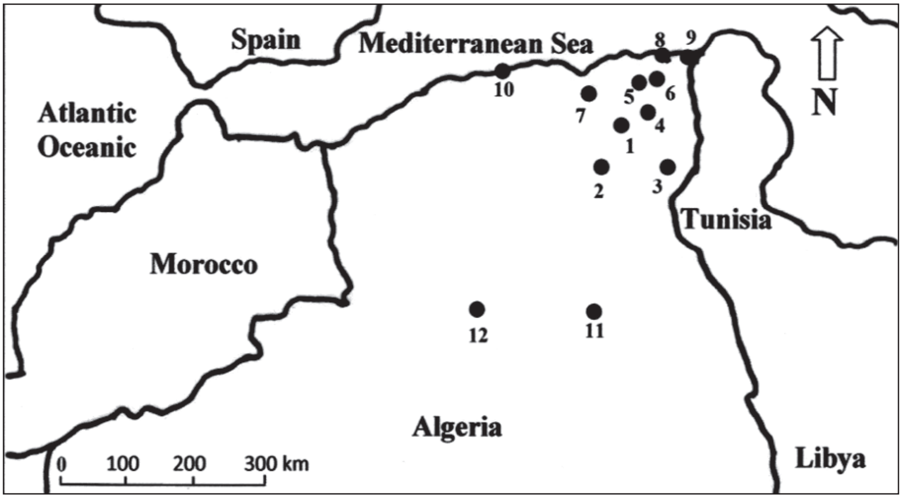

Figure 1. Map of the regions where samples were collected. **1** Batna **2** Biskra **3** Khenchela **4** Oum El Bouaghi **5** Constantine **6** Guelma **7** Setif **8** Annaba **9** Taref **10** Algiers **11** Ouargla **12** Ghardaia

tion for slide-mounting. They were identified using the keys of Blackman and Eastop (1994, 2000), Nieto Nafria et al. (2002, 2005) and Remaudière et al. (1985). The nomenclature used was that proposed by Remaudière and Remaudière (1997). The aphid preserving techniques are mainly based on the method of Hille Ris Lambers (1950). The majority of the studied and identified specimens were deposited in the insect collection of the Department of Agronomy, University of Batna (Algeria) and a minor part of aphids were deposited in the collection of the National Institute of Agronomic Research (INRA) at the CBGP in Montpellier, France.

Results

During this study, 320 samples were collected from the investigated regions. A total of 46 aphid species were reported including 36 species which were recorded for the first time in the country and 30 species which were recorded for the first time in the Maghreb (North Africa). The presence of 10 species already reported from Algeria was confirmed. Aphid species were listed in systematic category alphabetically, including the host plant and region for each aphid species (Table 1).

Table 1. List of aphid species present/found in Algeria.

Aphid species	Host plants	Regions
***Acyrthosiphon kondoi* Shinji, 1938	*Fagonia glutinosa* Delile	Biskra
Aphis acanthoidis (Börner, 1940)	*Carduncellus plumosus* Pomel	Khenchela
***Aphis acetosae* Linnaeus, 1761	*Rumex crispus* L.	Batna
***Aphis astragali* Ossiannilsson, 1959	*Astragalus armatus* Willd	Batna
***Aphis balloticola* Szelegiewicz, 1968	*Balota nigra* L.	Batna
***Aphis cytisorum* Hartig, 1841	*Calicotome villosa* (Poiret) Link	Guelma
**Aphis illinoisensis* Shimer, 1866	*Vitis vinifera* L.	Taref, Batna
***Aphis impatientis* Thomas, 1878	*Rosa damascena* Mill.	Biskra
***Aphis intybi* Koch, 1855	*Cichorium intybus* L.	Taref
***Aphis medicaginis* Koch, 1854	*Ononis angustissima* Lam.	Khenchela
***Aphis middletonii* Thomas, 1879	*Taraxacum officinale* F.H. Wigg	Khenchela
***Aphis potentillae* Nevsky, 1929	*Potentilla reptans* L.	Batna
***Aphis salviae* Walker, 1952	*Lavandula multifida* L.	Batna
***Aphis stroyani* Szelegiewicz, 1961	*Picris echioides* L.	Guelma
***Aphis thomasi* (Börner, 1950)	*Knautia arvensis* (L.) J.M. Coult	Batna
***Aphis umbrella* (Börner, 1950)	*Malva sylvestris* L.	Batna
Aphis verbasci Schrank, 1801	*Verbascum thapsus* L.	Batna
**Brachycaudus persicae* (Passerini, 1860)	*Ononis natrix* L.	Batna
**Brachyunguis tamaricis* (Lichtenstein, 1885)	*Tamarix gallica* L.	Biskra
**Chaitophorus leucomelas* Koch, 1854	*Populus alba* L.	Guelma
Cinara cedri Mimeur, 1936	*Cedrus atlantica* (Endl.) G. Manetti ex Carrière	Batna

Aphid species	Host plants	Regions
***Cinara juniperi* (de Geer, 1773)	*Juniperus oxycedrus* L.	Batna
**Clypeoaphis suaedae* (Mimeur, 1934)	*Suaeda fruticosa* Forsk.	Biskra
Capitophorus elaeagni (del Guercio, 1894)	*Silybum marianum* Garten, *Lawsonia inermis* L.	Biskra
Dysaphis tulipae (Boyer de Fonscolombe, 1814)	*Iris germanica* L.	Batna
**Greenidea ficicola* Takahashi, 1921	*Ficus retusa* L.	Algiers
***Indiochaitophorus furcatus* Verma, (1970)	*Ulmus campestris* L.	Biskra
***Liosomaphis berberidis* (Kaltenbach, 1843)	*Achillea santolina* L.	Batna
***Macrosiphoniella grandicauda* Tak. & Mor.,1963	*Artemisia herba-alba* Asso	Biskra
Nasonovia ribisnigri (Mosley, 1841)	*Andryala integrifolia* L., *Geranium pusillum* L.	Batna
***Pterocomma pilosum* Buckton, 1879	*Salix pedicellata* Desf.	Batna
***Semiaphis heraclei* (Takahashi, 1921)	*Torilis nodosa* (L.) Gaertn.	Khenchela
Sipha maydis Passerini, 1860	*Digitaria sanguinalis* (L.) Scop	Guelma
***Sitobion lambersi* David, 1956	*Bromus squarrosus* L.	Batna
***Stomaphis pini* Takahashi, 1920	*Pinus halepensis* Mill.	Batna
***Therioaphis riehmi* (Börner, 1949)	*Trigonella anguina* Delile	Biskra
***Tinocallis takachihoensis* Higuchi, 1972	*Ulmus campestris* L.	Biskra
***Uroleucon ambrosiae* (Thomas, 1878)	*Carthamus lanatus* L.	Batna
***Uroleucon aeneum* (Hille Ris Lambers, 1939)	*Onopordum Illyricum* L.	Batna
***Uroleucon bifrontis* (Passerini, 1879)	*Dittrichia viscosa* (L.) Greuter	Khenchela
***Uroleucon carthami* (Hille Ris Lambers, 1948)	*Carthamus lanatus* L.	Batna
***Uroleucon chrysanthemi* (Oestlund, 1886)	*Calendula arvensis* L.	Khenchela
Uroleucon compositae (Theobald, 1915)	*Borago officinalis* L.	Batna
Uroleucon erigeronense (Thomas, 1878)	*Erigeron canadensis* L., *A. herba-alba* Asso	Khenchela
***Uroleucon inulicola* (Hille Ris Lambers, 1939)	*Senecio vulgaris* L.	Batna
Uroleucon pilosellae (Börner, 1933)	*Leontodon hispidus* L.	Biskra

* = species reported for the first time in Algeria, ** = species reported for the first time in the Maghreb

Discussion

With 46 species, this survey constitutes the most important contribution to the knowledge on aphid diversity in Algeria. Organization of the similar local studies would to play an important role in the applied entomological studies and may add more species to Algerian aphid fauna. There is a very large volume of literature about all the major pest aphid species and two factors that have the greatest influence on intraspecific variation in aphids: the life cycle and the host plant. Among the species inventoried, *Aphis illinoisensis* is the aphid that has the greatest agricultural importance. This invasive aphid was reported for the first time in the Mediterranean from southern Turkey in 2002, and identified as a new possible threat to the respective grape-growing areas (Remaudière et al. 2003). A general historical set of invasive grape aphid detection is as follows: 2002 in southern Turkey (Remaudière et al. 2003), 2005 in Crete - Greece

(Tsitsipis et al. 2005), 2007 in Israel (Barjadze and Ben-Dov 2011), 2009 in Tunisia (Ben Halima-Kamel and Mdellel 2010). In Algeria this aphid was detected for the first time in 2007 in several regions of viticulture (Laamari and Coeur d´Acier 2010).

Greenidea ficicola is considered as another invasive species. It was encountered for the first time in 2007 on *Ficus nitida* in Tunisia (Ben Halima-Kamel 2009). In Algeria it was collected in April, 2008.

A total of 34 aphid species were collected on the steppe plants specific of the Saharian Atlas. This mountain range forms the boundary between the northern (Mediterranean area) and southern (African area) of Algeria. It is home to many endemic plants, which may harbour very specific and uncommon aphid species. All aphid species reported as new to Algeria and North Africa were found in this transition area (Batna, Biskra and Khenchela regions).

Conclusion

In this study, 36 aphid species were reported for the first time in Algeria, increasing the number of species known to be present in this country to 156. Given the high level of climatic and plant diversity in Algeria, the expansion of prospect activities to a larger number of plant species and environments would undoubtedly provide a more accurate picture of the Algerian aphid fauna and would increase the number of species known to be present in this country. Furthermore, prospect studies in the Sahara and steppe zones, which are know to have a highly endemic flora, might lead to the description of species new to science.

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RESEARCH ARTICLE

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A preliminary study on the distribution patterns of endemic species of Fulgoromorpha (Hemiptera, Auchenorrhyncha) in Iran

Fariba Mozaffarian[1]

[1] *Insect Taxonomy Research Department, Iranian Research Institute of Plant Protection, Tehran, 19395, P.O. Box 1454, Iran*

Corresponding author: *Fariba Mozaffarian* (mozaffarian@iripp.ir; faribamozaffarian@gmail.com)

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Abstract

Iran is known as the most complex and varied country in southwest Asia, in terms of geography, vegetation, climate and consequently biological diversity. The rather high number of recorded endemic species of Fulgoromorpha in Iran indicates a high potential for speciation in some areas.

In this study, in order to identify the endemic zones for Fulgoromorpha of Iran, three main biogeographic regions of the country were divided into 13 primary zones, mainly according to the distribution of published and unpublished locality records of endemic species. Using Venn diagrams and cluster analyses on the primary zones, 6 final endemic zones were recognized: Caspian zone, southern slopes of Alborz, Zagros Mountains, Kerman Mountains, Khorasan Mountains, and Baluchestan and Persian Gulf coasts. Then a similarity map was produced for endemic zones using a Multidimensional analysis (Alscal) and the differences between the positions of the same zones in the similarity and geographic maps were discussed.

Keywords

Zoogeography, Iran, Fulgoromorpha

Introduction

Iran is located in southwest Asia between the latitudes of 25°30' and 40° north and the longitudes of 44° and 63°30' east and has a surface area of 1,648,195 square kilometers. It is limited by central Asia, Caspian Sea, Caucasus Mountains and Aras

River to the north, Anatolian Plateau and Mesopotamian region to the west, Persian Gulf and Oman Sea which is connected to the Indian Ocean to the south and Afghanistan and Pakistan to the east. The major part of the land of Iran is covered by the Plateau of Iran, a triangle between the Alborz Mountain Range in the north, the Zagros Mountains in the west and the Sulaiman Mountain Range in Pakistan and Afghanistan.

According to Manuel Berberian (1981), the continental crust of Iran has been originally developed by some complex movements which made the plate of the Alborz and central Iran and then the Zagros and Arabian plate detach from the Gondwana supercontinent in the southern hemisphere, drift northwards and attach to Eurasia from Permian to late Miocene. Consequently some parts of the old Tethys have been recognized in some parts of the country (Ghorbani 2002).

In terms of biodiversity richness, Iran is considered as an extremely complex area and wide ranges in the extremes of altitude (below sea-level in shores of the Caspian sea to 5,770 m of the Damavan Mt.), climate (humid and nearly jungle-like forests in the north to arid places in Dasht-e Lut with less than 100 m annual rainfall) and temperature (from -35°C in the northwest to 70°C in the deserts of Dasht- e Lut) (Hedge and Wendelbo 1978, Frey and Probst 1986, Zohary 1963). The high biodiversity of the Iranian fauna is also the result of its location and the influences of four ecozones from north (Palaearctic and old periodical connections with the Nearctic by Bering Strait), south (Afrotropical from the Arabian Peninsula) and southeast (Oriental) (Madjnoonian et al. 2005).

Biogeographic studies in Iran have been carried out mainly on plants (Zohary 1963, 1973, Frey and Probst 1886, Hedge and Wendelbo 1978, Hangay and Szekely 2005). Those studies recognized three main biogeographic regions in Iran which are usually applied as useful framework and references in analyses: Hyrcanian, Irano-Turanian and Nubo-Sindian and also a small area in the west of Iran which is touched by the Saharo-Arabian region according to Zohary (1973) (Fig. 1).

The oldest zoogeographic division was performed by Zarudny (1911), an ornithologist who organized some trips to different parts of Iran during 1884–1904 and divided Iran into 9 zones: south Caspian Sea, northwest, Khorasan, Kerman, southwest, Sistan, Baluchestan, Karun plains and south coasts. In 1968, Anderson recognized 13 zones in his extensive study on endemic lizards of Iran: the central plateau, the Urmia basin, the Sistan basin, the Caspian region, the Khuzestan plain and Persian Gulf coast, Baluchestan and Makran coast, the Turkmen steppe, the Mogan steppe, the Zagross, the western foothills of the Zagros, the Kope Dag, the Alborz, the Islands of the Persian Gulf. Emeljanov (1974) considered Iran in the Sethian Desert Region in his Palaearctic biogeographic divisions and showed 2 subregions inside Iran: Sahara-Arabian (Makran mixed and Sind plane) and Irano-Turanian (Middlear eastern mixed (Armenian and Zagrossan), Hyrcanian Mountain, Iranian Mixed and Khorasan Mountain). Dlabola (1981) classified different habitats in Iran and described the origin of studied Auchenorrhyncha species in three groups: arboreal, eremian and oreal.

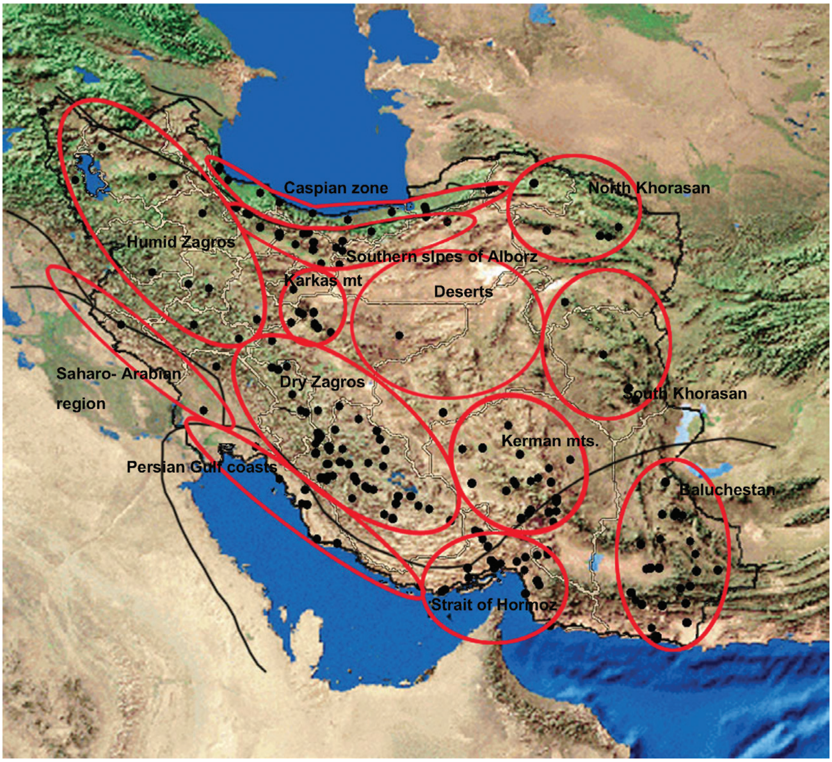

Figure 1. Distribution of endemic Fulgoromorpha of Iran, Phytogeographical regions (Black lines) (after Zohary 1973, altered by Frey and Probst, 1986 and Primary divisions (Red lines) suggested for the distribution pattern of endemic planthoppers of Iran.

A total of 235 species of Fulgoromorpha have been recorded from Iran since 1902 (Mozaffarian and Wilson 2011), 117 of which from 13 families have never been recorded from other parts of the world and are restricted to the borders of Iran according to our knowledge. The high endemism (nearly 50%) in the recorded fauna of Iran shows a high potential of speciation inside Iran. The aim of this study is recognizing distribution patterns and endemic areas for endemic species of Fulgoromorpha in Iran.

Materials and methods

A total of 473 locality records of 117 species of planthoppers endemic to Iran were gathered, 416 of which derived from publications, 48 were newly collected and identified species in the Hayk Mirzayans Insect Museum (HMIM), and 9 were studied in the Zoological Institute of the Russian Academy of Science (ZIN). Due to the lack of the exact locality data of 3 endemic species: *Phantia lactea* Rusiecka, 1902 (Flatidae), *Ph. putoni* Rusiecka, 1902 (Flatidae) and *Oliarus convergens (*Melichar, 1902) (Cixiidae), they were deleted from further analyses. Then the distribution maps were prepared using Arc Map 9.3. and the country was divided into 13 primary zones according to the distribution of the endemic planthoppers, topography, climate condition and published zoogeographic zones (Fig. 1). Venn diagrams and cluster analyses were performed using Gliffy venn diagram software and NTSYS (2.02g) (Rohlf 1998) to find the relationship between those primary zones and to identify the final zones. The input data for cluster analyses were qualitative data: 1 and 0 for presence and absence of any species in any division, respectively. The similarity between final endemic zones was shown by a similarity map using a multidimensional scaling analysis (Alscal) by SPSS.

Results and discussion

Hyrcanian district

This is a small area in northern Iran, from the Caucasian-Euxino-Hyrcanian province of the Euro-Siberian region (Frey and Probst 1986). The district is limited to the Alborz Mountain and Caspian Sea, stretches from Talesh in Azarbaijan in the west to Gorgan in the east and characterized by predominantly deciduous forests.

The district is considered as one zone (Caspian zone) in this study. Fifteen endemic planthoppers of Iran have been recorded from this zone, 9 of which are endemic to the region (Table 1 and Fig. 2). The high and wall-like Alborz Mountain separates the south coast of the Caspian Sea from the Irano-Turanian region. This barrier not only prevents the fauna from migrating to south parts but also limits the high humidity of the Caspian Sea to the north and produces two very different climatic regions in the northern and southern slopes which can be considered a major factor for differentiating the fauna of north Iran from other parts of the country. Most of the Iranian endemic species common between Hyrcanian and other regions are limited to the Alborz Mt. and are distributed in areas very close to the borders of the Hyrcanian district. *Malenia masirica* Dlabola, 1986 (Derbidae) is the only endemic planthopper recorded in all three main regions. There are only a few records of the presence of this species in Iran which belong mostly to the southern Zagros, the Nubo-Sindian region, close to Irano-Turan, and one record of a female specimen from the north of Iran, all made by Dlabola (1986), and the specimens are deposited in Prague. *Morsina persica* Melichar, 1902 (Nogodinidae) is the only endemic planthopper common between the Caspian zone and the Nubo-Sindian in spite of the distance and lack of records in the Irano-Turanian. The species was originally described from southeast of Iran by Melichar (1902) and there are also other published and unpublished records of this species from there, deposited in HMIM. However the only record of the presence of this species in the Hyrcanian district is made by Dlabola (1981) and he mentioned the species as an eremian faunal element which can be often found as oreal. According to this reference, the only specimen of this species from the north of Iran belongs to the museum of Plant Pests and Disease Research Institute, Tehran-Evin which is the

Table 1. List of endemic species of Iran, indicating endemic species of suggested endemic zones (Extracted from Mozaffarian and Wilson 2011 and new data).

Endemic species	**Caspian zone**	**Kerman Mountains**	**Zagros mountains**	**Khorasan Mountains**	**Southern Slopes of Alborz**	**Baluchestan and Persian Gulf coasts**
Family: Caliscelidae						
Adenissus baluchestanicus Dlabola, 1980						*
Adenissus isinus Dlabola, 1980						*
Adenissus zabolicus Dlabola, 1980				*		
Adenissus zahedanicus Dlabola, 1980						*
Aphelonema brunneolutea Dlabola 1994					*	
Perissana dlabolai Gnezdilov & Wilson, 2006						
Reinhardema pasagarda (Dlabola, 1982)			*			
Family: Cixiidae						
Duilius v-atrum (Dlabola, 1985)						
Cixius persicus Distant, 1907				*		
Myndus genocolus Dlabola, 1985						*
Myndus sarbazus Dlabola, 1989						*
Anoculiarus ornatus Dlabola, 1985		*				
Eumecurus apunctatus Dlabola, 1985						
Eumecurus baluchestanicus Dlabola, 1985			*			
Eumecurus octopus Dlabola, 1985						*
Eumecurus superstylus Dlabola, 1985		*				
Eumecurus transpunctatus Dlabola, 1985						*
Eumecurus vilbastei Dlabola, 1985						*
Hyalesthes restultus Dlabola, 1994			*			
Hyalesthes zabolicus Dlabola, 1985						
Oliarus convergens Melichar, 1902						
Pentastira bahtiaricus (Dlabola, 1981)			*			
Pentastira superspicata Dlabola, 1985			*			
Pentastira shul (Dlabola, 1985)			*			
Reptalus eremicus Dlabola, 1985						
Reptalus reductus Dlabola, 1994		*				
Reptalus ziaran Dlabola, 1985					*	
Family: Delphacidae						
Tropidocephala prasina Melichar, 1902						*
Muirodelphax amol Dlabola, 1981	*					
Pseudaraeopus curtulus Dlabola, 1960						*
Pseudaraeopus iranicus Dlabola, 1960						*
Ribautodelphax hyrcanus Dlabola, 1981	*					
Family: Derbidae						
Malenia isinica Dlabola, 1986						*
Malenia masirica Dlabola,1986						
Proutista jezeki Dlabola, 1981						*
Family: Dictyopharidae						
Callodictya kazeruna (Dlabola, 1986)			*			
Dictyophara albata Dlabola & Heller, 1962						

Endemic species	**Caspian zone**	**Kerman Mountains**	**Zagros mountains**	**Khorasan Mountains**	**Southern Slopes of Alborz**	**Baluchestan and Persian Gulf coasts**
Dictyophara exoptata Dlabola & Heller, 1962						
Dictyophara pazukii (Dlabola, 1984)			*			
Dictyophara hoberlandti Dlabola, 1974						
Kumlika mandrita Emeljanov, 1997				*		
Nymphorgerius convergens Emeljanov, 1972						
Nymphorgerius emeljanovi Dlabola, 1979					*	
Nymphorgerius mullah Dlabola, 1979					*	
Nymphorgerius rostratus Emeljanov, 2009						
Family: Flatidae						
Bahuflata punctata Dlabola, 1979						*
Derisa atratula Melichar, 1902						
Mesophantia kanganica Dlabola, 1983						
Mesophantia pallens Melichar, 1902						
Mesophantia sabzevaranica Dlabola, 1983						
Mesophantia tisina Dlabola, 1983						
Persepolia jasmuriana Dlabola, 1982						*
Persepolia secunda Dlabola, 1981						*
Persepolia servadeina Dlabola, 1982						
Phantia borazianica Dlabola, 1989						*
Phantia crucispina Dlabola, 1989						*
Phantia denasuta Dlabola, 1989						*
Phantia finita Dlabola, 1989			*			
Phantia helleri Linnavuori, 1962						
Phantia lactea Rusiecka, 1902						
Phantia ovatospina Dlabola, 1989				*		
Phantia picea Dlabola, 1989						*
Phantia putoni Rusiecka, 1902						
Tisia esfandiarii Dlabola, 1981						*
Family: Issidae						
Cavatorium ardakanum Dlabola, 1980			*			
Cavatorium bispinatum Dlabola, 1980			*			
Cavatorium quadrispinatum Dlabola, 1980			*			
Cavatorium sarbaz Dlabola, 1980						*
Eusarima iranica Gnezdilov & Mozaffarian 2011					*	
Inflatodus astyages Dlabola, 1982					*	
Inflatodus kyaxares Dlabola, 1982					*	
*Inflatodus persicus (*Dlabola, 1981)					*	
Inflatodus viridans (Dlabola, 1974)					*	
Iranodus amygdalinus Dlabola, 1980						
*Iranodus dumetorus (*Dlabola, 1981)			*			
Iranodus khatunus (Dlabola, 1981)						
Iranodus nishabur Dlabola, 1982				*		
Iranodus repandus (Dlabola, 1981)			*			
Iranodus transversalis Dlabola, 1980		*				

Endemic species	**Caspian zone**	**Kerman Mountains**	**Zagros mountains**	**Khorasan Mountains**	**Southern Slopes of Alborz**	**Baluchestan and Persian Gulf coasts**
Mycterodus astragalicus Dlabola, 1974			*			
Mycterodus demavendinus Dlabola, 1981					*	
Mycterodus elbursicus (Logvinenko, 1974)	*					
Mycterodus fagetophilus Dlabola, 1980	*					
Mycterodus guilanicus Dlabola, 1981	*					
Mycterodus hezarmeshedi Dlabola, 1980		*				
Mycterodus inassuetus Dlabola, 1981	*					
Mycterodus kandavanicus Dlabola, 1980						
Mycterodus krameri Dlabola, 1974						
Mycterodus lanceatus Dlabola 1997	*					
Mycterodus peterseni Dlabola, 1980	*					
Mycterodus sexpunctatus Dlabola, 1980						
Mycterodus shahrudicus Dlabola, 1980					*	
Pentissus bamicus Dlabola, 1980						
Phasmena adyoungi Dlabola, 1982						*
Phasmena telifera Melichar, 1902						*
Quadriva aurita (Dlabola, 1982)			*			
Quadriva dehbakrina (Dlabola, 1980)		*				
Quadriva lassa (Dlabola, 1981)			*			
Quadriva proxima (Dlabola, 1980)		*				
Quadriva sabzevarana (Dlabola, 1980)		*				
Quadriva taftanica (Dlabola, 1980)						*
Quadriva tangesarhena (Dlabola, 1980)						
Scorlupaster emersum (Dlabola, 1981)	*					
Family: Kinnaridae						
Perloma boroumandi (Dlabola, 1981)						*
Perloma satrapa (Dlabola, 1981)						
Perloma zarudnyi (Emeljanov, 1984)						*
Family: Meenoplidae						
Anigrus farsicus Dlabola, 1986						*
Family: Nogodinidae						
Hadjia nerii Dlabola, 1981						*
Hadjia quadrifasciata Dlabola, 1981						*
Iranissus ephedrinus Dlabola, 1980						
Morsina persica Melichar, 1902						
Philbyella glarea Dlabola & Heller, 1962						
Family: Ricaniidae						
Ricania soraya Dlabola, 1983			*			
Family: Tettigometridae						
Tettigometra demavenda Dlabola, 1981					*	
Family: Tropiduchidae						
Kazerunia leguaniforma Dlabola, 1977						*
Kazerunia ochreata Dlabola, 1974			*			
Kazerunia undulata Dlabola, 1977						*

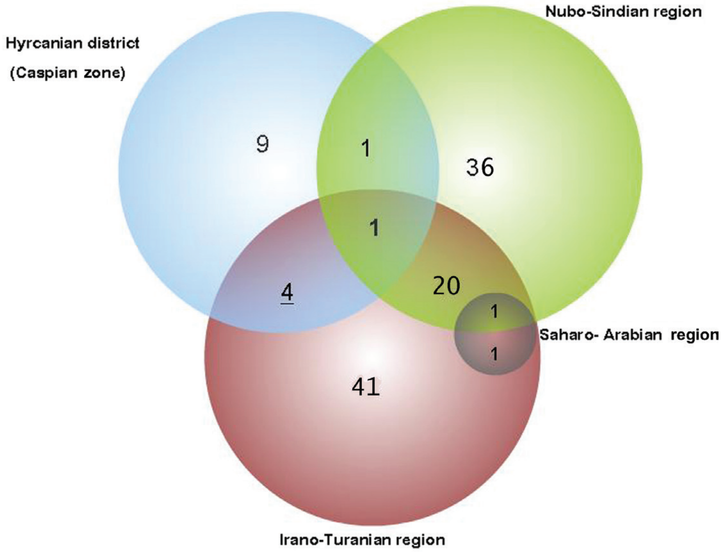

Figure 2. The number of endemic planthoppers of Iran in the main biogeographic areas.

former name used for HMIM, while it is not mentioned in the list of museum specimens (Mirzayans 1995) and is not currently existing in this museum either. However another specimen of this species is deposited in the HMIM museum collected from southeast of Iran, by the same collector and in the same date mentioned by Dlabola's northern specimen. Therefore the presence of this species in the Hyrcanian district is doubtful and appears to be a mistake in recording the locality in Dlabola (1981).

Historically, the north of Iran was occupied by the old Tethys 55-20 mya (Ghorbani 2002) so the occupation should have occurred after the area got dry. During the Pliocene ice age (100,000 years ago) the region was used as a refugee, and species spread northwards after the ice age, which may be a reason for rather small numbers of endemic species in this region. Hedge and Wendelbo (1978) also indicated rather small numbers of endemic Phanerogamic plants in this area. However the area has a considerably different climate and fauna from other parts of Iran and has been considered as a separate zoogeographic division both by Zarudny (1911), Anderson (1968) and Emeljanov (1974).

Saharo-Arabian region

According to Zohary (1973), the west of Iran is touched by the Saharo-Arabian region. Short and mild winters and long and dry hot summers are typical for this part of the country (Frey and Probst 1986). Two endemic planthoppers of Iran (*Callodictya kazeruna* (Dlabola, 1986) (Dictyopharidae) and *Phantia helleri* Linnavuori, 1962 (Flatidae)) have been recorded from this part while the former is in common with other parts of the Irano-Turan (Zagros Mt.) and the latter has a rather wide distribution in the Irano-Turanian and Nubo-Sindian regions (Fig. 2). Hence this region is not considered as an endemic zone in distribution patterns of endemic planthoppers.

Irano-Turanian region

The region covers nine tenths of the land of Iran and major parts of the Iranian Plateau, from Central to south of Asia. The region consists of plains, deserts and mountains which are divided into 8 primary divisions in this study: Kerman, Karkas Mt., Humid Zagros, Dry Zagros, north Khorasan Mt., south Khorasan Mt., southern slopes of Alborz Mt. and Deserts and Plains.

Kerman Mountains

The complex of the Kerman Mts located in the southeast of the Irano-Turanian region and partially in the Nubo-Sindian (Fig. 1). The mountain range is a part of the Zagros chain but far from the other mountains and surrounded by deserts. The mountain and the deserts around have been considered as a zoogeographic zone by Zarudny (1911). Twenty eight endemic planthoppers of Iran were recorded from this mountain range, 8 of which endemic for there (Table 1, Fig. 3). The mountain range appears to be rather isolated from the Zagros and is limited by the Jazmurian lowlands in the south, Dasht-e Lut kavirs and other Irano-Turanian plains on the other sides. The isolation of mountains by plains and deserts creates a rather suitable condition for isolating populations and speciation. The high mountains in this complex (eg.: Hezar: 4,465 m, Lalehzar: 4,351 m, Tang-e Dalfard, 3,348 m) may be convenient places for relict species after the cold temperature of the Pleistocene ice age. However the fauna of endemic species is rather affected by both Nubo-Sindian (19 common species) and other parts of Irano-Turan (10 common species) (Fig. 3).

Zagros mountains (Humid and Dry Zagros and Karkas Mt.)

The Zagros mountain chain stretches from northwest of Iran to southwast near the Strait of Hormoz and is considered as the south branches of the Alpine-Himalayan orogenic belt (Dewey et al. 1986). The formation of the Zagros orogenic belt is subjected to controversy. Some geologists believe it has been made by the collision between the Afro-Arabian and Eurasian plate during the Cenozoic (Takin 1972, Agard 2005). As a result of this collision, several parallel folds were formed (Alan, 1969). The long mountain chain divides the Mediterranean climatic zone from the arid regions of west Asia. It is also a barrier between Mesopotamia and the Plateau of Iran with some corridors for the distribution of the fauna between the two zones (Anderson 1968).

In this study the Zagros chain was divided into 3 primary zones (Fig. 1): “Humid Zagros” in the northwest which consists of higher mountains and is affected by Mediterranean winds, “Dry Zagros” in the southeast with a drier climate and rather isolated mountains as the result of wider parallel valleys, and the Karkas mountain which ap-

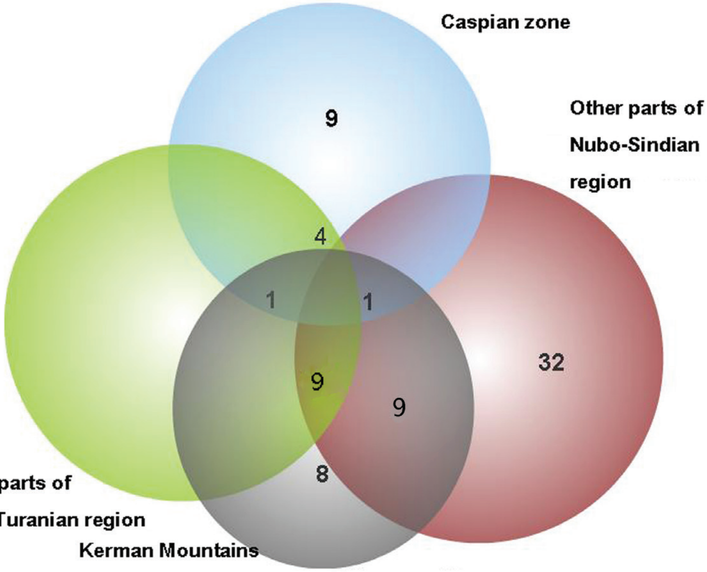

Figure 3. Venn diagrams for the number of endemic species in Kerman Mts and other areas with common species.

pears to be a rather isolated mountain surrounded by Maranjab kavir and other lower lands around. Two different zones in northwest and southeast Zagros are also applied by Hedge and Wendelbo (1978) for distribution patterns of endemic phanerogamic plants, named: Armeno-Kurdic and Zagros, respectively. Similarly, Zarudny (1911) recognized the northwest of Zagros as a separate zone with a fauna similar to the Caucasus. Northwest of Zagros, (Armenian) was mentioned as a different area from southeast of Zagros, (Zagrossan) in Emeljanov (1974) as well. However both of them were considered as divisions of "Middle Eastern mixed".

A total of 36 endemic planthoppers of Iran have been recorded from Zagros Mts, 19 of which are endemic to the Zagros (Table 1), 17 endemic to Dry Zagros, and 2 in common with Dry Zagros and Karkas Mt. or Humid Zagros (Fig. 4). The Venn diagram (Fig. 4) shows there are no endemic species for Humid Zagros and Karkas Mt. and the fauna of Iranian endemic planthoppers in those primary zones are mainly in common with Dry Zagros and partially with the south Alborz and Caspian zones. Therefore, those two primary divisions of the Zagros Mountains are not considered as endemic zones. Differently from the wall-like Alborz Mt., the Zagros chain comprises series of parallel ridges and valleys. The distances between mountains increases from northwest to southeast. Although the wider lower lands between the mountains in the south of Zagros (Dry Zagros) form corridors for the distribution and migration of species, mountains surrounded by those lower lands can provide a vicariant condition for speciation or at least prevent the distribution of species to other locations. The fauna of endemic planthoppers in Dry Zagros has some species in common with the Nubo-Sindian (10) and Kerman Mt. (2) which can be explained by the rather short distance between them.

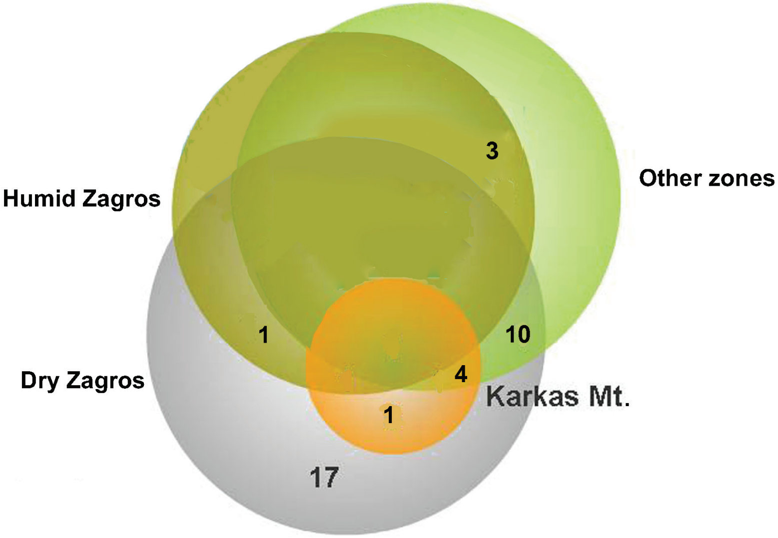

Figure 4. Venn diagram for the number of endemic species in Zagros Mts. (Humid Zagros, Dry Zagros and Karkas Mt.) and other areas with common species.

Khorasan mountains

It is believed that Iran has been connected to central Asia since the Oligocene. Then the plateau of Iran was uplifted during the Tertiary orogeny and consequently Kope Dagh (northeast of Iran), Hindukush and Himalaya were created (Anderson 1968). Mountains in northern Khorasan are a continuation of the Alborz but lack the wall-like integration of the Alborz and the humidity of the Caspian Sea, and mountains in both northern and southern Khorasan are rather parallel with the Zagros. In this study they were considered as different primary zones due to their distances and the distribution of endemic planthoppers.

A total of 11 Iranian endemic planthoppers have been recorded from Khorasan Mts, 5 of which are endemic to this mountain range (Table 1), 3 in the south, 1 in the north and 1 in common (Fig. 5). The cluster analysis shows the similarity of the northern and southern fauna (Fig. 6). Hence the two mountains can be considered as a same zone in the distribution pattern. While south parts, which are surrounded by Kavir-e Lut and Dasht-e Kavir to the west and lowlands in Afghanistan to the east, have more endemic species and appear to be more suitable places for speciation.

Southern slopes of Alborz

The Alborz mountain chain represents a north branch of the Alpine-Himalayan orogenic system (Dewey et al. 1986). It stretches from northwest of Iran to southeast of the Caspian Sea and includes the highest mountain of west Asia, Damavand 5,670 m. It forms a consistent barrier between the fauna of the Caspian zone and the Plateau of Iran.

Seventeen endemic planthoppers of Iran are recorded from the south of Alborz, 12 of which endemic to the region (Table 1, Fig. 7). The southern slopes of Alborz have

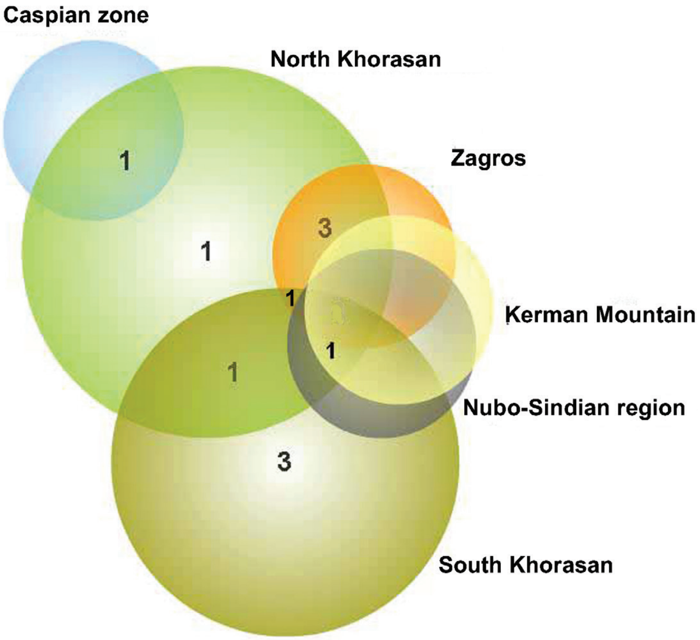

Figure 5. Venn diagram for the number of endemic species in Khorasan Mts and common species with other areas.

an absolutely different climatic condition from the northern Slopes due to the lack of corridors for receiving the humidity of the Caspian Sea. The presence of the Dasht-e Kavir desert in the south can be another factor for preventing the distribution of populations and probably speciation. There is only one common endemic planthopper between the southern slopes of Alborz and northern Khorasan whereas three species in common with the Zagros show a relationship with the western mountains.

Deserts and plains

Two big salt pans or Kavirs in central Iran are undrained basins and the lands surrounding them have typical features such as clayey or sandy soil and a high amount of salt on the surface. The inner lands of these salt marshes are nearly free of vegetation (Hangay and Szekely 2005, Frey and Probst 1986, Zohary 1973). It is said that Dasht-e Lut is considered as the hottest place in the world exceeding 70°C of temperature in some parts of it (Mildrexler et al. 2011). There are marshes and mud grounds with large crusts of salt in inner parts of Kavirs while some parts have a steppe-like appearance and some other regions are surrounded by *Tamarix* spp., *Calligonum* spp. etc. (Frey and Probst 1986). Hedge and Wendelbo (1978) and Anderson (1968) recognized deserts and plains of the central Plateau of Iran as biogeographic zones. However Zarudny (1911) did not mention them in his list. The distribution patterns of the Iranian endemic planthoppers appear to be very restricted in central Iran. *Malenia masirica* Dlabola, 1986, *Mesophantia pallens* Melichar, 1902 and *Persepolia servadeina*

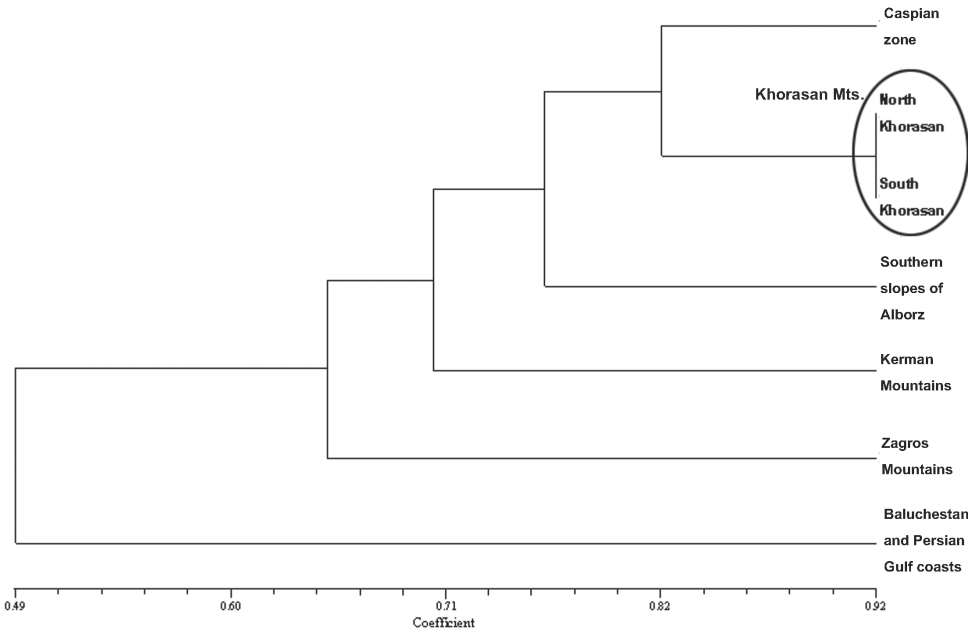

Figure 6. Cluster diagram for the endemic areas of Fulgoromorpha in Iran.

Dlabola, 1982 are the only endemic species recorded from this part of the country while none of them are endemic for those deserts. The two first species have a rather wide distribution in Iran and the third one has been collected so close to Kerman Mt. Few records of endemic Iranian planthoppers from the deserts may be simply because of less collecting in those dry areas or poor vegetation in some parts of them. None the less, according to our current knowledge, deserts and plains of the Irano-Turan cannot be considered as an endemic zone for planthoppers.

Nubo-Sindian region

This part of the country in southern and southeastern Iran is the only region which is not considered as Palaearctic but as a part of the Oriental. A varied terminology has been used for this region. Hedge and Wendelbo (1978) used the term "Sahara-Sindian" to show a west to east continuum from southwest Asia to Send deserts while Frey and Probst (1986) preferred Nubo-Sindian because they believed the distribution patterns of the Nubo-Sindian province are obvious here while Saharo-Arabian and Mediterranean species have migrated to this region.

By subtracting the endemic species of a small part of the Kerman Mountain from the Nubo-Sindian, 54 recorded endemic species of Iran, which is more than half of the total, are distributed in this region and 32 of these are endemic to the region (Table 1). The distribution of endemic Fulgoromorpha shows three rather separate

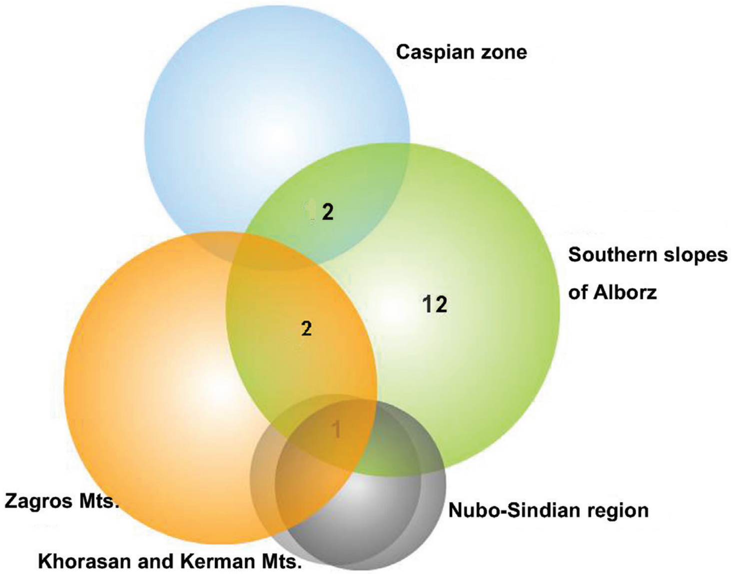

Figure 7. Venn diagram for the number of endemic species in southern slopes of Alborz and common species with other areas.

groups which are recognized as three primary zones here: Baluchestan, the Strait of Hormoz and the coasts of the Persian Gulf (Fig. 1). The cluster analysis showed the similarity of the fauna of the endemic species in the Strait of Hormoz and the Persian Gulf coasts (Fig. 8) so those two primary zones can be considered as a same zone. Anderson (1968) found a discontinuity in the faunal elements of southern and south-eastern Iran and justified it with the relatively recent position of the Persian Gulf and lower sea levels during the Pleistocene which must have caused dry land contact between Iran and Arabia. This belief is confirmed by evidence for ecological continuity across the two sides of the Persian Gulf. Therefore the higher sea levels after the ice age can also produce a vicariant condition in the Persian Gulf coasts and isolating

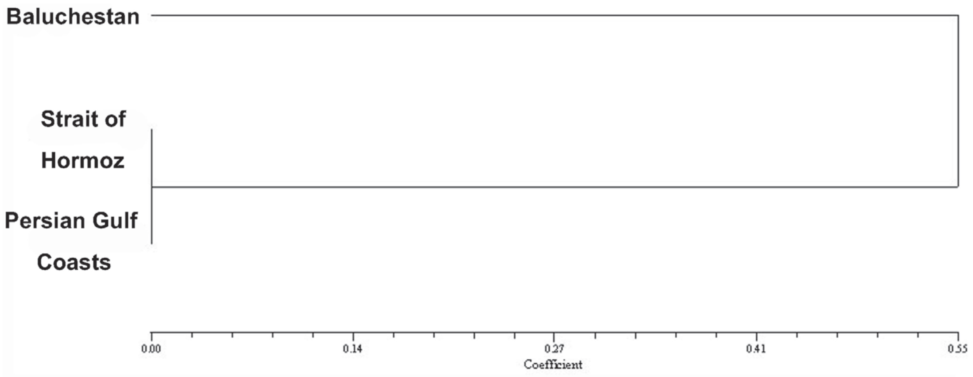

Figure 8. Cluster diagram for the primary zones of endemic Fulgoromorpha in tjr Nubo-Sindian region.

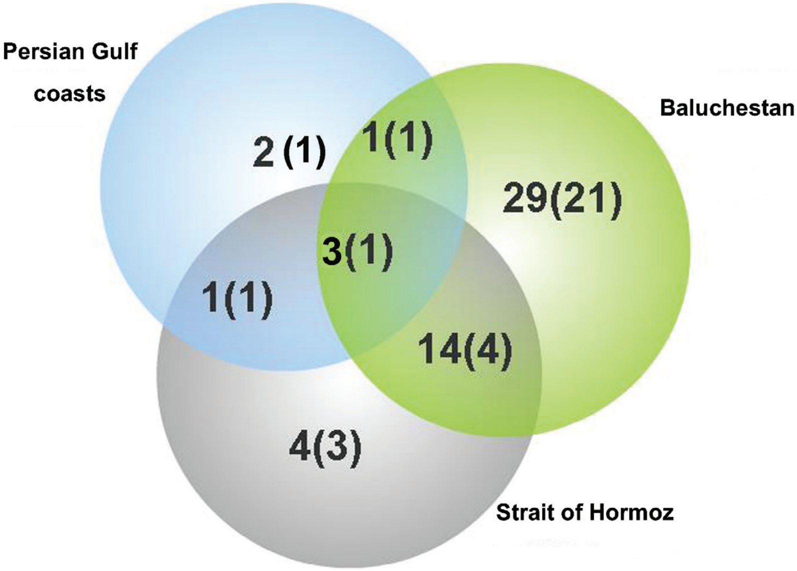

Figure 9. Venn diagram for the number of endemic species of the Nubo-Sindian region in three primary zones (Numbers in the parentheses are the number of endemic species in that specific primary zone)

endemic species between mountains and a different climate condition to the north and the waters of the Persian Gulf to the south. The number of endemic species in the Nubo-Sindian is reduced from east to west which may be because of the isolation of the eastern species by the Kavie-e Lut and Jazmurian lowlands. On the other hand, the Venn diagram (Fig. 9) shows a rather high number of common species between Baluchestan and the two other adjacent areas. Hence according to our current knowledge of distribution patterns of endemic planthoppers, the Baluchestan primary zone can also be united with the other primary zones of the Nubo-Sindian region. The area was also considered mainly as one division (Makran mixed) with a very small area of Baluchestan in southeast (Sind plane) by Emeljanov (1974). According to Ghorbani (2002), some parts of Baluchestan, the Strait of Hormoz and the area between them had been occupied by the old Tethys so the common endemic species between Baluchestan and two other primary zones in southern Iran should have crossed the area after drying.

The final 6 endemic zones (Caspian zone, south slopes of Alborz, Khorasan Mts, Zagros Mts, Kerman Mts and Baluchestan and Persian Gulf coasts) are shown in Fig. 10. The cluster analysis on six final endemic zones of Iranian planthoppers (Fig. 6) indicates Baluchestan and Perisan Gulf coasts the only region which is considered as a part of the Oriental Region, as the most different zone from the others. Then Zagros Mts, Kerman Mts, Alborz, Khorasan Mts and Caspian zones are diverging, respectively. Alscal analysis produced a map according to the similarity of endemic zones. Rotating the similarity map canvas horizontally (Fig. 11), makes it more comparable with the geographic map (Fig. 10). The Caspian zone and the Nubo-Sindian region

Figure 10. Final endemic zones and distribution of endemic Fulgoromorpha of Iran.

are located in similar situations in both maps. While the Khorasan zone is closer to the Caspian zone in the similarity map rather than its geographic situation. This similarity can be justified by the possibility of specimens migrating between two zones at the end of the wall-like mountains of Alborz at the east of the Caspian zone. This is why the southern slopes of Alborz go farther in the Alscal map and confirms the efficiency of the barrier of the Alborz mountain in separating species of the two adjacent zones. Although the Zagros mountain has rather similar situations in both maps, it is farther from the Nubo-Sindian in similarity rather than its geographic situation. The reason may be the higher number of endemic species in Baluchestan rather than in the coasts of Persian Gulf and the Strait of Hormoz close to the Zagros Mountains. The situation of the Kermann Mts in the similarity map moved from its geographic situation towards the north. The rather far distance of this zone from the others, confirms the isolation of the species living there. However, deleting the doubtful record of *Morsina persica*, common between the Caspian zone and the Nubo-Sindian part of the Kerman Mountains may move the situation of the Kerman zone in the similarity map towards the south.

The records of the endemic planthoppers of Iran belong to recent 110 years (Mozaffarian and Wilson 2011). The nature of Iran, like any other land, has been exposed to various changes during this long period by events, such as agriculture, war, fire in

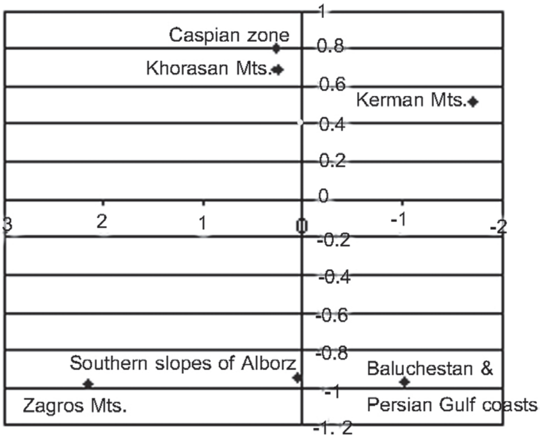

Figure 11. A similarity map of endemic zones of Fulgoromorpha of Iran resulted from Aslcal analysis.

woods and forests, overgrazing, urbanization and so on. Hence, probably the presence of some endemic species with a limited distribution and the probable extinction of some of them should be subjected to further investigations.

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Trigonocranus emmeae Fieber, 1876 (Hemiptera, Fulgoromorpha, Cixiidae) – a new species for Poland

Krzysztof Musik[1], Marcin Walczak[1], Łukasz Depa[1],
Łukasz Junkiert[1], Anna Jedynowicz[2]

[1] *Department of Zoology, Faculty of Biology and Environmental Protection, University of Silesia, Bankowa 9, 40-007 Katowice, Poland* [2] *Brzezinka, ul. Skotnicka 3A 32-600 Oświęcim, Poland*

Corresponding author: *Krzysztof Musik* (krzysztof.musik@us.edu.pl)

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Abstract

A single macropterous female of *Trigonocranus emmeae* Fieber, 1876 has been found during the faunistic studies in semi-natural plant communities of Oświęcim city in southern Poland. It is the first record of this species in Poland. *Trigonocranus emmeae* is rarely collected within the wide range of its distribution, mostly due to its hidden life mode.

Keywords

Faunistics, new records, *Trigonocranus*, Cixiidae, Fulgoromorpha

Introduction

The Fulgoromorpha and Cicadomorpha are represented in Europe by 2053 species (Hoch 2012). In Poland the fauna of Auchenorrhyncha comprises 537 recorded species, including the latest checklist by Chudzicka (2004) and species that were missed (Łabanowski and Soika 1997, Gębicki 2003, Świerczewski and Gebicki 2003) or published later than 2004 (Gaj et al. 2009, Świerczewski and Stroiński 2011a, 2011b, Świerczewski and Walczak 2011, Walczak et al. 2012).

During the recent studies in Brzezinka, a suburban district of Oświecim city (southern Poland) a single female of *Trigonocranus emmeae* Fieber, 1876 has been collected. It is the first record of this poorly studied representative of Cixiidae in Poland.

Material and methods

Faunistic studies on planthoppers and leafhoppers (Cicadomorpha and Fulgoromorpha) were conducted during the vegetation season of 2008. The area of the research was a suburban district of Oświęcim city – Brzezinka (UTM:CA64) (50°2'51"N, 19°9'38"E).

Insects were collected by a standard sweeping net (Ø 35cm) from the end of April till the end of October, altogether 15 samples per plot were taken. The collected material was transferred to a container with ethyl acetate. In the laboratory the collected insects were mounted on glue boards and determined. The key used to identify the species was Biedermann and Niedringhaus (2004).

Chorological and ecological data used in this work are accordant to Nickel and Remane (2002) and Nickel (2003). To determine the plant associations the key provided by Matuszkiewicz (2008) was applied.

Collected material is deposited in the Collection of Department of Zoology, University of Silesia, Katowice.

Results

Trigonocranus emmeae Fieber, 1876 – new species for Polish fauna (Fig. 1).

Material examined

A single specimen of this species was collected on 22.06.2008 in Oświęcim-Brzezinka (southern Poland), [UTM CA64], 50°2'51"N, 19°9'38"E, in the meadow belonging to the *Molinio-Arrhenatheretea* class, macropterous ♀, leg. A. Jedynowicz, det. M. Walczak, C. Gębicki rev. (specimen deposited in the collection of Department of Zoology, University of Silesia).

The first locality of *T. emmeae* in Poland was located in Oświęcim-Brzezinka, Leśna street (Fig. 2). It was a *Molinio-Arrhenatheretea* class meadow surrounded by forest. The dominant plant species were: *Holcus mollis, Dactylis glomerata*, *Alopecurus pratensis* and *Agrostis capillaris*, in less percentage: *Anthoxanthum odoratum*, *Elymus repens*, *Carex hirta*, *C. acutiformis* and *C. vulpia*. During the studies in 2008 apart from *T. emmeae* there were 36 other species recorded in this plot. The dominant species were: *Cicadella viridis* (Linnaeus, 1758) (23.57% of collected material), *Cicadula quadrinotata* (Fabricius, 1794) (8.02%), *Arthaldeus pascuellus* (Fallén, 1826) (5.02%) and *Stenocranus major* (Kirschbaum, 1868) (3.31%) (Jedynowicz, 2009).

Figure 1. *Trigonocranus emmeae* macropterous female (photo by A. Stroiński).

Figure 2. Habitat of *T. emmeae,* Oświęcim-Brzezinka (photo by A. Jedynowicz).

Discussion

According to the literature *T. emmeae* is widely distributed in Europe, but very rarely collected. This species was recorded in Austria, Switzerland, France, Great Britain (Nast 1972), Slovenia (Holzinger and Seljak 2001, Seljak et al. 2003), Croatia, Spain, Italy, Bulgaria, Germany, Georgia, southern Russia (Holzinger et al. 2003, Nickel 2003), Czech Republic (Malenovský and Lauterer 2010, 2012), Luxemburg (Niedringhaus et al. 2010) and Sweden (Larsson 2010).

According to Nickel (2003) nymphs and brachypterous adults are unpigmented with reduced number of ommatidia and live on the soil surface and leaf litter. This species occurs from the end of May till the end of July, hibernates in the egg stage and is univoltine. *T. emmeae* represents the European chorological element. It lives on moderately warm sites covered by vegetation of medium density, probably feeding on roots of shrubs. The mentioned specimen was collected on a moderately moist meadow. The data from Great Britain indicates that this species may be also collected in damp sites (Bantock 2012). The host plant species is unknown (Nickel and Remane 2002, Nickel 2003). There are no data about the trophic relations of this species, therefore it is unknown if it is mono-, oligo- or most probably polyphagous. The majority of collected specimens were caught by sweeping net or Malaise traps during the dispersal flight (Nickel 2003). *T. emmeae* can be also and effectively collected by an underground pitfall trap (M. Wilson, pers. comm.).

The difficulties in collecting *T. emmeae* result in lack of detailed biological and ecological data. This species is probably not as rare as it seems, however the right collection method must be applied to reveal its cryptic presence. Distribution of this species in Poland needs further research.

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Mitochondrial COI and morphological specificity of the mealy aphids (*Hyalopterus* ssp.) collected from different hosts in Europe (Hemiptera, Aphididae)

Rimantas Rakauskas[1], Jekaterina Havelka[1], Audrius Zaremba[1]

[1] *Department of Zoology, Vilnius University, M. K. Čiurlionio 21/27, LT-03101, Vilnius, Lithuania*

Corresponding author: *Rimantas Rakauskas* (rimantas.rakauskas@gf.vu.lt)

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Abstract

Forty three European population samples of mealy aphids from various winter and summer host plants were attributed to respective species of *Hyalopterus* by means of their partial sequences of mitochondrial COI gene. Used *Hyalopterus* samples emerged as monophyletic relative to outgroup and formed three major clades representing three host specific mealy aphid species in the Neighbor joining, Maximum parsimony, Maximum likelihood and Bayesian inference trees. *H. pruni* and *H. persikonus* emerged as a sister species, whilst *H. amygdali* was located basally. Samples representing different clades in the molecular trees were used for canonical discrimination analysis based on twenty two morphological characters. Length of the median dorsal head hair enabled a 97.3 % separation of *H. amygdali* from the remaining two species. No single character enabled satisfactory discrimination between apterous viviparous females of *H. pruni* and *H. persikonus*. A modified key for the morphological identification of *Hyalopterus* species is suggested and their taxonomic status discussed.

Keywords

Europe, *Hyalopterus amygdali*, *H. pruni*, *H. persikonus*, molecular phylogeny, mitochondrial COI, morphological key to species

Introduction

Mealy aphids of the genus *Hyalopterus* Koch are reported to be serious pests of stone fruits all over the World (Barbagallo et al. 1997, Blackman and Eastop 2000, Lozier et al. 2009). Therefore, their morphology, biology, systematics, evolution, invasion history and potential harmfulness have been substantially studied (Smolarz 1970, Tscharntke 1989, Mosco et al. 1997, Poulios et al. 2007, Lozier et al. 2008, Tewksbury et al. 2002, Penvern et al. 2010, Symmes et al. 2012, for more and earlier references see Blackman and Eastop 2000). Nonetheless, the species level classification of mealy aphids remains unclear despite the long lasting debate. Since the very beginning, mealy aphids inhabiting various prunoideous plants have been described as a single species, *Hyalopterus pruni* (Geoffroy, 1762). Later on, almond inhabiting aphids were separated as *Hyalopterus amygdali* Blanchard, 1840. Such a viewpoint has been subjected for a long lasting controversy (e.g. Börner 1952, Shaposhnikov 1972, Eastop and Hille Ris Lambers 1976, Stroyan 1984, Heie 1986, Remaudiere and Remaudiere 1997). Recently, in addition to the two above mentioned species, *Hyalopterus persikonus* Miller, Lozier and Foottit, 2008 has been separated from H. amygdali by Lozier et al. (2008). For the present, three host plant associated *Hyalopterus* species are recognized. All three might inhabit reeds (Phragmites) as a summer hosts, but are different in their winter host specificity: *H. amygdali* is associated with almonds, whilst *H. pruni* and *H. persikonus* with plums and peaches, respectively. Nonetheless, apricot has been reported as a shared resource among the three *Hyalopterus* species supporting the possibility of interspecific hybridization (Lozier et al. 2007, Poulios et al. 2007, Lozier et al. 2008). *Hyalopterus* species, although well-defined on molecular level (Lozier et al. 2008), still remain difficult to separate by their morphological characters (Basky and Szalay-Marszȯ 1987, Blackman and Eastop 1994, 2000, 2006), including the most recent identification key (Lozier et al. 2008). For example, mealy aphids, collected on apricots in Lithuania, run to *H. amygdali* in the key of Blackman and Eastop (2000), but appeared difficult to identify by means of the key suggested by Lozier et al. (2008) (Kudirkaitė-Akulienė and Rakauskas 2009). Moreover, the above keys do not concern mealy aphid populations on summer hosts, reeds. Host plant mediated developmental pathways might influence morphological characters, therefore, samples from reeds must be included in the analysis, together with those from stone fruit crops.

The aim of this study was to elaborate morphological identification key of the genus *Hyalopterus* based on the material from Europe that was identified by means of partial CO-I sequences.

Material and methods

Material studied

Forty three population samples of mealy aphids from five European countries were collected from various winter and summer host plants (Table 1). The entire data set has been subdivided: 21 samples (bolded in Table 1) were used for canonical discrimination procedures and subsequent evaluation of the received discrimination functions was performed on remaining 22 samples.

Table 1. Aphid material used in the present study. Samples used for the morphological discrimination analysis with *a priori* specified group membership are given in bold.

Place, date, collection No	GenBank Accession No
***Prunus domestica* (plum)**	
Galata, Bulgaria, 2012.06.18, z12-101	JX943533
Costinesti, Romania, 2012.06.13, z12-67	JX943536
Gilau, Romania, 2012.06.19, z12-114	JX943537
Toplita, Romania, 2012.06.10, z12-46b	JX943538
Constanta, Romania, 2012.06.14, z12-78	JX943539
Valu lui Traian, Romania, 2012.06.14, z12-77	JX943540
Michalovce, Slovakia, 2012.06.08, z12-43a	JX943545
Mezopeterd, Hungary, 2012.06.20, z12-121	JX943541
Derecske, Hungary, 2012.06.20, z12-123	JX943542
Gemzse, Hungary, 2012.06.08, z12-44	JX943543
Jieznas, Prienai distr., Lithuania, 2012.05.30, 12-24	JX943544
Daugai, Alytus distr., Lithuania, 2012.05.30, 12-31	JX943547
Ignalina, Ignalina distr., Lithuania, 2012.06.19, 12-65	JX943549
***Prunus cerasifera* (cherry plum)**	
Ditrau, Romania, 2012.06.11, z12-52	JX943534
Gheorheni, Romania, 2012.06.11, z12-53	JX943535
Blagojevgrad, Bulgaria, 2012.06.25, 12-81	JX943550
Alytus, Alytus distr., Lithuania, 2012.05.30, 12-28	JX943546
Eišiškės, Šalčininkai distr., Lithuania, 2012.06.13, 12-41	JX943548
***Prunus cerasifera* var. *Pissardii* (red plum)**	
Costinesti, Romania, 2012.06.13, z12-65	JX943553
***Prunus armeniaca* (apricot)**	
Costinesti, Romania, 2012.06.15, z12-88	JX943551
Murfatlar, Romania, 2012.06.13, z12-64	JX943531
Vama Veche, Romania, 2012.06.16, z12-93	JX943552
Mezopeterd, Hungary, 2012.06.20, z12-120	JX943555
Kairėnai, Vilnius distr., Lithuania, 2010.07.01, z10-5	JX943558
***Prunus persica* (peach)**	
Goron, Bulgaria, 2012.06.09, z12-111	JX943519
Bucuresti, Romania, 2012.06.13, z12-58	JX943521
Constanta, Romania, 2012.06.14, z12-79	JX943522
Costinesti, Romania, 2012.06.15, z12-86	JX943523
Murfatlar, Romania, 2012.06.13, z12-63	JX943524
Pieta Porta Alba, Romania, 2012.06.14, z12-70	JX943525
Valu lui Traian. Romania, 2012.06.14, z12-75	JX943526
Mezopeterd, Hungary, 2012.06.20, z12-119	JX943527
Szikso, Hungary, 2012.06.20, z12-124	JX943528
Csobad, Hungary, 2012.06.20, z12-126	JX943529
Foro, Hungary, 2012.06.20, z12-127	JX943530
***Prunus persica* var. *nectarina* (nectarine)**	
Pieta Porta Alba, Romania, 2012.06.14, z12-73	JX943520

Place, date, collection No	GenBank Accession No
***Prunus dulcis* (almond)**	
Varna, Bulgaria, 2012.06.18, z12-104	JX943517
Varna, Bulgaria, 2012.06.18, z12-108	JX943518
***Prunus maritima* (beach plum)**	
Kairėnai, Vilnius distr., Lithuania, 2010.07.01, z10-4	JX943557
***Phragmites australis* (common reed)**	
Vama Veche, Romania, 2012.06.16, z12-91	JX943532
Biharkeresztes, Hungary, 2012.06.20, z12-118	JX943554
Baltupiai, Vilnius, Lithuania, 2010.06.30, z10-1	JX943556
Palanga, Klaipėda distr., Lithuania, 2010.07.15, z10-24	JX943559

DNA extraction, PCR amplification and sequencing

For molecular analysis, a single aphid individual from one sampled plant was considered as a unique sample. Total genomic DNA was extracted from a single aphid using the DNeasy Blood & Tissue kit (Qiagen), which involved at least a 2 h digestion of tissue with proteinase K. Partial sequences of mitochondrial COI were PCR-amplified using previously published primers (Turčinavičienė et al. 2006). PCR amplification was carried out in a thermal cycler (Eppendorf) in 50 µl volumes containing 1–2 µl genomic DNA, 5 µl of each primer (10 µM), 5 µl of PCR-reaction buffer, 5 µl of dNTP mix (2mM each), 4–8 µl of 25mM $MgCl_2$ and 1.25 U of AmpliTaq Gold 360 polymerase (5U/µl) and ddH_2O to 50 µl. The cycling parameters were as follows: denaturizing at 95°C for 10 min (1 cycle), denaturizing at 95°C for 30”, annealing at 49°C for 30” and extension at 72°C for 30” (32–37 cycles in total), and a final extension for 5 min (1 cycle). PCR products were subjected to electrophoresis on 2% TopVision agarose (Fermentas, Lithuania), stained with ethidium bromide and sized against a MassRuler Low Range DNA ladder (Fermentas, Lithuania) under UV light. PCR products were purified and sequenced at Macrogen Europe (Amsterdam, the Netherlands). The amplification primers were also used as sequencing primers. DNA sequences for each specimen were confirmed with both sense and anti-sense strands and aligned in the BioEdit Sequence Alignment Editor (Hall 1999). Partial sequences of COI gene were tested for stop codons and none were found. The sequence data have been submitted to the GenBank, Accession numbers JX943517- JX943559.

Analysis of DNA sequences

Forty three sequences of three *Hyalopterus* species were analyzed. Sequences of *Aphis gossypii* Glover, 1877 (Aphidini) and *Nasonovia ribisnigri* (Mosley, 1841) (Macrosiphini) were selected as outgroups for the phylogenetic analyses, which included Neighbor joining (NJ), Maximum parsimony (MP), Maximum likelihood (ML) and Bayesian inference in phylogeny (BI). NJ, MP and ML analyses were performed using MEGA

5 (Tamura et al. 2011). For NJ analysis Kimura 2-parameter (K2P) model of base substitution was used. Bootstrap values for NJ, MP and ML trees were generated from 1000 replicates. For ML analysis Tamura 3-parameter model with Gamma distribution (T92+G) was selected by MEGA 5 model selection option (Tamura et al. 2011). Bayesian analysis was conducted in MrBayes 3.2.1 (Ronquist and Huelsenbeck 2003) using General Time Reversible model with Gamma distribution (GTR+G), which was selected by jModeltest (Posada 2008). Four simultaneous chains, 3 heated and 1 "cold", were run for 3 000 000 generations with tree sampling every 1000 generations. The topologies obtained by NJ, MP, ML and BI were similar, so only ML tree is shown with values of NJ/MP and ML/BI bootstrap support and posterior probabilities indicated above and below branches respectively.

Morphological study and discrimination analysis

Samples representing different clades in the molecular trees were used for canonical discrimination analysis: 2 samples from almond (*H. amygdali* clade), 10 samples from cultivated plums (*H. pruni* clade), and 9 samples from peaches (*H. persikonus* clade) (Table 1).

Based on the earlier references (Poulios et al. 2007, Lozier et al. 2008), twenty two metric (in mm) characters were studied:

A2L – length of antennal segment 2; A2W – width of antennal segment 2; A3BW – basal width of antennal segment 3; A3L – length of antennal segment 3; A3SL – length of the longest hair on antennal segment 3; A4L – length of antennal segment 4; A5L – length of antennal segment 5; A6BL – length of basal part of antennal segment 6; A6TPL – length of terminal process of antennal segment 6; AT8SL – length of submedian hair on abdominal tergite 8; BL – body length (excluding cauda); CL – length of cauda; DT3L – length of the second segment of hind tarsus; F3L – length of hind femur; FSL – length of the frons hair; HW – width of the head across eyes; MDHSL – length of median dorsal head hair; MDHSW – distance between the bases of median dorsal head hairs. SL – length of siphunculus; T3L – length of hind tibia; URL – length of ultimate rostral segment; URW – basal width of ultimate rostral segment.

Measurements of the slide-mounted apterous viviparous females were performed by means of interactive measurement system Micro-Image (Olympus Optical Co. GmbH). STATISTICA 8 version software (Statsoft 2007) was exploited for data analysis. Pearson's correlation coefficients were calculated to evaluate the correlation of morphometric characters with body length. Characters with strong ($|r| \geq 0.50$) statistically significant ($p<0.05$) correlation with body length were removed from the further analysis: BL ($r=1.00$), F3L ($r=0.58$), T3L ($r=0.59$), A2L ($r=0.57$), HW ($r=0.51$). Remaining seventeen characters were used for forward stepwise discriminant analysis with host plant species as grouping variable followed by canonical analysis. Discriminant analysis was conducted in three steps. The first step was performed to discriminate between the all three mealy aphid species emerged in the COI dendrogram (*H.*

amygdali, H. persikonus and *H. pruni*). The second step was carried out to discriminate between *H. persikonus* and non- *H. persikonus* (*H. amygdali* and *H. pruni*) samples. The third step of the discriminant analysis was performed on *H. amygdali - H. pruni* data set (*H. persikonus* samples excluded) to separate almond and plum mealy aphid species. Canonical scores were visualized as scatter plots. The morphological interrelationships among different samples were examined using hierarchical cluster analysis based on squared Mahalanobis distances (linkage method – UPGA).

Characters that contributed most in canonical discrimination functions were evaluated as having potential for species separation. The eventual species identification key based on these morphological characters and host plant information was constructed. Afterwards, it was applied on mealy aphid samples that were not used for the construction of the identification key (Table 1).

Results

Partial sequences of mitochondrial (COI)

Lozier et al. (2008) reported partial COI sequences being the most variable in *Hyalopterus* aphids and suggested them as a possible tool for the identification of the mealy aphid species complex. Forty three partial COI sequences of 3 *Hyalopterus* species from 5 countries were included in analysis. The alignment contained 564 bases in final set with 79 variable sites, 35 of which appeared parsimony informative. The sequences were heavily biased towards A and T nucleotides. The average base composition was A = 34.3 %, C = 14.1 %, G = 12.0 % and T = 39.7 %. The overall transition/transversion ratio R = 2.805 for all sites.

The maximum parsimony (MP) analysis of partial COI sequences resulted in 425 equally parsimonious trees (length = 152, CI=0.76, RI=0.95). ML tree (T92+G model) showed similar topology, the same as NJ analysis (Kimura 2-parameter distances) and BI (GTR+G model) analyses. NJ, MP and ML bootstrap values over 50 % together with BI posterior probabilities over 0.50 are given at respective nodes of the same tree in Fig. 1. One can ensure that used *Hyalopterus* samples emerge as monophyletic relative to outgroup and form three major clades representing three host specific mealy aphid species. *H. pruni* and *H. persikonus* are placed as a sister species, whilst *H. amygdali* is located basally.

Morphology

The scatter plot of the first two canonical variates for samples from 18 different geographical localities representing three mealy aphid species (apterous viviparous females) is shown in Fig. 2. All individuals were reclassified correctly into their *a priori* specified groups. The following characters proved to be important predictors when separating

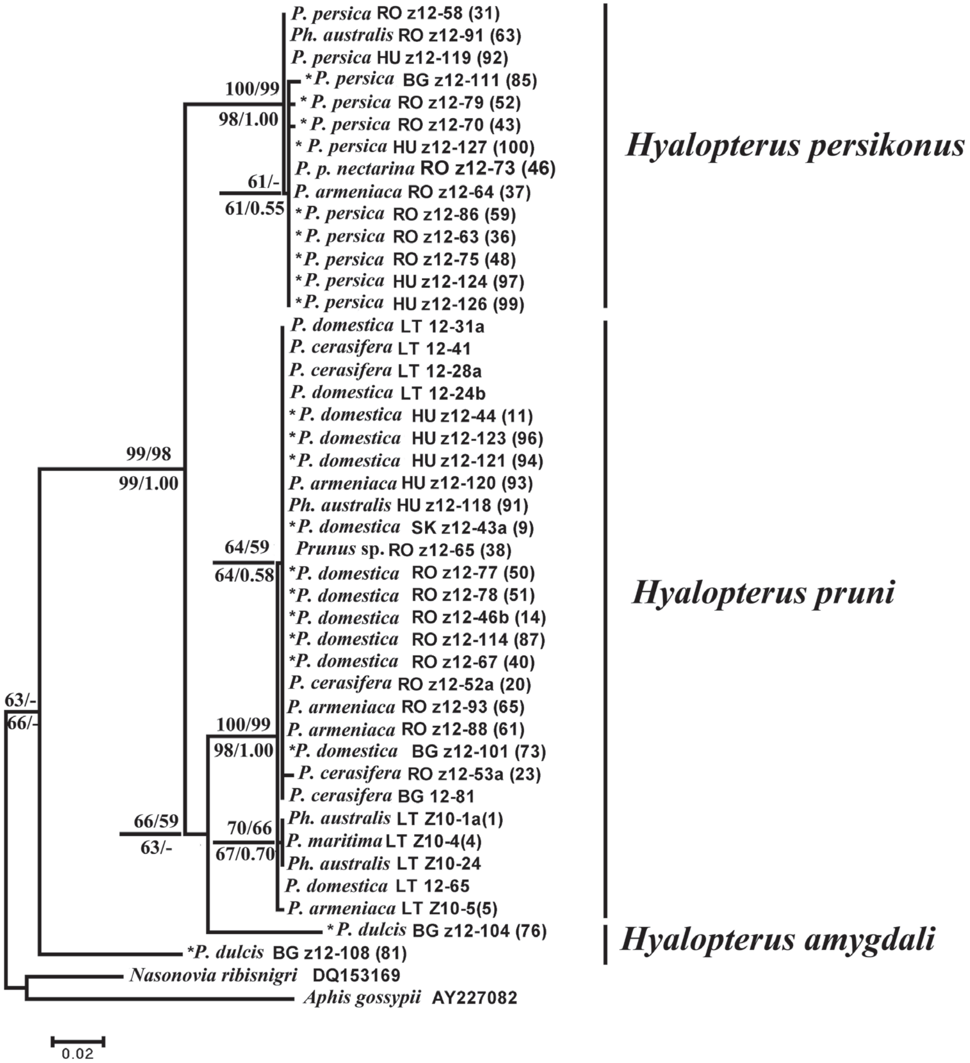

Figure 1. Maximum likelihood (ML) tree showing phylogenetic relationships among three *Hyalopterus* species based on partial sequences of mitochondrial COI (564 positions in final set). Numbers above branches indicate support of NJ (left) and MP (right) bootstrap test with 1000 replicates, and numbers below branches indicate support of ML (left) bootstrap test with 1000 replicates and posterior probabilities of BI analysis (right). Samples used for the discriminant analysis with *a priori* specified group membership followed by the construction of identification key are asterisked (*). The remaining samples were used for the *post hoc* classification. Sample numbers are the same as given in Table 1, together with the abbreviated symbol of respective country: **BG** Bulgaria, **HU** Hungary, **LT** Lithuania, **RO** Romania, **SK** Slovakia.

between three *Hyalopterus* species: MDHSL, URW, T3L/CL (Table 2). The *post hoc* classification of samples gave 96.7 % correct identification of *H. persikonus* (n=46), 100 % of *H. amygdali* (n=10) and 99% of *H. pruni* (n=94) specimens.

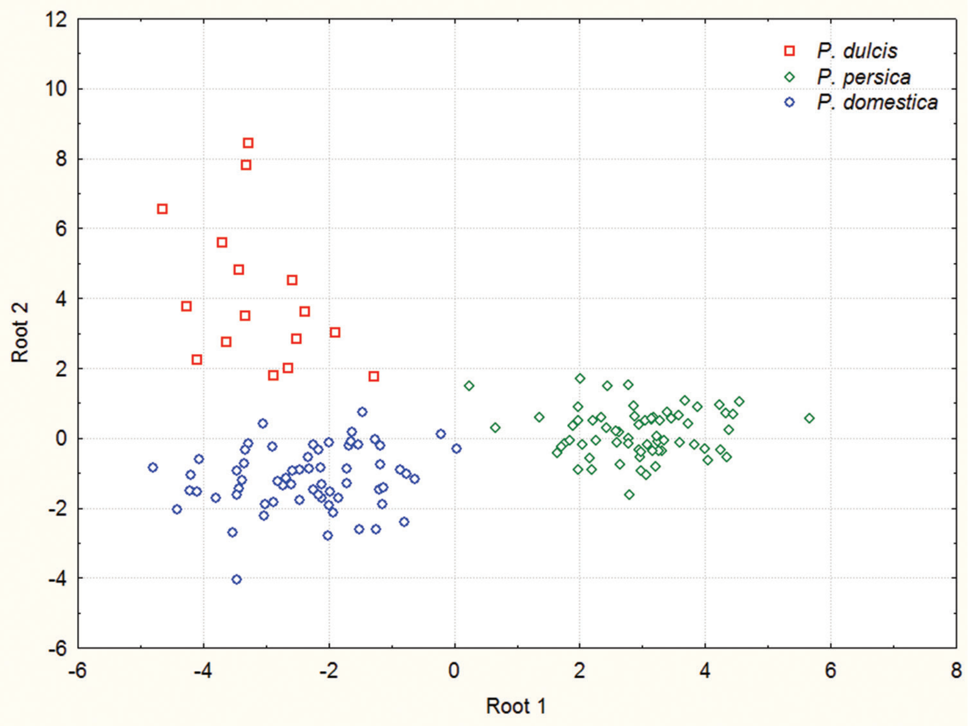

Figure 2. Scatter-plot of the individual canonical scores of the first two canonical variates discriminating 21 samples of *Hyalopterus* collected from different host plants in five European countries (Bulgaria, Hungary, Lithuania, Romania, Slovakia).

To discriminate between apterous viviparous females of *H. persikonus* and non- *H. persikonus* (*H. amygdali* and *H. pruni*) samples the following canonical function (for character acronyms see above) was obtained: 74.6150*URW-1.2696*T3L/CL+1. The values of canonical scores were >0 for *H. persikonus* and <0 for *H. amygdali* + *H. pruni*. This combination of canonical variables separated 100 % of *H. persikonus* (n=71) specimens involved in the analysis with *a priori* specified group membership. The *post hoc* classification gave 94.4 % correct identification of *H. persikonus* (n=46) specimens.

To discriminate between apterous viviparous females of *H. amygdali* and *H. pruni* samples the following canonical function (for character acronyms see above) was obtained: -2.2645*SL-18.6609*MDHSL+1. The values of canonical scores were >0 for *H. amygdali* and <0 for *H. pruni*. This combination of canonical variables separated 94.5 % of *H. amygdali* (n=18) and 100% of *H. pruni* (n=67) specimens involved in the analysis with *a priori* specified group membership. The *post hoc* classification gave 100 % correct identification of *H. amygdali* (n=10) and 94.7% of *H. pruni* (n=94) specimens.

Out of eleven morphological characters included in the canonical function discriminating between sampled apterous viviparous females of mealy aphid species complex, the length of median dorsal head hair (MDHSL) enabled separation of 97.3 % *H. amygdali* specimens. Namely, the lengths of median dorsal head hair from 0.026

Table 2. Contribution of eleven morphological characters to the canonical functions discriminating 23 European samples of *Hyalopterus*. Character abbreviations the same as in the text (Material and methods).

	Wilks' Lambda	Partial Wilks' Lambda	F-remove (2,135)	p-level	Toler.	1-Toler. (R-Sqr.)
T3L/CL	0,05	0,66	34,70	0,00	0,71	0,29
MDHSL	0,04	0,81	15,40	0,00	0,14	0,86
URW	0,04	0,82	14,33	0,00	0,86	0,14
URL	0,04	0,89	8,37	0,00	0,81	0,19
DT3L	0,04	0,97	1,98	0,14	0,69	0,31
A6TPL	0,04	0,86	11,14	0,00	0,60	0,40
MDHSW	0,06	0,58	48,13	0,00	0,12	0,88
MDHSW/ MDHSL	0,06	0,58	49,50	0,00	0,07	0,93
A5L	0,04	0,90	7,57	0,00	0,40	0,61
SL	0,04	0,92	6,30	0,00	0,75	0,25
A6BL	0,04	0,96	3,04	0,05	0,60	0,40

to 0.039 mm were characteristic of *H. amygdali*, whilst 0.036 – 0.067 mm – for other two species. Yet we failed to find any single character or ratio enabling satisfactory discrimination between apterous viviparous females of *H. pruni* and *H. persikonus*. For the present, the following morphological identification key might be suggested to identify apterous viviparous females of the mealy aphid species complex.

Species key (apterous viviparous females)

1 Canonical discrimination function 74,6150*URW - 1,2696*T3L/CL + 1 value exceeding 0. Setae on frons stout. On peaches, nectarines, apricots or reeds .... ***H. persikonus***

– Canonical discrimination function value less than 0. Setae on frons filiform. On almonds, plums, apricots or reed **2**

2 Length of the median dorsal head hair (MDHSL) 0.026 – 0.039 (average 0.031) mm. Canonical discrimination function -2.2645*SL - 18.6609* MDHSL + 1value exceeds 0. On almond or reeds .... ***H. amygdali***

– MDHSL 0.036 –0.067 (0.05) mm. Canonical discrimination function value less than 0. On plums, apricots or reeds .... ***H. pruni***

Discussion and conclusions

Our analysis shows the morphological separation of mealy aphid species complex being a really difficult task which is in accordance with the earlier references (Poulios et al. 2007, Lozier et al. 2008). Nonetheless, it appeared that certain morphological char-

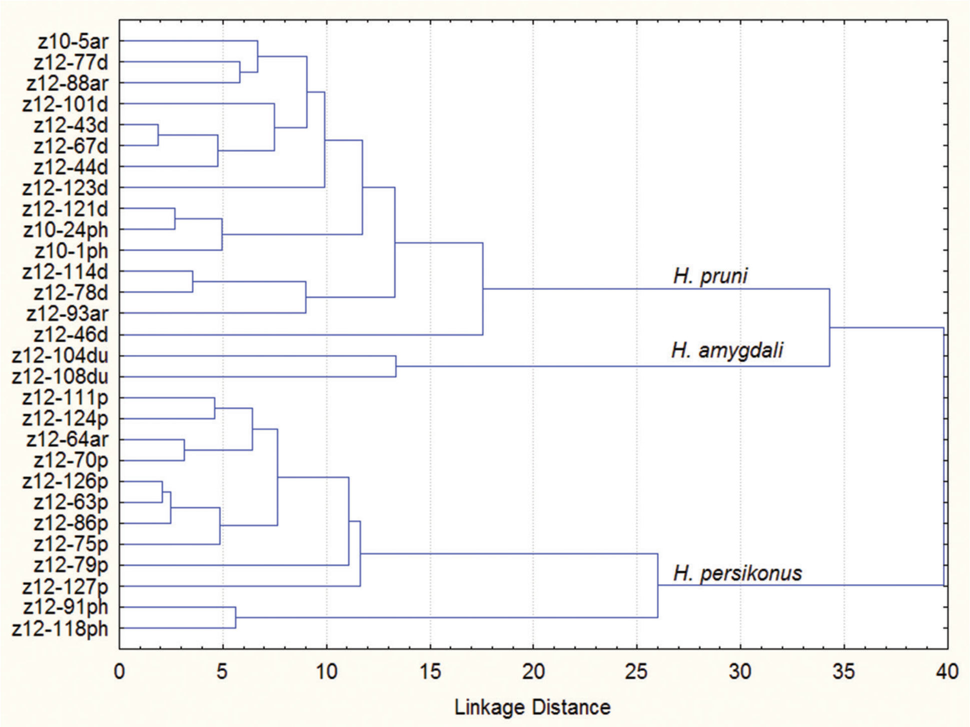

Figure 3. Dendrogram of hierarchical cluster analysis based on 17 morphological characters (squared Mahalanobis distances) using unweighted pair-group average linkage among 29 samples of *Hyalopterus*. Sample numbers the same as in Table 1. **ar** samples from *Prunus armeniaca*, **d** *P. domestica*, **du** *P. dulcis*, **p** *P. persica*, **ph** *Phragmites communis*.

acters are effective when applied independently on different data. Namely, the length of median dorsal head hair (MDHSL) has been included in the key of Lozier et al. (2008) to separate *H. amygdali* from *H. pruni*/*H. persikonus*. This character enabled separation between *H. amygdali* and *H. pruni*/*H. persikonus* in our analysis also. Ratio hind tibia length/cauda length (T3L/CL) has been employed in the key of Lozier et al. (2008) to discriminate between *H. pruni* and *H. persikonus*, although they reported remarkable overlapping of this character values in *H. pruni* (4.6–8.3, average 6.1) and *H. persikonus* (3.7–7.6, average 5.1). This was also the case in our study: 4.47–6.71 (5.46) for *H. pruni*, 3.76–5.36 (4.41) for *H. persikonus* and 4.73–6.72 (5.29) for *H. amygdali*. In addition to the above mentioned characters, our analysis showed the basal width of the ultimate rostral segment being of certain use when discriminating between the mealy aphid species. Its values were 0.059–0.075 mm (average 0.067) for *H. pruni*, 0.064–0.083 (0.073) for *H. persikonus* and 0.061–0.071 (0.066) for *H. amygdali*.

When performing discriminant analyses, the body length should be eliminated from the data set together with characters that have strong and statistically significant correlation with the body length. In our case, when the entire data set of morphological characters was used for discriminant analysis, samples from reeds appeared the most different (not shown). Contrary, after the body length and correlated characters were removed from analysis, samples from reeds scattered amongst samples from plum and peach.

The results of cluster analysis based on morphological data (Fig. 3) show *H. persikonus* being more distantly related with *H. pruni* and *H. amygdali*. This contradicts the results of morphological analysis by Poulios et al. (2007) and supports the opinion of Mosco et al. (1997) on the early separation of *H. persikonus* from *H. pruni/amygdali* stem, which was also supported by the subsequent molecular analyses (Lozier et al. 2007, 2008). Such long lasting controversy might be explained by the fact that all three species share apricot as a winter host (see Lozier et al. (2008) for broader discussion), enabling interspecific gene flow. To clear the matter, precise studies of the host specificity and life cycles of the three taxa (including experimental transfers from plums to reeds and vice versa), together with hybridization trials, are needed. For the present, phylogenetic relationships of the three *Hyalopterus* species remain uncertain.

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Preliminary study of wing interference patterns (WIPs) in some species of soft scale (Hemiptera, Sternorrhyncha, Coccoidea, Coccidae)

Ewa Simon[1]

[1] *Department of Zoology, University of Silesia, Bankowa 9, 40-007 Katowice, Poland*

Corresponding author: *Ewa Simon* (ewa.simon@us.edu.pl)

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Abstract

The fore wings of scale insect males possess reduced venation compared with other insects and the homologies of remaining veins are controversial. The hind wings are reduced to hamulohalterae. When adult males are prepared using the standard methods adopted to females and nymphs, i.e. using KOH to clear the specimens, the wings become damaged or deformed, an so these structures are not usually described or illustrated in publications. The present study used dry males belonging to seven species of the family Coccidae to check the presence of stable, structural colour patterns of the wings. The visibility of the wing interference patterns (WIP), discovered in Hymenoptera and Diptera species, is affected by the way the insects display their wings against various backgrounds with different light properties. This frequently occurring taxonomically specific pattern is caused by uneven membrane thickness and hair placement, and also is stabilized and reinforced by microstructures of the wing, such as membrane corrugations and the shape of cells. The semitransparent scale insect's fore wings possess WIPs and they are taxonomically specific. It is very possible that WIPs will be an additional and helpful trait for the identification of species, which in case of males specimens is quite difficult, because recent coccidology is based almost entirely on the morphology of adult females.

Keywords

Scale insects, Coccidae, wings, males, WIP, interference colour patterns

Introduction

The superfamily Coccoidea or scale insects contains 7500 species of plant feeding hempiterans, comprising 48 families (according to ScaleNet data base). Many of them are economically important pest to agriculture, horticulture and forestry (Gullan and Cook 2007).

Within this superfamily, there is a very marked dimorphism between the adult male and female, both in their morphology and life histories, such that it is impossible to identify the male and female of the same species (or even family) using the same combination of characters (Koteja 1996).

Adult females are sack-like, with the head, thorax and abdomen fused together. They are all wingless and many have reduced legs and antennae but the mouth parts are usually well developed. They can be quite long lived, surviving for several months on their host plants. The adult males are delicate, ephemeral insects without mouth parts, and so live as adults for only a few days. They are usually alate, although characterized by diptery, and resemble small delicate flies (Gullan and Martin 2009).

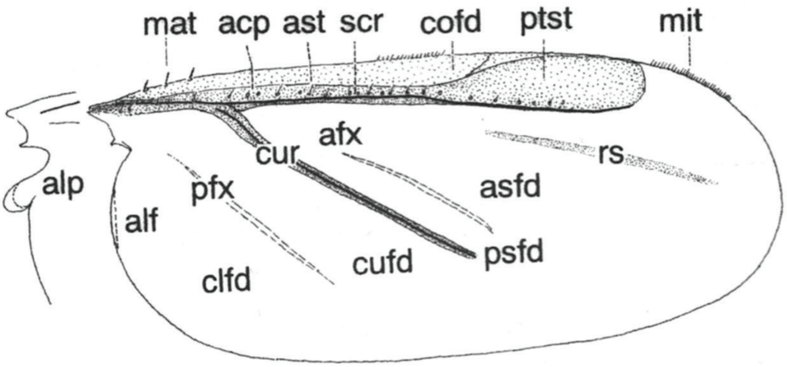
Species of Coccoidea are almost always described based on female structure, whilst most males are so poorly known that they are mostly unidentifiable to species (Hodgson and Foldi 2006). For example, within the entire Coccidae family, the adult males of only about 90 species have been described adequately to date as they are rarely collected and seldom studied. In contrast, the adult females of approximately 1200 species have been well described in just the family Coccidae (Hodgson and Henderson 2004).

As was mentioned above, only male Coccoidea possess wings. These structures have a very simplified venation in the fore wings whilst the hind wings are reduced to hamulohalterae. Because of this simplification and because the wings have been lost from all females, it was considered that the wings were featureless and therefore their morphology has been neglected (Szelegiewicz 1971).

The males are polymorphic with respect to the wings, i.e. winged, brachypterous, and wingless forms have been accepted by natural selection. During further evolution and adaptation to different ecological conditions the polymorphism has been retained or one morph has been preferred. Wing and wingless form may occur in different groups or within the same taxon, sometimes even in the same species (Kosztarab and Kozar 1988, Koteja 1985, 1996). The terminology connected with the wing morphology used here is that of Koteja (1996, 2008) and the general scheme of the fore wing presented on Fig.1 comes from the Koteja's work (2008).

The anterior wings are folded flat and overlap along the abdomen in resting position which facilitates the moving among soil particles, plant parts, etc. Shape of the wing is usually oval, but also with parallel anterior and posterior margins, with distal part wider than proximal one or reversely; with broad or narrow base, with rounded or acute apex.

For reception hamuli serves the narrow anal fold or projecting alar lobe with a pocket. On the wing there are two ridges: subcostal ridge which runs along costal margin from wing base toward wing apex; cubital ridge which originates from the former at about 1/5 wing length and runs obliquely to posterior wing margin. On the membrane of the wing might be present flexing patches (light lines) anterior – between



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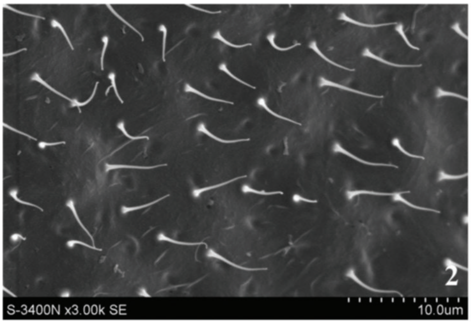
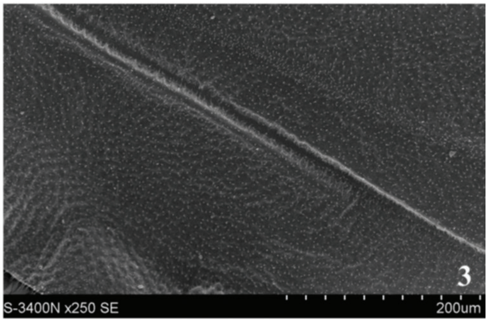
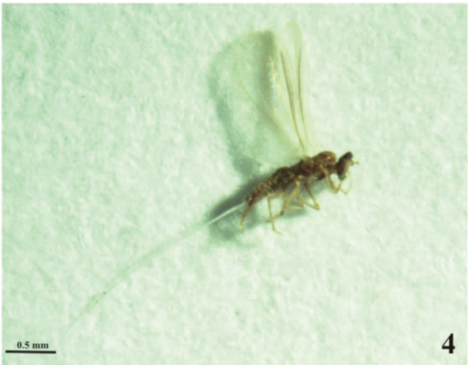






Figures 1–5. 1 General scheme of the fore wing (after Koteja 2008) acp-alar cupolae, afx-anterior flexing patch, alf-alar fold, alp-alar lobe, asfd-anterior subcostal field, ast-alar setae, clfd-claval (anal) field, cofd-costal field or thickening, cufd-cubital field, cur-cubital ridge, mat-macrotrichia, mit-microtrichia, pfx-posterior flexing patch, psfd-posterior subcostal field, ptst-pterostigma, rs-"radial sector", scr-subcostal ridge **2, 3** *Pulvinaria vitis* (Linnaeus): scanning electron microphotographs of the wing, showing its microsculpture **4, 5** Male of *Pulvinaria vitis* (Linnaeus) on white background, with invisible WIPs, and 2 on a black background, showing WIPs.

subcostal ridge and cubital ridge and posterior – between cubital ridge and posterior wing margin. A slightly sclerotized oblique patch, which runs posterior to subcostal ridge is called radial sector. The ridges and flexing membranes divide the wing into fields, which are illustrated on Fig. 1. Depending on the development of ridges and flexing patches the fields assume various shapes, size, and may join or disappear. Pterostigma is present in some Archaeococcids and is hypodermal club-shaped thickening in front, or behind, subcostal ridge, not bordered with any veins (Koteja 2008). In all Neococcids and few groups of Archaeococcids the surface of the wing is covered with small hairlike microtrichia. Along the anterior margin of the subcostal ridge might be present a row or cluster of cupolae and alar setae might be interspersed among them or occur at the wing base (Koteja 1996).

Compared with most other structures, the wings of scale insects are best preserved dried or as fossils and have thus been found to be important in paleontological studies. The wings of recent specimens, prepared using standard methods adopted to females and nymphs (i.e. using KOH solution), become deformed or damaged, and usually are not described or drawn in publications (Koteja 2008). The present study looks at a new character present on scale insects wings, which has never been examined before in coccidology - the interference wing patterns (WIPs) of soft scales (Coccidae). Figs 4 and 5 illustrate the changes in the visual appearance of the wings (of *Pulvinaria vitis*) when the background is switched from white to black. WIPs occur on transparent wings with a very thin membrane, i.e. mainly in small insects. The colour patterns appear when wings are viewed against a dark background and show the uneven thickness of the wing membrane (Shevtsova 2012). The thickness of the composite chitinous membrane varies with the topography of the wing and the areas of different thickness reflect different interference colours that together produce a specific colour pattern, the WIP. Taxon specific colour patterns depend also on pigmentation, venation, and hair placement. The optically refracted pattern is also stabilized by membrane corrugations and spherical cell structure (Shevtsova et al. 2011). Observations of WIPs in many groups of Hymenoptera and Diptera suggest that species identification is enhanced if WIPs are added to the taxonomic characters (Shevtsova and Hansson 2011, Hansson 2011, Hansson and Shevtsova 2012).

Material and methods

WIPs of seven species of the family Coccidae belonging to six genera were studied: *Eriopeltis lichtensteini* Signoret, *Eulecanium tiliae* (Linnaeus), *L. frontalis* Green, *Luzulaspis nemorosa* Koteja, *Parthenolecanium corni* (Bouche), *Pulvinaria vitis* (Linnaeus) and *Sphaerolecanium prunastri* Boyer de Fonscolombe. This material comes from Koteja's collection of scale insects deposited in Department of Zoology (University of Silesia, Katowice, Poland), and from author's collection (only puparia with accompanied females were collected) (Table 1).

The method used for preparation of the wings was standardized, as suggested by Shevtsova and Hansson (2011), i.e. dry wings were horizontally arranged (with the magnification 2 or 3×) and, flattened between a glass slide and glass cover. The underside of the glass slide was stained with black ink to make a pitch black background.

Table 1. The collection data of the studied material (KC – Koteja's collection, AC – author's collection).

Species	Number of specimens studied	Collection	Date of collection	Place of collection	Plant	Geographical coordinates
Eriopeltis lichtensteini Signoret, 1877	25	KC	28.7.1967	Makowska Gora near Sucha, Poland	*Agrostis vulgaris*	
			20.09.1968	-	-	
			31.07.1969	Mikoszewo, Poland	different grasses	
			05.08.1969	Mikoszewo, Poland	*Calamagrostis epigejos*	
Eulecanium tiliae (Linnaeus, 1758)	5	AC	02.05.2012	Ruda Slaska, Poland	*Acer platanoides*	50°15'24.12"N, 18°54'5.64"E
			16.05.2012	Niegowonice, Poland	*Tilia cordata*	50°23'55.69"N, 19°26'8.92"E
Luzulaspis frontalis Green, 1928	13	KC	06.1962	Wolski Forest Cracov, Poland	*Carex brizoides*	
Luzulaspis nemorosa Koteja, 1966	15	KC	21.08.1967	Ojcow Cracov, Poland	*Luzula nemorosa*	
Parthenolecanium corni (Bouché, 1844)	6	AC	30.04.2007	Ruda Slaska, Poland	*Tilia cordata*	50°16'5.24"N, 18°53'8.64"E
			07.05.2012	Ruda Slaska, Poland	*Ulmus laevis*	50°15'23.85"N, 18°54'6.42"E
Pulvinaria vitis (Linnaeus, 1758)	31	AC, KC	29.08.1987	Ruda Rozaniecka Roztocze , Poland	*Salix* sp.	
			26.08.1987	Ruda Rozaniecka Roztocze, Poland	*Betula verrucosa*	
			21.08.2011	Katowice, Poland	*Alnus glutinosa*	50°14'3.77"N, 19°0'55.71"E
Sphaerolecanium prunastri (Boyer de Fonscolombe, 1834)	6	AC	02.06.2012	Kuznia Raciborska, Poland	*Prunus spinosa*	50°12'9.02"E, 18°19'56.48"E
			16.05.2012	Niegowonice, Poland	*Prunus spinosa*	50°23'54.86"N, 19°26'15.78"E

Photos of the wings were taken with a Nikon DN 100 camera unit on a Nikon stereomicroscopes SM2 1500.

Photos from scanning microscope were taken from a Hitachi S-3400N microscope and made in the Department of Materials Science of the Silesia University of Technology.

The brightness was individually adjusted in COREL DRAW X, subsequent editing included cleaning and cropping the photo. The studied wings were put between two cover glasses (glued together by small drops of transparent nail polish) and deposited with the original specimen.

The wings were also observed on whole specimens. In order to ensure that the colour patterns are stable, the wings on the unmounted specimens were observed in different arrangement against a black background, and viewed at different incident angles of the light, which was narrowly concentrated in one direction at a slight angle to the wings surface.

According to Shevtsova and Hansson (2011) the observation and documentation of WIPs do not require a special light source and can be done on dry specimen with intact wings arranged against a black background. In present studies material was illuminated by fiber optic illuminator Cold Light L-150A (Quartz halogen light source color temperature- 3200K).

Results

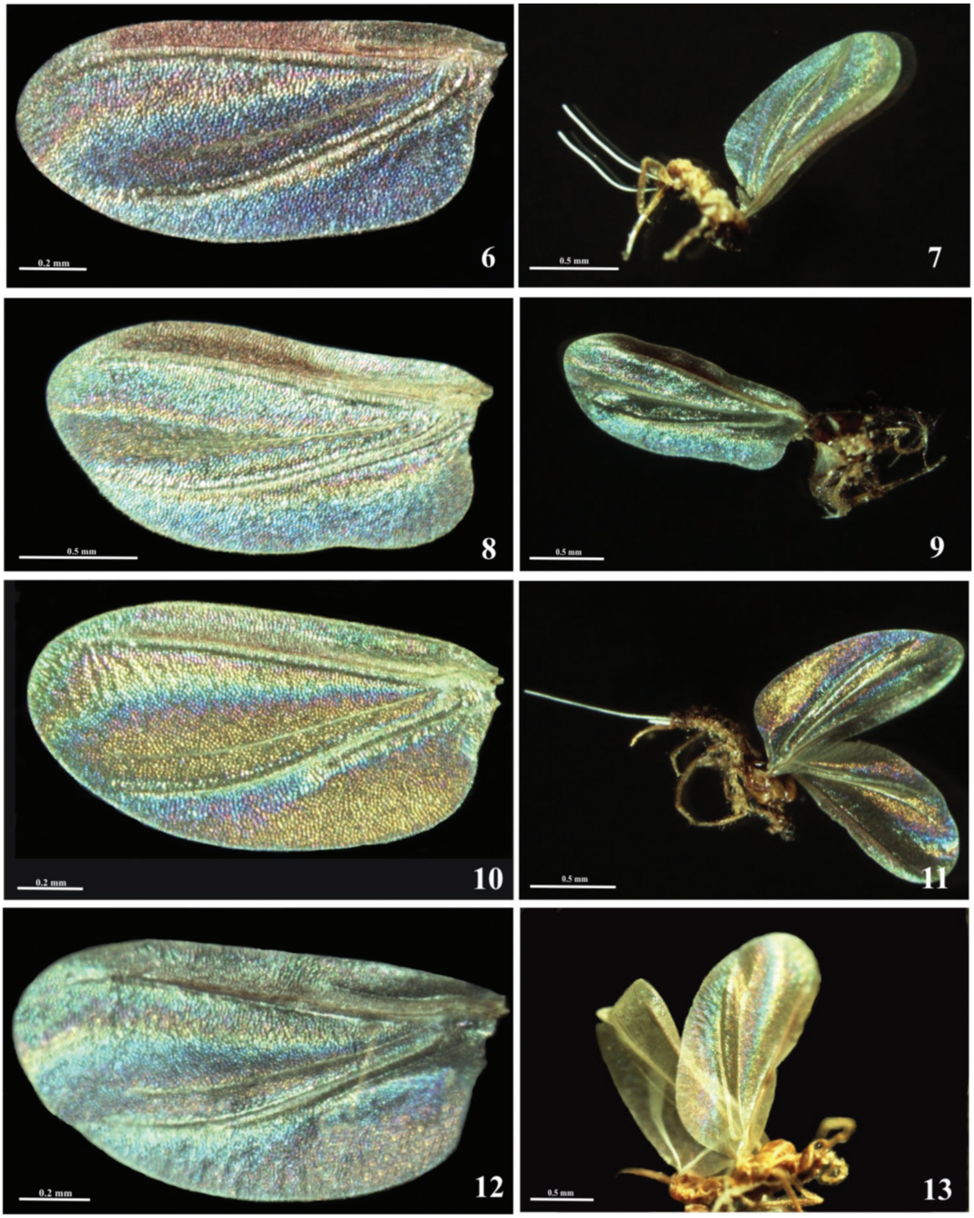
The present study confirmed that WIPs are present on the dry, minute and semi-transparent wings of male scale insects. SEM observations (Figs 2, 3) showed that membrane of the scale insect wing is characterized by the presence of corrugations and microtrichia.

In case of Hymenoptera and Diptera such membrane corrugations and hair placement together with uneven membrane thickness form stable and taxon specific colour patterns.

Convex ridges of a corrugated wing membrane act as a dioptres to stabilize the interference reflection and eliminate the iridescence effect over a large range of light incidences, it means that provide optical stabilization to WIPs. According to Shevtsova (2012) the convex ridges of a corrugated wing membrane reflect thin film interference colours from the top. When such a wing is tilted these "tops" move along the ridge and show the same interference colour. That is because they keep nearly horizontal at each point and maintain the same distance for the light beams that travel inside the wing.

Among examined species all of them exhibited its own WIP which could be distinguished from that of other species. Among the species two main types of patterns could be distinguished: "horizontally striped pattern", encountered on broad wings of species which Giliomee (1967) assigned to the "Coccus group" (*Pulvinaria, Parthenolecanium*) and "Eulecanium group" (*Eulecanium, Parthenolecanium* and *Sphaerolecanium*). According to Hodgson's classification (1994), *Pulvinaria* and *Parthenolecanium* belong to subfamily Coccinae, *Eulecanium* and *Sphaerolecanium* to subfamily Eulecaninae. This pattern here is characterized by the presence of longitudinal stripes of different interference colours on the field between the subcostal and cubital ridges (terminology after Koteja 2008). This striped band is curved a little and the stripes rich the margin of the wing. The main differences between the patterns of this group are connected with the semitriangular region delimited by lower margin of cubital ridge, posterior wing margin up to the wing base and the part which surrounds the first light line. In *Sphaerolecanium prunastri* (Figs 6, 7), this semitriangular region is a deep blue, the region anterior to the cubital ridge rich purple and than blue. In *Eulecanium tiliae* (Figs 8, 9), the main part of mentioned above semitriangular region is blue, but the area which adjoin to the cubital ridge has yellowish and purple stripes.

In *Pulvinaria vitis* (Figs 10, 11), the main part of the region delimited by cubital ridge, posterior wing margin and the margin near the wing base is golden-hued. The same golden color surrounds the first light line. To these golden-hued areas adjoin from above purple-blue stripes. The WIP of the *Parthenolecanium corni* (Figs 12,



Figures 6–13. Males with "horizontally striped patterns" of WIPs, subfamilies Eulacaninae and Coccinae: **6–7** WIP of *Sphaerolecanium prunastri* (Boyer de Fonscolombe) **8–9** WIP of *Eulecanium tiliae* (Linnaeus) **10, 11** WIP of *Pulvinaria vitis* **12–13** WIP of *Parthenolecanium corni* (Bouché).

13) is quite similar to that of *P. vitis* but, in the former species, there is broad blue-purple band on the part which lies below the cubital ridge (in *P. vitis* there is only narrow purple-blue stripe). Only narrow yellowish stripes surround the first light line (in *P. vitis* there is broad golden band). But the purple-blue band which adjoins

to golden-hued area (which surrounds the first light line in *P. vitis*) here, in *P. corni* is much broader.

The pattern of the second type of WIP can be described as "elliptical" - colours follow one by one, and do not form distinct stripes beneath the subcostal ridge which reach the apical margin of the wing, as in previous type.

This type of WIP is present on long and narrow wings of *Eriopeltis lichtensteini, Luzulaspis frontalis* and *L. nemorosa*. The apical part of the wing is covered only by one colour. These two genera were grouped by Giliomee in the "Eriopeltis group" and in the subfamily Eriopeltinae by Hodgson (1994). Likewise, as in species of the previous group (horizontally striped pattern), the WIPs are taxonomically specific, not only at generic level but at the species level too. The patterns of *Luzulaspis frontalis* and *L. nemorosa* are significantly different. In *Luzulaspis frontalis* (Figs 14, 15), the area which surrounds the first light line is golden-hued, than from above it turns into purple, than in deep blue and than light blue. Whole part of the membrane which lies beneath the cubital ridge is golden-hued.

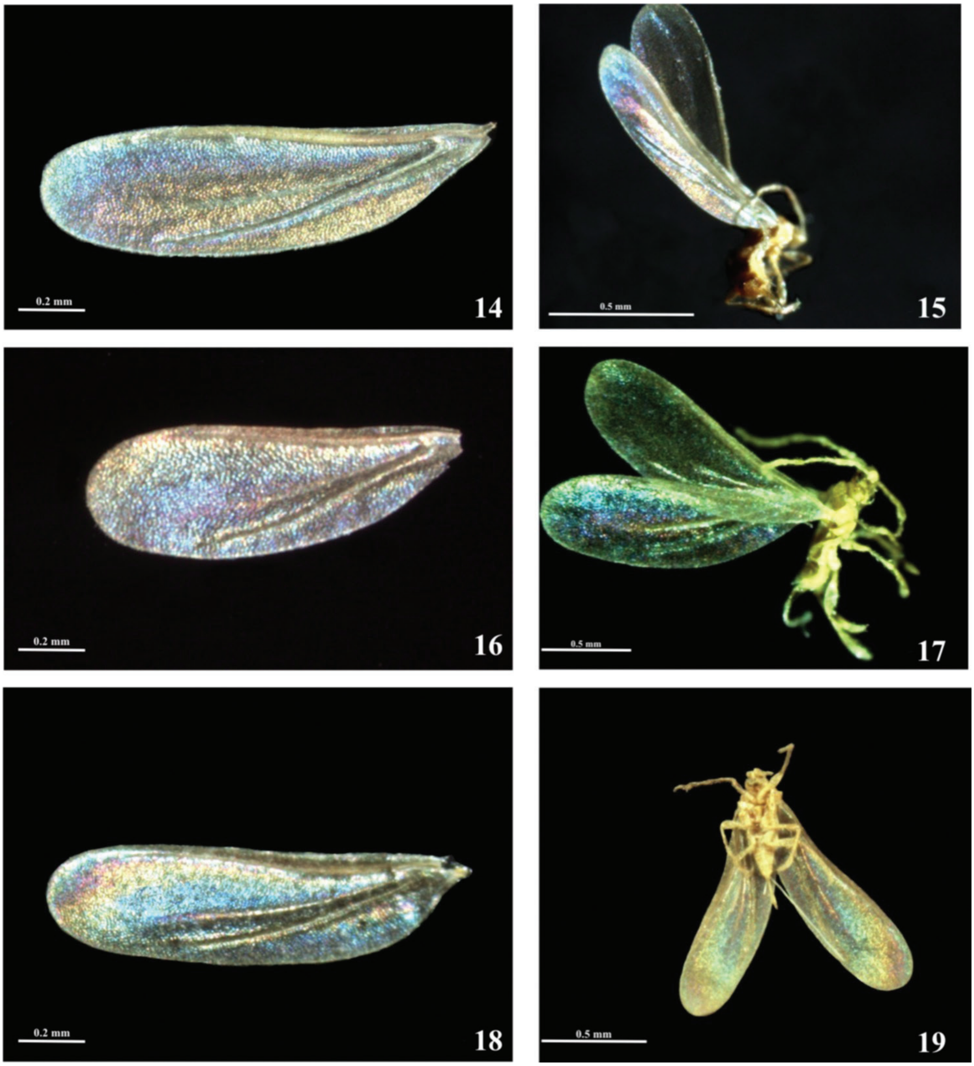
In *L. nemoralis* inner part, which surrounds the first light line is purple, than colour turns into blue and near the anterior edge of the wing is yellowish-green (Figs 16, 17). All part below the cubital ridge is purple-bluish. In *Eriopeltis lichtensteini* (Figs 18, 19) first light line and cubital ridge are surrounded by blue area. Near the subcostal ridge blue turns into yellowish green. Very characteristic is purple spot near the apical part of the wing.

The WIPs of each of these seven species are significantly different and could provide additional insights into species recognition. These colour patterns are stable and can be seen not only on horizontally arranged wings but also on hole specimen (Figs 7, 9, 11, 13, 15, 17 19), the only requirements are black background and proper illumination.

Discussion

The use of wing interference patterns (WIPs) as a morphological character is so new that very little is known about their significance, either to the behavior of the species or in terms of morphological taxonomy, although they have already proven to be useful for generic- and even species–level classifications, particularly in Hymenoptera (Shevtsova and Hansson 2011, Hansson and Shevtsova 2012). These patterns have been even investigated from an evolutionary standpoint for the Cynipoidea (Hymenoptera) (Buffington and Sandler 2011). The preliminary studies outlined above show that each of the seven species has its own WIP, probably after further research, which include more species, these colour patterns could find practical applications in morphological studies of this family.

In other insect groups, such as Diptera and Hymenoptera, it is believed that WIPs are not only a byproduct of physical traits, but probably also function in intra- and interspecific signaling. Thus wing display play a central role in visual courtship communication in several groups of Diptera (e.g. Sepsidae, Tephritidae) and Hymenoptera (e.g. Chalcidoidea: Pteromalidae) (Shevtsova et al. 2011, Shevtsova 2012).



Figures 14–19. Males with "eliptical" patterns of WIPs, subfamily Eriopeltinae: **14, 15** WIP of *Luzulaspis frontalis* Green **16–17** WIP of *Luzulaspis nemorosa* Koteja. **18–19** WIP of *Eriopeltis lichtensteini* Signoret.

At the present time, in geological history only male Coccoidea possess wings. Females are often sedentary, only have simple unicorneal eyes and all are completely apterous. It seems, therefore, unlikely that these females are able to see sophisticated colour patterns on male's wings. However Koteja (1990) suspected that "the coccid male at some time had functional mouthparts and well-developed metathoracic wings, and that the female was alate and possesed compound eyes" Shcherbakov (2007) considered that the family Naibiidae is ancestral to the true scale insects. Representatives of the Naibiids were not sexually dimorphic, bouth sexes were presumably feeding and flying. Obviously we cannot check whether WIPs were present on the four-winged ancestors of scale insects, but it is possible that in Mesozoic times, WIPs played a significant role in inter- and intra-specific signaling.

Interestingly, Koteja (2001) noted that male *Porphyrophora* sp. (Margarodidae) performed flight stretching and repositioning of the wings under laboratory conditions. In the same paper, Koteja quoted very similar observations by Jakubski (1929) ("the males made an impression of being ill - they exposed and reposed the wings in hopeless efforts of flight"). Furthermore, both authors noted that the halters were vigorously vibrated when the fore wings were still. The same was observed by Pflugfelder (1939 in Koteja 2001) in males of *Kerria lacca* (Kerridae) when females were nearby. Maybe these examples of wing movement and haltere trembling are remnants of a visual communication by their ancestors, connected with displaying the wings and their patterns.

The types of WIPs seen in this study appear to reflect the affinity between the members of Coccidae. Indeed, the types of WIPs found here might be connected with their ecology, in so far as the "horizontally striped pattern" occurs in species which are present on woody plants: *Sphaerolecanium prunastri* feeds mainly on representatives of Rosaceae, and *Eulecanium tiliae, Parthenolecanium corni* and *Pulvinaria vitis* are common poliphagous species also encountered on different woody host plants (Kosztarab and Kozar 1988), while all species with the "elliptical pattern" (*Eriopeltis lichtensteini, Luzulaspis frontalis* and *L. nemorosa*) feed on monocotyledonous plants: Cyperaceae, Juncaceae and Poaceae (Kosztarab and Kozar 1988). Because of the limited number of observed species this ecological dependance of the pattern might be only a convergence of circumstances but it is worth to checked in other species of this family.

According to Shevtsova et al. (2011) and Shevtsova and Hansson (2011), WIPs are intraspecifically variable and phenotypically plastic in small wasps and diptera, although they are largely uniform among conspecifics and often appear to be characteristic of a species.

On the basis of the examined material, the WIPs of male Coccids appear to be uniform among conspecifics. However, more material from different localities and from different host plants, etc need to be studied to know if there is any intraspecific variability or phenotypical plasticity. If WIPs are used by their bearers for visual communication and, if this signalling system is involved in reproductive isolation and species recognition (Shevtsova 2012), it will be interesting to check the variability between scale insect species belonging to a single genus but which are either allopatric or sympatric, as investigated Hansson and Shevtsova in the eulophid genus *Omphale* Haliday (Shevtsova 2012).

The importance of the adult male structure for the proper understanding of the relationships within the Coccoidea was recognized by Hodgson and Henderson (2004), who considered that no satisfactory system of scale insect classification would be achieved without an understanding of male structure. Most species of scale insects reproduce sexually, but there is a lot of species which are parthenogenetic and reproduce without males, only in some *Icerya* ssp. hermaphroditism has been reported (Gullan and Kosztarab 1997, Gavrilov and Kuznetsova 2007). In case of many others species males are not known at all. Because scale insects are known as serious plant pests in several cases of important, sometimes quarantine species male pheromone traps are used for survey and monitoring. In this case for correct species identification molecular techniques are available (Tobias et al. 2010) and WIPs might support and faciliate species determination.

If the usage of WIPs in coccidology becomes as useful as in the studies on Hymenoptera and Diptera, it will be very important to keep the wings under dry conditions. At present, the most common method of specimen storage prior to making microscopic slides is to preserve the specimens in ethanol. Unfortunately, the WIP colour patterns are invisible on specimens mounted in Canada balsam, while scale insect wings which have been preserved in alcohol either do not show WIPs at all or the patterns are not as bright and clear as those using dry wings.

For a long time, wings of scale insects have been regarded as being poor in morphological features because of their reduced venation and lack of pigments. WIPs might be an additional trait for facilitating species identification. Because studies on scale insect wings are easy and cheap, studies of the wing interference patterns might be a helpful tool in species recognition and for clarifying many taxonomic problems, together with very important and common molecular techniques (Gullan et al. 2010, Tobias et al. 2010, Malausa et al. 2011).

Conclusions

These preliminary studies confirmed the presence of stable and taxonomically specific wing intereference patterns (WIPs) on scale insects wings. The thin wings of males display vivid structural colour patterns due to thin film interference when viewed against black background using white light. The use of WIPs as a species character in the species studied here has produced some convincing patterns and therefore these small, semitransparent organs should not be regarded as unimportant features anymore. However, if WIPs on male wings are to be studied, it is imperative that are stored dry and not preserved in ethanol or mounted in Canada balsam.

It is intended that these studies will continue, using a wide range of species from different scale insect families and also to consider any effects of intraspecific variation and phenotypic plasticity.

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First report on C-banding, fluorochrome staining and NOR location in holocentric chromosomes of *Elasmolomus* (*Aphanus*) *sordidus* Fabricius, 1787 (Heteroptera, Rhyparochromidae)

Vikas Suman[1], Harbhajan Kaur[2]

1 *Department of Entomology, Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan 173 230, Himachal Pradesh, India* **2** *Department of Zoology and Environmental Sciences, Punjabi University, Patiala 147 002, Punjab, India*

Corresponding author: *Vikas Suman* (viks_suman@yahoo.co.in)

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Abstract

In spite of various cytogenetic works on suborder Heteroptera, the chromosome organization, function and its evolution in this group is far from being fully understood. Cytologically, the family Rhyparochromidae constitutes a heterogeneous group differing in chromosome numbers. This family possesses XY sex mechanism in the majority of the species with few exceptions. In the present work, multiple banding techniques viz., C-banding, base-specific fluorochromes (DAPI/CMA$_3$) and silver nitrate staining have been used to cytologically characterize the chromosomes of the seed plant pest *Elasmolomus* (*Aphanus*) *sordidus* Fabricius, 1787 having 2n=12=8A+2m+XY. One pair of the autosomes was large while three others were of almost equal size. At diplotene, C-banding technique revealed, that three autosomal bivalents show terminal constitutive heterochromatic bands while one medium sized bivalent was euchromatic. Microchromosomes (m-chromosomes) were positively heteropycnotic. After DAPI and CMA$_3$ staining, all the autosomal bivalents showed equal fluorescence, except CMA$_3$ positive signals, observed at both telomeric heterochromatic regions of one medium sized autosomal bivalent. Silver nitrate staining further revealed that this chromosome pair carries Nucleolar Organizer Regions (NORs) at the location of CMA$_3$ positive signals. The X chromosome showed a thick C-band, positive to both DAPI /CMA$_3$ while Y, otherwise C-negative, was weakly positive to DAPI and negative to CMA$_3$, m-chromosomes were DAPI bright and CMA$_3$ dull.

Keywords

C-banding, DAPI, CMA$_3$, NOR location

Introduction

Heteroptera is a large cosmopolitan suborder comprising about 42,300 known species (Henry 2009). The species of Heteroptera are distributed into 7 infraorders and a total of 24 superfamilies worldwide (Schuh and Slater 1995). Lygaeidae, Rhyparochromidae Pyrrhocoridae, Coreidae, Pentatomidae, Reduviidae and Miridae are some of the major families, each having its individual economic importance (Schaefer and Panizzi 2000). Rhyparochromidae (seed bugs) were considered by most workers to be a subfamily within the Lygaeidae until revision by Henry (1997) who recognized them at the family level. Rhyparochromids are mostly ground dwellers, living in the shadow vegetation and feeding primarily on seeds. *Elasmolomus* (*Aphanus*) *sordidus* is a serious pest, occurring on pods left drying in the fields and in stores. Groundnuts and sesame pods infested by this insect have shrivelled kernels. Like other heteropterans, Rhyparochromidae are characterized by holokinetic chromosomes and post reductional division of sex chromosomes, as well by presence of m-chromosomes and XY sex mechanism in all the species with few exceptions (Ueshima 1979).

In the present contribution, cytological characterization of *E.* (*Aphanus*) *sordidus*, reported as *Aphanus sordidus* having chromosomal complement 2n=12=8A+2m+XY (Parshad 1957), has been done using different banding techniques. The amount and location (C-banding) and composition (AT/GC base richness) of heterochromatin have been studied. Further silver banding was employed to locate the position and number of nucleolar organiser regions (NORs). The application of CMA_3/DAPI banding revealed correspondence between NORs (r-DNA sites) and GC rich domains.

Material and methods

Adult males of *E. sordidus* (9 specimens) were collected from fields of sesame and groundnut plants in Punjab (India). Insects were dissected remove the gonads and air dried slides were prepared. Aged air dried slides were used for C-banding after Kaur et al. (2010). To study the localization of NORs, silver staining was done using one step method with a protective colloidal developer (gelatine and formic acid) (Howell and Black 1980). To reveal the base composition of C-heterochromatin, two fluorochromes: AT sequence specific DAPI (4-6' Diamidino-2-phenylindole) and GC sequence specific CMA_3 (chromomycin A_3), were applied, following the protocol suggested by Manicardi and Gautam (1994). Well-spread stages were photographed under the microscope Nikon-Optiphot-2. Slides stained with fluorochrome dyes DAPI/CMA_3 were studied and photographed under Nikon fluorescent microscope using UV filter (for DAPI) and BV (for CMA_3).

Results

The chromosomal complement consisted of twelve elements. Of these, eight were autosomes, two were m-chromosomes, while two of different sizes were sex chromosomes, large X and small Y respectively. The chromosomal complement was confirmed as 2n=12=8A+2m+XY.

C-banding

At diplotene, three bivalents showed terminal C-bands while one was euchromatic. The X chromosome showed thick C-band covering almost two thirds of the chromosome while Y was C-negative; m-chromosomes were slightly C-positive (Figs 1, 2).

DAPI/CMA$_3$ staining

All the four autosomal bivalents showed equal fluorescence with both DAPI and CMA$_3$ (Figs 3, 4). However, one of the medium sized autosomal bivalents showed bright CMA$_3$ signals at both ends, which correspond to NORs (Fig. 4). The X was positive to both DAPI/CMA$_3$ while Y was weak to DAPI and negative to CMA$_3$; m-chromosomes were DAPI bright and CMA$_3$ dull (Figs 5, 6).

Silver staining

NORs were found to be associated with both ends of a medium-sized autosomal bivalent (Figs 7, 8).

Discussion

E. sordidus is a pest of pod crops, mainly groundnut and sesame in India. Parshad (1957) was first to study its standard chromosomal complement (2n=12=8A+2m+XY) and male meiosis of this species (as *Aphanus sordidus*). The same chromosomal complement has been observed by the present authors. In the present study, C-banding, silver staining and DNA sequence-specific staining have been used to reveal the distribution and constitution of constitutive heterochromatin and also to find the correspondence between NORs and GC-rich regions.

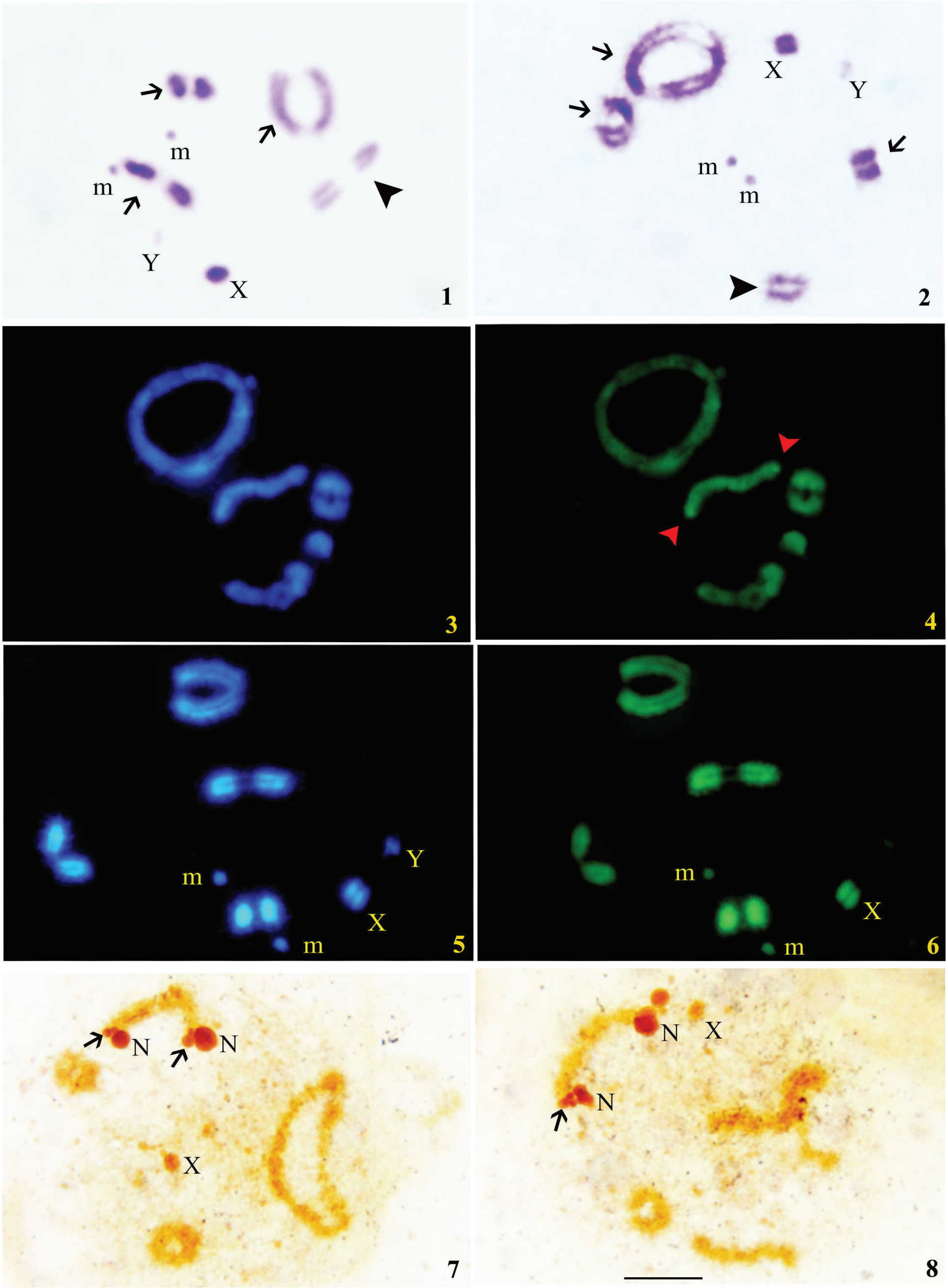

Figure 1–8. C-banding (1, 2) 1, 2 Diplotene stages showing distribution of C-bands. Arrows showing heterochromatic chromosomes while arrowhead showing single euchromatic chromosome. **Sequence-specific banding (3–6) 3** Diplotene stage with DAPI **4** Diplotene stage with localized CMA$_3$ signals on one autosomal bivalent (shown by arrows) **5** Late diplotene stage with DAPI **6** Late diplotene stage with CMA$_3$. **Silver banding (7, 8) 7, 8** Diplotene stages showing location of NORs (shown by arrows) and nucleolar bodies (N). Bar=0.01 mm.

C-banding

Terminal C-bands have been observed in three autosomal pairs of *E. sordidus*. In Heteroptera, the terminal C-bands are of wide occurrence. This kind of C-band location has been reported in *Antiteuchus mixtus* (Fabricius, 1787) (Pentatomidae) by Lanzone and Souza (2006), in *Dieuches uniguttatus* (Thumb, 1822) and *D. insignis* (Distant, 1918) (Rhyparochromidae) by Kaur et al. (2010). Usually, telomeric bands are absent, if interstitial blocks are present in a chromosome. This is reported in one or two chromosomes of *Nezara viridula* Linnaeus, 1758 (Pentatomidae) and *Triatoma patagonica* Del-Ponte, 1929 (Reduviidae) by Camacho et al. (1985) and Panzera et al. (1997) respectively.

One of the autosomal bivalent in *E. sordidus* was found to be euchromatic. A similar condition is observed in *Nezara icterica* (Horvath, 1889) (Pentatomidae) by Dey and Wangdi (1990), in *Dieuches coloratus* Distant, 1909 (Rhyparochromidae) by Kaur et al. (2010) and in *Neophysopelta schlanbuschi* Ahmad & Abbas, 1987 (Largidae) by Suman et al. (2012).

The X chromosome is almost (2/3) completely C-positive and this condition has been earlier reported in Pentatomidae by Camacho et al. (1985), in Tingidae by Grozeva and Nokkala (2001) and in Nabidae by Grozeva et al. (2004), whereas, the Y chromosome, is C-negative. This condition is not uncommon in Heteroptera and has been reported previously in some species belonging to Coreidae, Pentatomidae and Tingidae (Muramoto 1980, Camacho et al. 1985, Dey and Wangdi 1990, Grozeva and Nokkala 2001).

Microchromosomes were originally described by Wilson (1905); since then they have been discovered in many heteropteran families, including Rhyparochromidae. Microchromosomes are C-positive in *E. sordidus*. Similar observation have been made in *Leptoglossus impictus* (Stål, 1860) and *Phthia picta* (Drury, 1773) (Coreidae) by Bressa et al. (2005) and in *Dieuches uniguttatus* and *D. insignis* (Rhyparochromidae) by Kaur et al. (2010). Microchromosomes are DAPI bright and CMA_3 dull. Similar set of observations have been previously made by Kaur et al. (2010) in *Dieuches uniguttatus* and *D. insignis* (Rhyparochromidae). Information on chromatin composition of m-chromosomes is still very poor and their genetic constitution is not fully known.

DAPI/CMA_3 staining

The use of DNA binding fluorochromes having different base specificities allows a better characterization of heterochromatic regions in terms of their relative enrichment with AT or GC base pairs. In Heteroptera, still there is little information on heterochromatin base composition. The bright fluorescence after DAPI and CMA_3 staining observed in *E. sordidus* indicates that the constitutive heterochromatic regions possess interspersed AT and GC repeats. Similar observations have been made in *Edessa meditabunda* (Fabricius, 1974) and *E. rufomarginata* (De Geer, 1773) (Pentatomidae) by

Rebagliati et al. (2003), in *Antiteuchus mixtus*, *A. macraspis* (Perty, 1834), *A. sepulcralis* (Fabricius, 1803) (Pentatomidae) by Lanzone and Souza (2006) and in *Arachnocoris trinitatus* Bergroth, 1916 (Nabidae) by Kuznetsova et al. (2007).

After silver banding and fluorochrome staining, the localization of CMA_3 positive bands in NOR regions on medium sized autosomal bivalent was revealed. It was confirmed that ribosomal genes are GC rich. This correspondence of CMA_3 signals with NORs have also been reported for several true bug species at interstitial or terminal positions either on autosomes or sex chromosomes by Gonzalez-Garcia et al. (1996), Papeschi et al. (2003), Rebagliati et al. (2003), and Grozeva et al. (2004). However, NORs do not always show GC base richness as is reported in *Carlisis wahlbergi* Stål, 1858 (Coreidae) by Fossey and Liebenberg (1995).

A common feature of the sex chromosomes of Heteroptera is that they demonstrate bright fluorescence after both DAPI and CMA_3 during the meiotic prophase (Rebagliati et al. 2003). In the present study, the X chromosome showed fluorescence after both DAPI and CMA_3. Similar observations have been also made in *Cimex emarginatus* Simov, Ivanova & Schunger, 2006 by Grozeva and Nokkala (2002), *Cimex lectularius* (Cimicidae) by Grozeva et al. (2010), in *Edessa meditabunda* and *E. rufomarginata* (Pentatomidae) by Rebagliati et al. (2003), in *Athaumastus haematicus* (Stål, 1860), *Leptoglossus impictus* and *Phthia picta* (Coreidae), *Jadera sanguinolenta* (Fabricius, 1775) (Rhopalidae) by Bressa et al. (2005), in *Antiteuchus mixtus*, *A. macraspis* and *A. sepulcralis* (Pentatomidae) by Lanzone and Souza (2006). In the present study, however, the Y chromosome is C-negative, but DAPI positive and CMA_3 negative. Similar observations have been made in *Triatoma vitticeps* (Stål, 1859) (Reduviidae) by Severi-Aguiar et al. (2006).

Silver staining

The silver impregnation stains not only the NORs but also the nucleolus at specific points of some chromosomes (Castanhole et al. 2008). In the present study, NORs were found to present on terminal regions of one of medium sized autosomal pairs of *E. sordidus*, like in *Nysius californicus* Stål, 1859 (Lygaeidae) (Souza et al. 2007), and in *Arachnocoris trinitatus* Bergroth, 1916 (Nabidae) (Kuznetsova et al. 2007). However, in Belostomatidae, NORs have been reported on either autosomes, on sex chromosomes or on both autosomes and sex chromosomes (Papeschi and Bidau 1985).

Conclusion

Till date, very few Rhyparochromid species have been analysed cytologically based on banding techniques. The present study was able to reveal some cytogenetic characters which were used as markers for better knowledge of chromosome organization and the identification of separate chromosomes in *E. sordidus*. Much more information about true bug chromosomes could be obtained if new molecular cytogenetic techniques involving FISH (fluroscence *in situ* hybridization) mapping of chromosomes are used (Grozeva et al. 2011 and references therein, Kuznetsova et al. 2012 and references therein).

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Madagascar Flatidae (Hemiptera, Fulgoromorpha): state-of-the-art and research challenges

Dariusz Świerczewski[1], Adam Stroiński[2]

[1] *Department of Zoology and Animal Ecology, Jan Długosz University, Al. Armii Krajowej 13/15, 42-201 Częstochowa, Poland* [2] *Museum and Institute of Zoology PAS, Wilcza 64, 00-679 Warszawa, Poland*

Corresponding author: *Dariusz Świerczewski* (dswier@ajd.czest.pl)

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Abstract

The paper provides a historical review of the research on Flatidae in Madagascar and indicates future prospects. While the first two species of Madagascar Flatidae were described by Guérin-Méneville (1844), it was Signoret (1860) who made the first real attempt to enhance our knowledge of the Hemiptera fauna of Madagascar by describing several additional species. Over the following century and a half, several investigators have turned their attention to this group of insects, with the final number of species recorded for the island reaching 79. Despite this long history of research, it is evident that much still remains to be done. Detailed taxonomic research will allow the natural history of Madagascar and changes in the biological diversity of its endemic ecosystems to be better understood. This paper should be considered as an introduction to a complex study on the systematics and phylogeny of worldwide Flatidae planthoppers.

Keywords

Fulgoromorpha, Flatidae, taxonomy, research, history, Madagascar

Introduction

Flatidae constitute one of the largest families within planthoppers (Fulgoromorpha, Hemiptera) with 1446 species described in 299 genera and 12 tribes distributed worldwide (Bourgoin 2013). These phytophagous insects are highly diverse in terms of their colour and size (from 4.5 up to 32 mm), and are found on all continents, but are especially common and abundant in the tropics (O'Brien 2002). They are divided into two subfamilies – Flatinae and Flatoidinae, which, in most cases, can be easily distinguished from each other by the shape of the body. A greater number of Flatinae are flattened laterally, in contrast to Flatoidinae which hold their wings horizontally (O'Brien and Wilson 1985). About 20 species of Flatidae are regarded as serious pests of economically important crops such as coffee, tea, cacao, mango, citrus, apple and cherry (Wilson and O'Brien 1986). In Europe the only recognized pest is *Metcalfa pruinosa* (Say, 1830), a flatid species introduced into Italy from USA in 1973 (Arzone et al. 1987).

Data resources

The data underpinning the analyses reported in this paper are deposited in the Dryad Data Repository at doi: 10.5061/dryad.d43j8

Madagascar as a global biodiversity hotspot

Madagascar is one of eight important global biodiversity hotspots owing to its unique biota and the high level of threat to its natural habitats (McNeely et al. 1990, Myers et al. 2000, Ganzhorn et al. 2001). Being a part of the southern supercontinent Gondwana, it started to separate from Africa as a Madgascar-India block ca. 130 million years ago. At ca. 90 million years, India started breaking off from Madagascar and drifting northeastwards (Ali and Aitchison 2008). Despite Madagascar's extreme isolation from India and its geographical proximity to Africa, a high proportion of the biota of the Madagascar region reveals some Asian affinities (Yoder and Nowak 2006). The suggested explanation of this might be the results of analyses obtained by Warren et al. (2010), which support the repeated existence of sizeable islands across the western Indian Ocean, reducing the distance of open ocean to be crossed.

Madagascar has evolved an incredible wealth of biodiversity, with thousands of species that can be found nowhere else on earth. On the one hand, this is due to its long isolation from all other landmasses (Storey et al. 1995), on the other, several alternative mechanisms have generated local endemism such as isolation within watersheds (Wilmé et al. 2006), adaptation along environmental gradients (Smith et al. 1997) and ecologically mediated postspeciation range shifts (Losos and Glor 2003). The relative importance of these mechanisms, both for Madagascar and globally, is still under discussion (Pearson and Raxworthy 2009, Vences et al. 2009). For example, of its estimated 12 000 plant species, nearly 10 000 are unique to Madagascar (Gautier and Goodman 2007). Among the fauna, vertebrates have been the most thoroughly studied Madagascan animals (Raxworthy and Nussbaum 1996, Raxworthy et al. 2002, Goodman and Ganzorn 2004). With regard to invertebrates, and insects in particular, the best known groups are butterflies (Torres et al. 2001, Zakharov et al. 2004), dung beetles (Wirta et al. 2008), minnow mayflies (Monaghan et al. 2005) and ants (Fisher 1997).

However, unsustainable use of natural resources such as wood for charcoal, bushmeat for protein supply and land for crop cultivations and cattle farming are having a profound impact on the Malagasy environment (Brown 2007). According to Kull (2012), an aerial photograph-based analysis of land-cover change of Madagascar's high plateau in the latter half of the 20th century, based on a stratified rand sample of twenty eight sites, reveals a dramatic expansion of the cultural landscape of villages and agro-ecosystems into wetland and grassland environments. In response, significant environmental conservation efforts have been undertaken by the Malagasy government with international funding and technical support (Mittermeier et al. 2005). These environmental efforts in Madagascar have evolved over the past two decades from a Yellowstone model – transformation of large tracts of land into uninhabited, strictly protected areas, through the Integrated Conservation and Development Project (ICDP), which combines conservation of biological diversity with the social and economic needs of local people, to more recent initiatives that are the cutting edge of environmental innovation (Marcus and Kull 1999).

Flatidae research in Madagascar: a historical account

The Flatidae fauna of Madagascar has intrigued natural historians for centuries and continues to attract more interest with time. The first description of flatid species dates back to the first half of the 19th century when French entomologist Félix Édouard Guérin-Méneville (1799–1874) gave a drawing and a short note on *Flata malgacha* (presently in genus *Flatida* White, 1846) and *Flatoides tortrix* in the work Iconographie du Règne Animal (Guérin-Méneville 1844). However, it was Victor Signoret (1816–1889) who made the first real attempt to enhance our knowledge of the Hemiptera fauna of Madagascar (Signoret 1860) by describing several additional species, in particular: *Nephesa antica*, *Nephesa suturalis*, *Phyllyphanta nivea*, *Elidiptera madagascariensis*, *Flatoides cicatricosus*, *F. hyalinipennis*, *F. sinuatus*, *F. vicinus* (presently in the genera *Latois* Stål, 1866, *Flatopsis* Melichar, 1902, *Ulundia* Distant, 1910 and *Flatoidessa* Melichar, 1923). Moreover, the second half of 19th century was the realase of further papers by such eminent naturalists-hemipterologists as Carl Stål (1833–1878) and Ferdinand Karsch (1853–1936), which provided descriptions of additional representatives of Madagascan Flatidae (Stål 1866, Karsch 1890). Leopold Melichar (1856–1924), the foremost worker on Hemiptera at that time, made a substantial contribution with his two-part monograph of the world fauna of Flatidae by publishing re-descriptions of a number of species and describing a large number of new taxa, including several restricted just to Madagascar (Melichar 1901, 1902). This work was followed by a more concise volume of *Genera Insectorum* (Melichar 1923) also dedicated in part to Flatidae. Further species were described by Victor Lallemand (1880–1965) and Jacques Auber (1916–1995) (Lallemand 1933, 1950, Auber 1954, 1955). In 1956, Belgian entomologist Henri Synave (1921–1980) gave a short overview of Madagascan Flatinae, providing a key to all known species and simplified illustrations of some genital characters (Synave 1956). He also published a faunistic paper based on material collected in Madagascar during an expedition organized by The Natural History Museum in Basel, which was in fact the last one dedicated to Madagascan flatids (Synave 1966). Although John T. Medler (1914–2006), an outstanding researcher on the world fauna of Flatidae, later published two papers on west and southern African flatids (Medler 1988, 2001), neither of them contained any data referring to Madagascar. Summarizing, the Madagascan flatid fauna presently consists of 18 genera with 40 species of Flatinae and 12 genera with 39 species of Flatoidinae (Metcalf 1957, Stroiński and Świerczewski 2011, Stroiński and Świerczewski 2012a).

Flatidae as a tool for biodiversity conservation: preliminary results

The accurate and rapid measurement of patterns of species richness, species turnover, and endemism is fundamental to current conservation efforts in Madagascar (Fisher 2007). One approach is to sample taxa that are ecologically important, but at the same time relatively easily collected, diverse at site and contain a high level of information for conservation planning. Flatidae meet these criteria and so might serve as an appropriate environmental indicator. According to Prof. Thierry Bourgoin from The Natural History Museum in Paris, this is the most abundant and easily collected group of the hemipterans in Madagascar (pers. comm.). Yet, the knowledge of the group is still very limited.

The wildlife of Madagascar is considered to be one of the most important human heritage resources of our time. The lack of appropriate tools for the recognition of biodiversity, which would also be useful in the protection of environment and natural resources, is a great disadvantage. Studies of Flatidae as a model group of phytophagous insects could be the solution for these needs, especially in relation to rare and endangered ecosystems. One of these is tapia woodlands – a short, endemic, sclerophyllous forest formation in Madagascar, with dominant canopy tree species *Uapaca bojeri* Baillon, 1874 or tapia in Malagasy. It can be found in four zones located in the central and southern part of the island, covering approximately 2600 km^2 (Kull 2002). Tapia woodlands reveal strong adaptations to fire and are specifically human-shaped through controlled burning and selective cutting as they serve as a source of non-timber forest products for local residents (Kull 2003). The characteristic species for this ecosystem was recently described *Phleboterum tapiae* Świerczewski & Stroiński, 2012 (Świerczewski and Stroiński 2012b). Moreover, we discovered two new species *Flatopsis medleri* Świerczewski & Stroiński, 2011 and *Latois nigrofasciata* Świerczewski et Stroiński, 2012 confined exclusively to littoral forests (Świerczewski and Stroiński 2011, Świerczewski and Stroiński 2012a). Littoral forests have once formed an uninterrupted, narrow band along the entire length of Madagascar's eastern coastline but as a result of anthropogenic activity their cover has been dramatically reduced to isolated, remnant fragments. Littoral forests are presently one of the smallest yet most diverse habitats in Madagascar. However, they are relatively unexplored and poorly documented ecosystems (De Gouvenain and Silander 2003). Approximately 13% of Madagascar's total native flora can been found in these ecosystems and over 25% of the 1535 plant species known from littoral forests are endemic to this community (Consiglio et al. 2006). With respect to fauna, littoral forest are one of four major areas of ant endemism in Madagascar (Fisher and Girman 2000) Additionally, mountain flatid fauna seems quite rich and diverse, with endemic species and genera restricted to particular mountain massifs (work in prep.). An example can be the representatives of the genus *Urana* Melichar, 1902 – *Urana paradoxa* Melichar, 1902 and *Urana unica* Stroiński et Świerczewski, 2012, which are exclusively related to high altitude mountain rainforests (Stroiński and Świerczewski 2012b). Finally, we discovered the first representatives of the tribe Phantiini in Madagascar – *Soares testudinarius* Stroiński et Świerczewski, 2012 and *Madoxychara unicornis* Stroiński & Świerczewski, 2013 (Stroiński and Świerczewski 2012a, Stroiński and Świerczewski 2013). Phantiini is a small flatid tribe established by Melichar (1923) distributed worldwide and numbering 12 genera with 35 species. In Afrotropic it is represented by 6 genera and 11 species.

Future research perspectives

Summarizing, despite a long history of observation and investigation, the state of knowledge of Madagascar's Flatidae is deeply unsatisfactory. After gathering material from the most important entomological collections and two years of study we realized how much still remains to be discerned. In the area of systematics our research efforts are focused on redescriptions of all Madagascan Flatidae based on type specimens, descriptions of new species, complete synonymy, identification keys for genera and species, documentation of research in the form of drawings, SEM images and maps and a distribution catalogue of the species. Reinterpretation of characters formerly used for the identification of species and distinguishing higher taxa (tegmen venation and male genital structures) will also be included. Additionally, as a novelty, we will provide analysis of Flatidae female genital structures.

With respect to biodiversity and endemism, the basic parameters of the distribution, dispersal and zoogeographic status have yet to be understood. Furthermore, distinguishing species characteristic for particular vegetational formations is key to understanding the dynamics of endangered ecosystems. The revision will make it possible to estimate the level of endemism of Madagascan flatid fauna and its connections with the fauna of Oriental and Afrotropical regions. The project presented above is the first step in a complex study on the systematics and phylogeny of worldwide Flatidae planthoppers. It aims to clear up views on the species variability and diversity, create a modern classification system, and know in detail all the world genera and species. The goal of the long-term project is to complete the work on cladistic analysis, phylogeny and the evolutionary scenario proposal for the family.

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The unusual Afrotropical and Oriental leafhopper subfamily Signoretiinae (Hemiptera, Cicadellidae): taxonomic notes, new distributional records, and description of two new *Signoretia* species

Daniela M. Takiya[1,†], Christopher H. Dietrich[2,‡], Chandra A. Viraktamath[3,§]

1 *Laboratório de Entomologia, Departamento de Zoologia, Instituto de Biologia, Universidade Federal do Rio de Janeiro, Caixa Postal 68044, Rio de Janeiro, 21941-971, Brazil* **2** *Illinois Natural History Survey, University of Illinois, 1816 S. Oak St., Champaign, IL 61820, USA* **3** *Department of Entomology, University of Agricultural Sciences, GKVK, Bangalore 560065, India*

† *urn:lsid:zoobank.org:author:7E88BC1C-8D6A-411D-B97B-52E64EF5BA70*
‡ *urn:lsid:zoobank.org:author:82FCB86C-54B4-456A-AE5E-D7847D271CB9*
§ *urn:lsid:zoobank.org:author:486F2132-7CE9-44DA-B1E9-305AE61CF99A*

Corresponding author: *Daniela M. Takiya* (takiya@gmail.com)

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Abstract

The leafhopper subfamily Signoretiinae is redescribed and includes two tribes: Signoretiini Baker and Phlogisini Linnavuori. Redescriptions of included tribes, diagnoses and a taxonomic key to genera are provided. New records for genera of Signoretiinae are as follows: *Phlogis* in Central African Republic, Malaysia and Thailand; *Preta* in Thailand; and *Signoretia* in the Republic of the Congo, Zambia, Thailand, Vietnam, and Taiwan (China). *Signoretia pacifica* is newly recorded from Cameroon. In addition, detailed illustrations of the male genitalia of the previously described species, *Chouious tianzeus*, *Preta gratiosa*, and *Signoretia yangli* are provided; the male genitalia of *Signoretia malaya* are described for the first time; and two new species of *Signoretia* are described, *S. delicata* **sp. n.** from the Philippines and *S. kintendela* **sp. n.** from the Republic of the Congo.

Keywords
Taxonomy, distribution, morphology, new species

Introduction

Signoretiinae is a small, poorly known subfamily of leafhoppers apparently restricted to tropical forests in the Afrotropical and Oriental regions. The group is represented by few specimens in collections and is easily distinguished from nearly all cicadellids by the deeply punctured and enlarged pronotum (see subfamily remarks); other striking morphological features include: face strongly convex with cibarial muscle scars prominent; forewing outer anteapical cell present (vein s present); and hind femur macrosetal formula 2+0+0. Some of these morphological features have led to difficulties in placing the included genera in the Cicadellidae higher classification scheme. Baker (1915) first recognized the group as a subfamily of Stenocotidae (including members of current subfamilies Evacanthinae, Megophthalminae, and Tartessinae) and later (1923) treated Signoretiidae as a family of the Jassoidea. Evans (1947) subsequently placed Signoretiini as a tribe of Aphrodinae. Linnavuori (1978) highlighted the many unusual or unique features present in the group and recognized it as a separate subfamily. For similar reasons, Linnavuori (1979) subsequently recognized an additional subfamily, Phlogisinae, based on a single female specimen of *Phlogis mirabilis* Linnavuori from west Africa.

Dietrich (2005) treated Phlogisinae as a junior synonym of Signoretiinae based on the enlarged, punctate pronotum extended to the scutellar suture in both groups. Subsequent morphology and DNA sequence-based phylogenetic analyses (Dietrich et al. 2010; unpublished data) indicate that these two taxa are sister groups, *i.e.*, together form a monophyletic group. Although the relationship of Signoretiinae *sensu lato* to other cicadellid subfamilies was poorly resolved by these analyses, the results indicate that the group belongs to a lineage comprising Cicadellinae, Evacanthinae, and Typhlocybinae.

Signoretiinae *sensu lato* are variable for some morphological characters generally used to define taxa at the subfamily-level in Cicadellidae. For example, the position of the ocelli differs between the two included tribes: in Signoretiini they are found on the crown margin close to the eyes; in Phlogisini they are found on the crown, far from the margin. Similarly, Phlogisini have hind tibiae with macrosetae in row PD, and forewings with crossveins at the bases of the inner and median anteapical cells; while Signoretiini lack these features. Finally, Phlogisini have a distinct maxillary suture and Signoretiini have a complete longitudinal carina on the frontoclypeus, traits fairly uncommon in leafhoppers. Due to all above-mentioned morphological differences found in these taxa, Phlogisini and Signoretiini are herein treated as valid tribes within Signoretiinae.

Signoretiini, as treated herein (Fig. 1), includes *Preta* Distant with two species restricted to the Oriental region and *Signoretia,* occurring both in the Afrotropical and Oriental regions, with 27 species. Phlogisini includes the monotypic genera *Phlogis* Linnavuori from Africa and *Chouious* Yang from China. Although the African Signoretiini were revised by Anufriev (1971) and Linnavuori (1978), the male genitalia have been illustrated and described for only a few species of Oriental Signoretiini. In the present study, we review morphological characters to separate the included tribes and genera of Signoretiinae and a taxonomic key to genera is given. Further taxonomic notes on genera and species of Signoretiinae, new distributional records, descriptions of the male genitalia of *Signoretia malaya* and of two new species of *Signoretia* are also given.

Material and methods

Morphological terminology follows Dietrich (2005). Specimens examined are deposited in the following institutions: American Museum of Natural History, New York, USA (AMNH); The Natural History Museum, London, UK (BMNH); Field Museum of Natural History, Chicago, USA (FMNH); Illinois Natural History Survey, Champaign, USA (INHS); Muséum national d'Histoire naturelle, Paris, France (MNHN); Northwest Agriculture and Forestry University, Yangling, China (NWAF); Royal Ontario Museum, Toronto, Canada (ROM); Taiwan Agricultural Research Institute, Taiwan (TARI); and United States National Museum, Washington, DC, USA (USNM). In quotations of type-material labels, a backslash (\) separates lines on a label.

Habitus images were taken with a Digital Lab XLT system by Microptics using a Nikon D1x digital SLR camera and genitalia images were taken with a Q Imaging Micropublisher 3.3 digital camera mounted on an Olympus BX41 compound microscope. Multiple images were combined using the CombineZP software (Hadley 2010). Photographs were modified with Adobe Photoshop and vector illustrations based on the photographs produced with Adobe Illustrator.

Taxonomy

Signoretiinae Baker, 1915

http://species-id.net/wiki/Signoretiinae
Figs 1–42

=Phlogisinae Linnavuori, 1979

Description. Medium-sized, cylindrical leafhoppers (Figs 2–14). Head (Figs 2–14) broader than pronotum; ocelli visible in dorsal aspect; frontoclypeus expanded with prominent transverse muscle scars; lateral frontal sutures extended ventromesad of ocelli; antennal ledges well developed; antennae subequal to or longer than width of head; anteclypeus convex and tapered from base to apex; lorum short, narrow, well separated from genal margin, partly bordering frontoclypeus; gena slightly emarginate below eyes, exposing proepisternum; rostrum tapered, surpassing front trochanters.

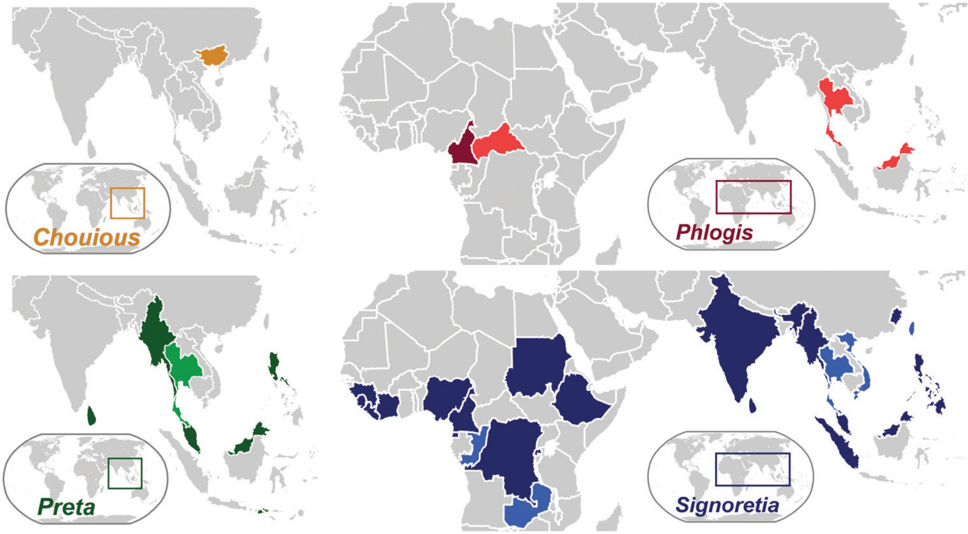


Figure 1. Current distribution of signoretiine genera, *Chouious*, *Phlogis*, *Preta*, and *Signoretia*. Countries marked with a lighter shade are new records given herein.

Pronotum (Figs 2–5, 7–11, 13, 14) greatly enlarged, strongly convex, distinctly punctate, weakly produced anterad, extended posterad to scutellar suture. Forewings (Figs 15, 17, 19) macropterous with venation distinct and opaque sclerotization, if present, limited to basal third; vein R with two (R1 not visible as separate vein) or three branches; crossvein s present (outer anteapical cell closed); inner apical cell elongate, parallel-sided, extended to wing apex. Hind wings (Figs 16, 18, 20) with venation complete; submarginal vein well separated from wing margin. Forelegs with femur with AM1 weakly developed or absent, intercalary row and distal half of AV well differentiated, each with several setae arranged in single row; tibia cylindrical, AD and PD undifferentiated. Hind legs with femur with macrosetal formula 2+0; tibia with macrosetae of dorsal rows reduced in size and number; tarsomere I without dorsoapical pair of macrosetae; pecten with 2 platellae.

Male genital capsule (Figs 21–24, 29–42) with valve articulated or fused laterally to pygofer; pygofer without distinct membranous clefts near base; segment X very large, well sclerotized, with or without processes; subgenital plates digitiform, broadest at base, usually with numerous fine setae dorsally but only rarely with well differentiated macrosetae; connective Y-shaped; style sigmoid; with or without sclerotized dorsal connective or other sclerotized processes between anal tube and aedeagus usually present.

Female ovipositor (Figs 26, 27) elongate, variable in shape and dentition.

Distribution. Afrotropical and Oriental.

Notes. With the exception of the proconiine sharpshooter genus *Tretogonia* Melichar, 1926 and the recently described dikraneurine (Typhlocybinae) genus *Sweta* Viraktamath & Dietrich, 2011, Signoretiinae are the only leafhoppers with fully developed wings that have the pronotum extended to the scutellar suture. Viraktamath and Dietrich (2011) discussed several characters supporting the placement of *Sweta* in

Typhlocybinae rather than Signoretiinae. Interestingly all these leafhoppers have the long pronotum distinctly punctate.

Nothing is known about the ecology or feeding behavior of Signoretiinae, although the strongly convex or inflated face suggests that they preferably feed on xylem sap.

Key to tribes and genera of Signoretiinae

1 Dorsal coloration black (Figs 2–7); crown without carinae (Figs 2, 4); ocelli on crown, each equidistant to adjacent anterior eye angle and other ocellus (Figs 2, 4); frontoclypeus with median londitudinal carina incomplete or absent (Figs 3, 5, 6); forewing with 3 closed anteapical cells (Fig. 15); hind wing submarginal vein not extended onto jugum (Fig. 16); hind tibia with macrosetae in row PD; male pygofer without posteroventral process (Fig. 21); valve fused laterally to pygofer (Fig. 21)........................... **Phlogisini, 2**

– Dorsal coloration usually white or yellow (Fig. 8–14); crown with transverse basal carina between ocelli (Figs 8, 10, 13); ocelli on crown-face transition, distinctly closer to adjacent eye angle than to median line of crown (Figs 8, 10, 13); frontoclypeus with complete median longitudinal carina (Figs 9, 12, 14); forewing with only outer anteapical cell closed, inner and median anteapical cells open at base (Figs 17, 19); hind wing submarginal vein extended onto jugum (Fig. 18, 20); hind tibia without macrosetae in row PD; male pygofer with posteroventral process (Figs 31, 34, 37); valve not fused laterally to pygofer, articulated by membranous connection (Fig. 31)............ **Signoretiini, 3**

2 Head in profile with lower part of clypeus distinctly produced and angulate, forming shelf over anteclypeus (Fig. 3); frontoclypeus with transverse carina ventrally and median longitudinal carina dorsally (Fig. 3); gena with conspicuous long, pale setae (Fig. 3)... ***Chouious***

– Head in profile evenly rounded, with lower part of frontoclypeus continuing contour of anteclypeus (Figs 6, 7); face without carinae (Fig. 6); gena without conspicuous long, pale setae (Figs 5, 6).. ***Phlogis***

3 Pronotum with complete paired longitudinal carinae (Fig. 8); forewings with claval veins fused for one-third of their distance (Fig. 17)................... ***Preta***

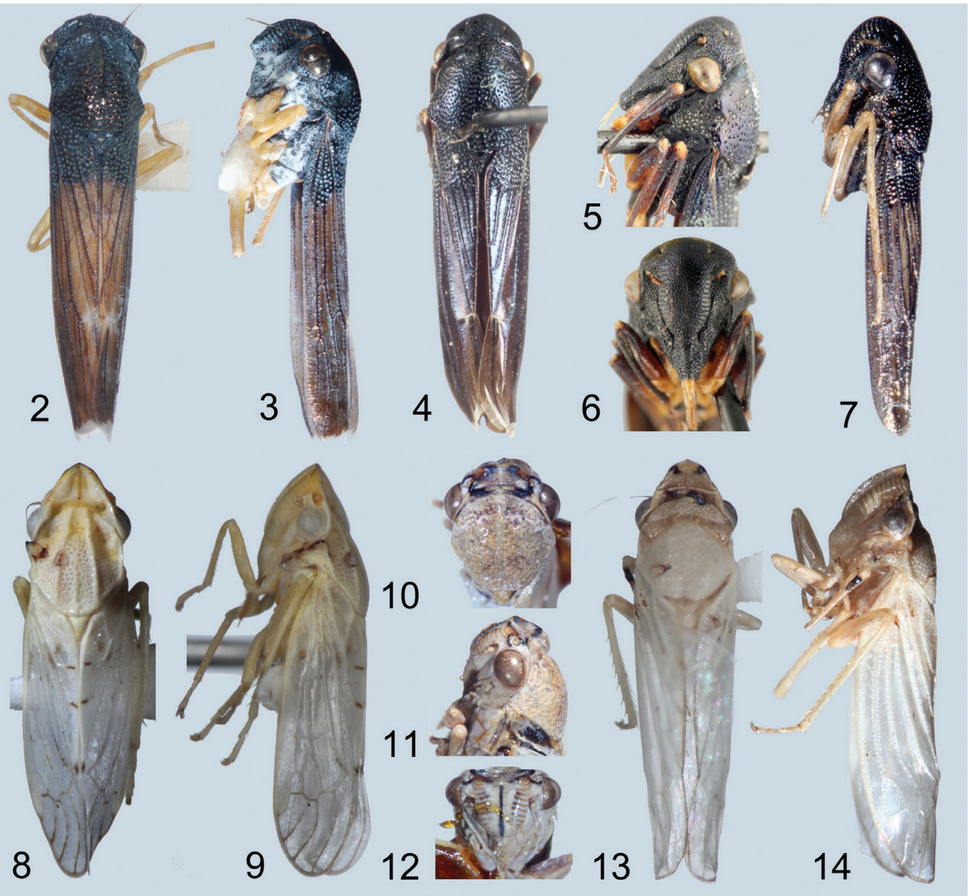
– Pronotum with or without incomplete paired longitudinal carinae at basal third (Figs 10, 13); forewings with claval veins separate (Fig. 19).... ***Signoretia***

Phlogisini Linnavuori, 1979

http://species-id.net/wiki/Phlogisini

Figs 2–7, 15, 16, 21–28

Description. Dorsal coloration dark brown to black (Figs 2–7). Head (Figs 2–7) with crown convex, punctate, carinae indistinct or absent, margins not elevated; ocelli on crown distant from anterior margin, approximately equidistant from eyes and midline;



Figures 2–14. Habitus photographs. **2, 3** *Chouious tianzeus*, dorsal and lateral **4–6** *Phlogis* sp. from Malaysia, dorsal and details of head lateral and face **7** *Phlogis* sp. from Thailand, lateral **8, 9** *Preta gratiosa*, dorsal and lateral **10–12** *Signoretia delicata* sp. n., detail of head, dorsal, lateral, and frontal **13, 14** *Signoretia kintendela* sp. n., dorsal and lateral.

with distinct depression laterad of each ocellus; transition from crown to face rounded; antennal ledges not prominent, evenly rounded; frontoclypeus without median longitudinal carina; anteclypeus with apex emarginated; maxillary suture present.

Pronotum (Figs 2–5, 7) evenly convex, without carinae or deep depressions. Forewings (Fig. 15) with or without R1 and crossveins r-m1 and m-cu2 present. Hind wings with crossvein m-cu perpendicular to CuA; submarginal vein not extended onto jugum. Forefemora with intercalary row strongly arcuate. Hind tibiae with row PD with macrosetae and row PV with some setae blunt-tipped.

Female ovipositor (Figs 26, 27) slender and evenly curved throughout length; first valvulae (Fig. 26) with dorsal sculpturing imbricate along margin and strigate ventrally; second valvulae (Fig. 27) with dorsal teeth small, simple, somewhat irregularly distributed, restricted to distal half. [Female characters of tribe based on *Phlogis*]

Male terminalia (Figs 21–24) with pygofer with apical two-thirds distinctly more sclerotized than base, without posteroventral process; valve fused laterally to pygofer;

subgenital plates not extended posteriorly as far as pygofer lobe apex; style without preapical teeth or denticuli; with distinct dorsal connective (separate sclerite connecting aedeagus to anal tube); anal tube segment X with (*Phlogis*) or without (*Chouious*) posterolateral processes.

Chouious Yang, 1991

http://species-id.net/wiki/Chouious
Figs 2, 3, 21–24

Chouious Yang, 1991: 82.

Type-species. *Chouious tianzeus* Yang, 1991.

Diagnosis. Head (Figs 2, 3) coarsely punctate, lateral frontal sutures elevated and carinate; frontoclypeus with median longitudinal carina dorsally, ventral part produced, in contour forming shelf over anteclypeus, with distinct transverse carina, area above carina depressed medially; genae conspicuously pubescent.

Notes. *Chouious* was described based on one new species, *Chouious tianzeus* from south China (Yang 1991). It is similar to *Phlogis* in external morphology, including wing venation and leg chaetotaxy, but differs in the structure of the head, as indicated in the key.

Distribution. China (Guangxi and Yang 1991).

Chouious tianzeus Yang, 1991

http://species-id.net/wiki/Chouious_tianzeus
Figs 2, 3, 21–24

Chouious tianzeus Yang, 1991: 82.

Notes. Forewings of the paratype studied lack crossvein s, but this should be an anomaly of this particular specimen.

Distribution. China (Yang 1991)

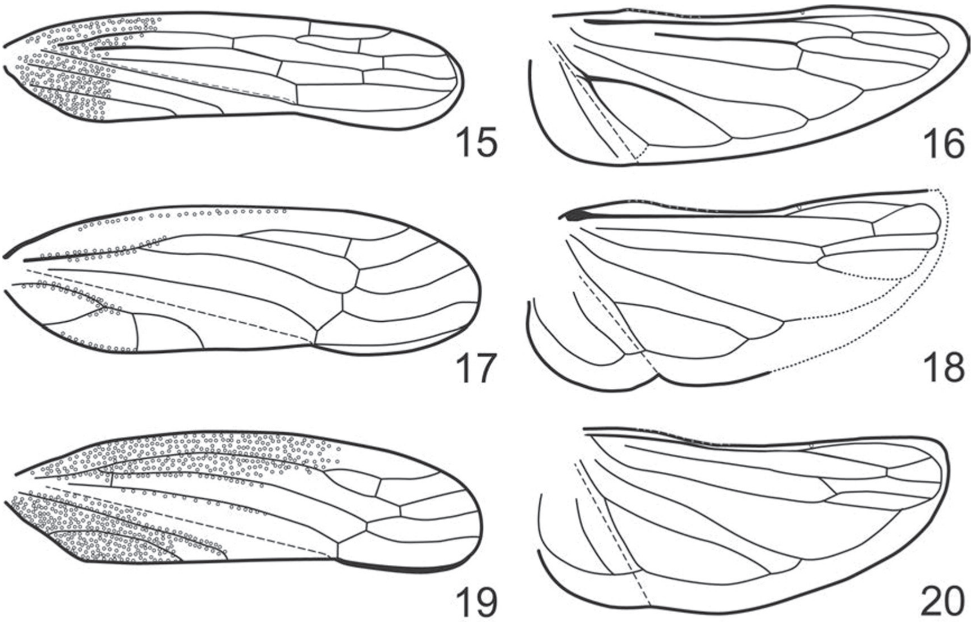
Material examined. Male paratype, China, Guanxi, Bose Prov., Tialin Co., 28–30 V 1982, NWAF.

Phlogis Linnavuori, 1979

http://species-id.net/wiki/Phlogis
Figs 4–7, 15, 16, 25–28

Phlogis Linnavuori, 1979: 684.

Type-species. *Phlogis mirabilis* Linnavuori, 1979.



Figures 15–20. Fore- and hindwing. **15, 16** *Phlogis* sp. from Thailand. **17, 18** *Preta gratiosa*. **19, 20** *Signoretia aureola*.

Diagnosis. Head (Figs 4–7) distinctly but finely punctate; lateral frontal sutures distinct, but not carinate; frontoclypeus evenly convex, without median or transverse carinae, in profile continuing contour of anteclypeus; genae bare.

Notes. *Phlogis* was originally described based on the single female type specimen of *P. mirabilis* from Cameroon (Linnavuori 1979). The genus is readily distinguished from *Chouious* based on the head morphology, as indicated in the key. Three new specimens are herein studied and assigned to this genus, including a male considered to be conspecific to *P. mirabilis* and undescribed females from the Oriental region.

Distribution. Afrotropical: Cameroon (Linnavuori 1979) and Central African Republic [**new record**]. Oriental: Malaysia [**new record**] and Thailand [**new record**].

Phlogis mirabilis **Linnavuori, 1979**

http://species-id.net/wiki/Phlogis_mirabilis

Phlogis mirabilis Linnavuori, 1979: 684.

Notes. Previously, the only known specimen of *Phlogis mirabilis* was the female type from Cameroon. A male specimen from Central African Republic is tentatively considered as conspecific to the type-specimen, based on distribution, external morphology, and size (7.4 mm). The male genitalia of this specimen agree with those of *Chouious* in the characters described for Phlogisini. However, this male can be easily distinguished from *Chouious* because its: (1) pygofer lobe lacks the deep concavity on the dorsal margin, (2) aedeagus lacks ventral atrial processes, but has paired apical recurved processes; and (3) anal tube segment X has posterolateral paired processes.

Distribution. Cameroon (Linnavuori 1979) and Central African Republic [**new record**].

Material examined. Central African Republic: male, Boukoko, 15 III 1969, Michel Boulard, MNHN.

***Phlogis* spp.**

Figs 4–7, 15, 16, 25–28

Notes. The only other known specimens of *Phlogis* are two females from the Oriental region, Malaysia and Thailand, examined for this study. Both specimens studied herein (Figs 4–7) agree in most respects with Linnavuori's original description of the genus, but differ in size (6.4 and 9.5 mm vs. 7.5 mm for *P. mirabilis*) and in some details of body form, indicating that they represent two additional, presumably new species. However, we do not provide formal descriptions, given the meager material available at present. The specimen from Malaysia (Figs 4–6) closely resembles *P. mirabilis*, but is longer (overall length 9.5mm vs. 7.5mm) and differs in the shape of the seventh sternite (Fig. 25). The specimen from Thailand is smaller (6.4mm) and has the shape of the seventh sternite (Fig. 28) very similar to that of *P. mirabilis* (comparison based on photographs of the type-specimen).

Material examined. Malaysia [**new record**]: female, Ranau, 500m, 22–25 I 1959, BMNH. Thailand [**new record**]: female, Petchaburi Kaeng Krachan National Park, km33 helipad, 12°50.177'N, 99°20.688'E 735m, Malaise trap, 18–25 V 2009, Sirichai, DNA voucher LH199, INHS.

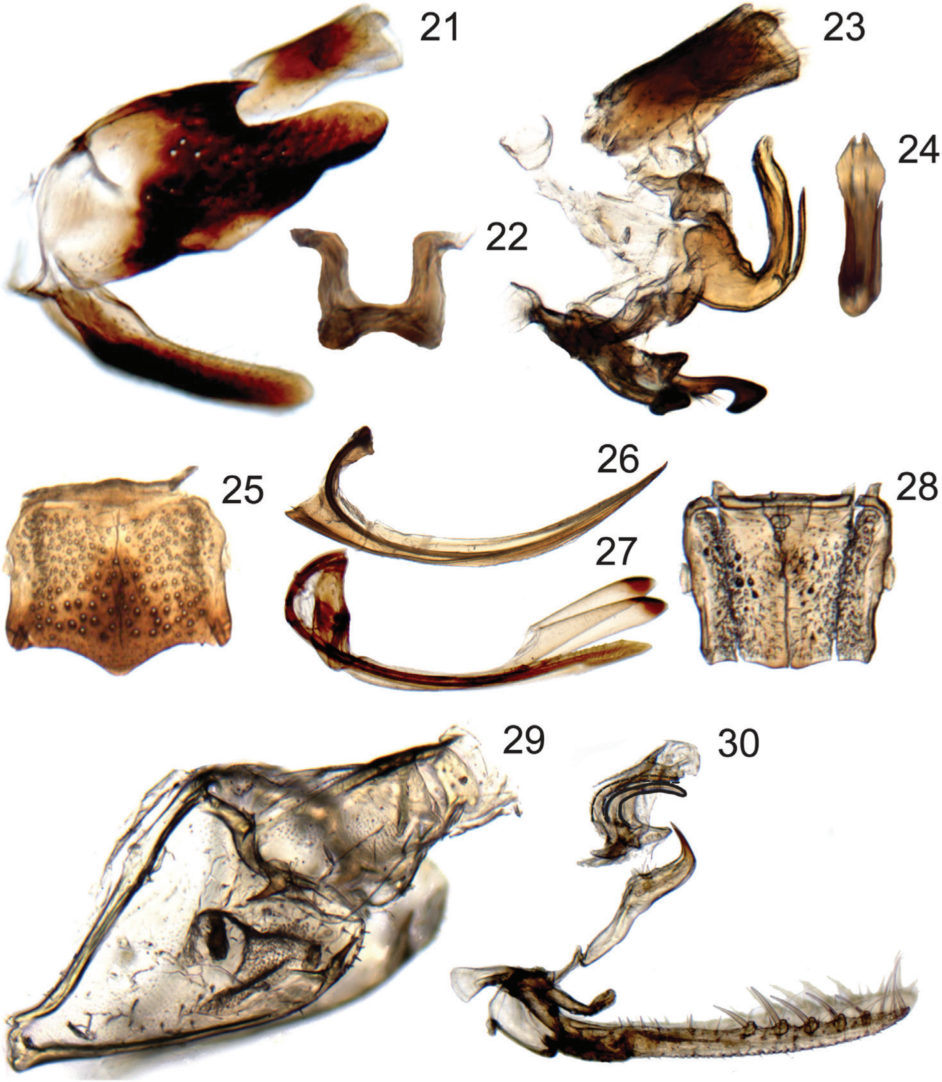
Signoretiini Baker, 1915

http://species-id.net/wiki/Signoretiini

Figs 8–14, 17–20, 29–42

Description. Dorsal coloration pale yellow to white (Figs 8–14; except *S. greeni* Distant, 1908). Head (Figs 8–17) with crown bearing prominent medial, lateral and posterior carinae, margins elevated, punctations indistinct; ocelli closely adjacent to eyes, laterad of submarginal carinae, directly above antennal ledges; transition from crown to face sharp, indicated by transverse carina; antennal ledges prominent, with anterior depression; frontoclypeus with complete median longitudinal carina; anteclypeus with apex truncate; maxillary suture absent.

Pronotum (Figs 8–11, 13–14) with pair of carinae or with median anterior depression. Forewings (Figs 17, 19) without R1 and crossveins r-m1 and m-cu2. Hind wings



Figures 21–30. Terminalia of *Chouious*, *Phlogis* and *Preta*. **21–24** *Chouious tianzeus*, male genitalia **21** genital capsule (without anal tube), lateral view **22** dorsal connective, caudal view **23** connective, styles, aedeagus, dorsal connective, and anal tube, lateral view **24** aedeagus caudal view. **25–27** female terminalia of *Phlogis* sp. from Malaysia **25** sternite VII, ventral view **26** first valvula of ovipositor, lateral view **27** second valvifers, second valvulae and gonoplacs of ovipositor, lateral view **28** *Phlogis* sp. from Thailand, sternite VII, ventral view **29, 30** *Preta gratiosa* **29** pygofer and segment X of anal tube, lateral view **30** subgenital plates, connective, styles, and aedeagus, lateral view.

(Figs 18, 20) with crossvein m-cu oblique relative to CuA; submarginal vein extended onto jugum. Forefemora with intercalary row weakly arcuate. Hind tibiae with row PD without macrosetae and row PV without blunt-tipped setae.

Female ovipositor sigmoid, broadened near midlength; first valvulae with dorsal sculpturing strigate; second valvulae with dorsal teeth numerous, close-set, and bidentate; toothed area occupying more than half entire length of valvula.

Male terminalia (Figs 29–42) with pygofer with well-developed posteroventral process; valve articulated laterally to pygofer; subgenital plates extended posteriorly beyond pygofer lobe apex; style with preapical teeth or denticuli; dorsal connective absent; anal tube segment X with or without lobes and/or processes at base or more apically; aedeagus divided into ventral paraphyses-like structure articulated to connective consisting of basal preatrium and paired robust processes and dorsal shaft, dorsal and ventral parts may be loosely connected by membrane (all Oriental species) or completely fused to eachother (some African species).

Preta Distant, 1908

http://species-id.net/wiki/Preta
Figs 8, 9, 17, 18, 29, 30

Preta Distant, 1908: 234.

Type-species. *Preta gratiosa* (Melichar, 1903).

Diagnosis. Head (Figs 8, 9) strongly and angulately produced. Pronotum (Figs 8, 9) with pair of well-developed submedial longitudinal carinae extended entire length. Forewings (Fig. 17) with claval veins fused for short distance near midlength.

Notes. *Preta* is restricted to the Oriental region and currently includes two species, *P. gratiosa* and *P. luzonensis* Baker, 1923, the latter known only from the Philippines. It can be easily distinguished from *Signoretia* by its complete paired longitudinal carinae on the pronotum (Fig. 8) and medially fused claval veins of forewings (Fig. 17), as indicated in the key.

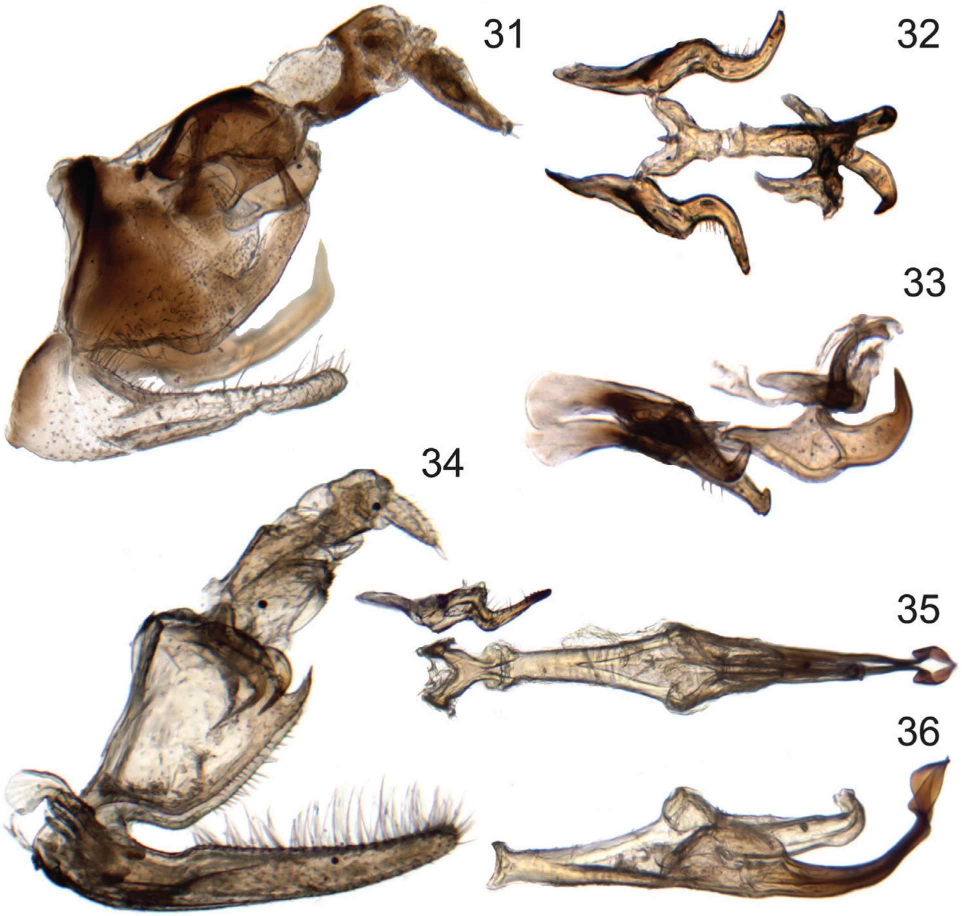
Distribution. Indonesia (Sumbawa, Jacobi 1941 *apud* Knight 2010), E. and W. Malaysia (Baker 1923), Myanmar (Distant 1908), Philippines (Luzon, Baker 1923), Singapore (Baker 1923), Sri Lanka (Melichar 1903), and Thailand [**new record**].

Preta gratiosa (Melichar, 1903)

http://species-id.net/wiki/Preta_gratiosa
Figs 8, 9, 17, 18, 29, 30

Signoretia gratiosa Melichar, 1903: 160.

Notes. Identification based on illustrations of the external morphology and male genitalia of this species (Melichar 1903: plate IV, Figs 8a, b; Distant 1908: fig. 148; Baker, 1923: plate 1, fig. 8; Anufriev 1971: Figs 20–22). Anufriev (1971) did not illustrate



Figures 31–36. Male genitalia of new species of *Signoretia*. **31–33** *Signoretia delicata* sp. n. **31** genital capsule, lateral view **32** connective, styles, and aedeagus, dorsal view **33** connective, styles, and aedeagus, lateral view **34–36** *Signoretia kintendela* sp. n. **34** genital capsule, lateral view **35** connective, style, and aedeagus, dorsal view **36** aedeagus, ventrolateral view.

the membranous shaft, only the paired ventrally recurved sclerotized processes. Aedeagus shaft imaged here.

Distribution. Indonesia (Sumbawa, Jacobi 1941 *apud* Knight 2010), E. and W. Malaysia (Baker 1923), Myanmar (Distant 1908), Singapore (Baker 1923), Sri Lanka (Melichar 1903); and Thailand [**new record**].

Material examined. Thailand: male, Phetchabun Khao Kho NP, mixed deciduous forest at Ta Phol River, 16°32.561'N, 101°2.479'E, 242m, Malaise trap, 5–12 XI 2006, Somchai Chachumnan & Saink Singhtong, INHS. Malaysia: specimen without abdomen, Kedah Province, Lang Kawi island, 25 V 1975, N. D. Penny, INHS.

Signoretia Stål, 1859

http://species-id.net/wiki/Signoretia
Figs 10–14, 19, 20, 31–42

Signoretia Stål, 1859: 289.

Type-species. *Thamnotettix malaya* Stål, 1855.

Diagnosis. Head (Figs 10–14) weakly to strongly produced. Pronotum (Figs 10, 11, 13, 14) with longitudinal carinae absent or, if present, weakly developed and not extended entire length. Forewings (Fig. 19) with claval veins separate throughout length.

Notes. *Signoretia* currently includes 10 Oriental species and 15 Afrotropical species, in addition to the new species described herein. Members of *Signoretia* can be easily distinguished from *Preta* by the lack of paired complete longitudinal carinae on pronotum (Figs 10, 13) and separate claval veins on forewings (Fig. 19). Several nominal species do not have the male genitalia described and illustrated, specially the Oriental ones.

Distribution. Afrotropical: Cameroon (Linnavuori 1978), Democratic Republic of Congo (Linnavuori 1978), Equatorial Guinea (Bioko, Anufriev 1971), Ethiopia (Linnavuori 1978), Guinea (Linnavuori 1978), Ivory Coast (Anufriev 1971), Liberia (Linnavuori 1978), Nigeria (Anufriev 1971), Republic of the Congo [**new record**], Rwanda (Linnavuori 1978), Sierra Leone (Anufriev 1971), and Sudan (Linnavuori 1978), and Zambia [**new record**]. Oriental: China (Li 1995), India (Baker 1923), Indonesia (Sumatra, Schimidt 1911 *apud* Knight 2010), E. and W. Malaysia (Baker 1923), Myanmar (Distant 1908), Philippines (Banahao, Luzon, Mindanao, Baker 1915, 1923), Singapore (Baker 1923), Sri Lanka (Distant 1908), Taiwan [**new record**], Thailand [**new record**], and Vietnam [**new record**].

Signoretia aureola Distant, 1908

http://species-id.net/wiki/Signoretia_aureola
Figs 19, 20

Signoretia aureola Distant, 1908: 232.

Notes. Identification of specimens at hand is based on Anufriev's (1971) illustration of the genitalia of a male syntype (BMNH). However, the male from Thailand has an additional larger median black spot near posterior margin of pronotum.

Distribution. Myanmar (Distant 1908) and Thailand [**new record**].

Material examined. Thailand: male, Chiang Mai, Doi Chiang Dao WS Nature trail, 19°24.278'N, 098°55.311'E, 491m, Malaise trap, 7–14 X 2007, Songkran and Apichart, DNA voucher LH193, INHS.

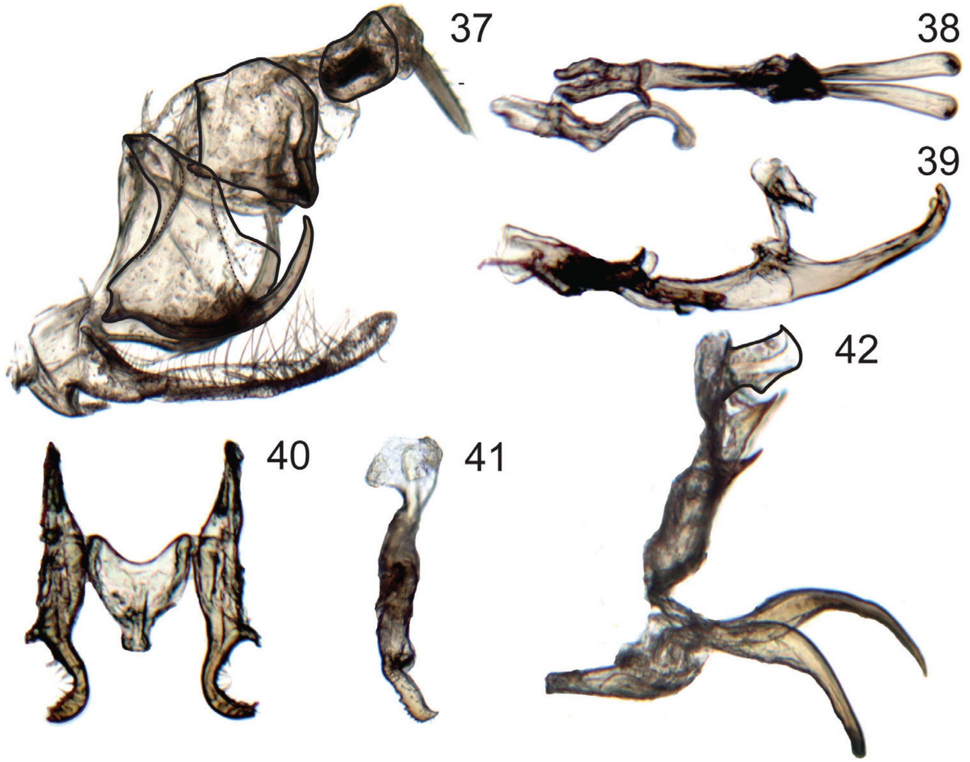


Figure 37–42. Male genitalia of *Signoretia*. **37–39** *Signoretia malaya*. **37** genital capsule, lateral view **38** connective, styles, and aedeagus, dorsal view **39** connective, styles, and aedeagus, lateral view **40–42** *Signoretia yangli* **40** connective and styles, dorsal view **41** style, lateral view **42** aedeagus, lateral view.

Signoretia delicata Takiya & Dietrich, sp. n.

urn:lsid:zoobank.org:act:B8DB41FA-7E49-4134-942D-EE3011CC62D6
http://species-id.net/wiki/Signoretia_delicata
Figs 10–12, 31–33

Body length. Holotype, 6.0 mm

Description. Crown (Figs 10, 11) very short, median length approximately half interocular and three-tenths of transocular width; median longitudinal carina obsolete. Male pygofer (Fig. 31) with caudal margin of lobe weakly sclerotized; ventral appendage robust, spiniform, produced posteriorly beyond pygofer lobe apex, abruptly narrowed and bent dorsad near apex. Valve triangular. Subgenital plates (Fig. 31) extending posteriorly beyond pygofer lobe apex by approximately one-third lobe length, with relatively few long, fine setae dorsally, concentrated near apex. Connective (Fig. 32) Y-shaped; with dorsal median keel and short, slender median anterior lobe. Style (Fig. 32, 33) slender, tapering towards apex; apex directed dorsolaterally. Aedeagus (Figs 32, 33) with ventral paraphysis-like structure with pair of robust, tapered, recurved distal processes; dorsal part consisting of pair of parallel dorsolateral arms and median shaft, shaft somewhat depressed and strongly arcuate. Anal tube (Fig. 31) basal section with pair of basal processes short, blunt, extended anteromesad, distal ring weakly sclerotized, retracted into basal section.

Coloration. Stramineous to white (Figs 10–12). Crown (Fig. 10) with paired black markings basolaterally, connecting to paired black maculae at apex. Frontoclypeus (Fig. 12) with longitudinal carina black. Legs yellow, coxae and femora infused with fuscous.

Etymology. The species epithet refers to the relatively small size of this species and its delicate habitus.

Notes. This species is described as new because it does not agree with any of the ten previously described Oriental species based on the following combination of characteristics: (1) stramineous dorsal coloration with two pairs of dark markings on crown; (2) median carina on crown absent; (3) each ocellus close to eye for distance of approximately its own diameter; (4) frontoclipeal longitudinal carina not continuing on clypellus; and (5) pronotum longer than wide and without paired incomplete longitudinal carinae on anterior portion, but with very faintly elevated median longitudinal carina. Exceptionally, the above-mentioned characteristics, will not separate *Signoretia delicata* sp. n. from *S. tagalica* Baker, 1915 (another Philippine species described from Luzon and Banahao), with which shares other morphological characters, such as the less produced crown, making the frontoclypeus appear more inflated, and very short outer anteapical cell. Nevertheless, based on the original illustrations and description, *S. tagalica* is larger (male is 6.5 mm) and has a much longer pronotum (more than 4 times the median length of crown) than the species described herein.

The short crown of this new species, shared with other described *Signoretia*, could be viewed as sufficient diagnostic characteristics to place this group in a new genus. Considering that at the moment only a small fraction of Oriental *Signoretia* have the male genitalia described, it would be premature to erect a new genus without reviewing all other described Oriental *Signoretia*.

Type material. Male holotype, "Mindanao: Davao;\ E. slope Mt. Apo,\ Camp Baclayan. Elev.\ 6500 ft. XI-11-1946", "CMHN-Philippine\ Zool.Exp. (1946–47)\ H.Hoogstraal leg.", FMNH.

Signoretia errans Linnavuori, 1978

http://species-id.net/wiki/Signoretia_errans

Signoretia errans Linnavuori, 1978: 37 (characters in key).

Notes. Linnavuori (1978) included this species in his key and provided illustrations of the male genitalia, but did not include a formal description or list of material examined. However, his figure captions indicate that he examined specimens from the Democratic Republic of Congo (Dingila and Mongbawu). The species is considered valid because Linnavuori (1978) satisfied the criteria of availability by including the species in his identification key for African *Signoretia* and providing illustrations of features that distinguish the species from its congeners.

Signoretia kintendela Takiya & Dietrich, sp. n.

urn:lsid:zoobank.org:act:ECC53C40-DD5D-483B-988D-4D276DEB9F81
http://species-id.net/wiki/Signoretia_kintendela
Figs 13, 14, 34–36

Body length. Holotype, 7.4 mm.

Description. Crown (Figs 13, 14) elongate, median length approximately six-tenths of interocular and half of transocular width; median longitudinal carina well developed. Male pygofer (Fig. 34) with ventral appendage short, spiniform, produced posteriorly beyond pygofer lobe apex. Valve short, rectangular. Subgenital plate (Fig. 34) extended posteriorly beyond pygofer lobe apex by approximately one-third lobe length, with numerous long, fine setae distributed evenly over entire length of dorsum. Connective (Fig. 35) Y-shaped; without dorsal median keel or median anterior lobe. Style (Fig. 28) slender, tapering towards apex; apex directed laterally, with several denticuli preapically. Aedeagus (Figs 35, 36) with ventral paraphysis-like structure with pair of elongate, recurved distal processes expanded preapically; dorsal part without sclerotized apodemes, consisting only of shaft, shaft strongly compressed, extended posterad, abruptly bent dorsad in distal third, distal part sinuate. Anal tube (Fig. 34) segment X with pair of posterolateral lobes each bearing small spine and several denticuli and at base with separately articulated robust process with pygofer, extended ventrad and terminating in anteriorly directed spine.

Coloration. Stramineous to white (Figs 14, 15). Crown (Fig. 14) with paired black markings at base of crown and paired maculae at apex of crown. Etymology. The specific epithet, “kintendela”, means “cicada” in Kongo language (Bentley 1895).

Notes. *Signoretia kintendela* sp. n. shares with other members of the *pacifica* group (Linnavuori 1978) the fusion of the aedeagal shaft to the paraphyses-like structure consisting of the robust and sclerotized paired basal aedeagal appendages and elongate preatrium. If the robust process interpreted herein as arising from the membrane between the anal tube and pygofer lobe was viewed as an anal tube appendage by Linnavuori (1978), then in the *pacifica* group, the new species is more similar to *S. congoensis* and *S. augur* because these species share a single pair of processes at base of the anal tube. Nevertheless, the new species can be distinguished from these and all other *Signoretia* by the shorter ventrocaudal processes of the pygofer lobe and very long and slender rami of basal appendages with sinuous and foliaceous apex.

Type material. Male holotype, “Rep. of Congo: Dept Pool;\ Iboubikro; Lesio-Loun Pk.\ 3°16.196'S, 15°38.267'E\ 330m, malaise trap, A138\ 23.x.2008, Braet & Sharkey”, INHS.

Signoretia malaya (Stål, 1855)

http://species-id.net/wiki/Signoretia_malaya
Figs 37–39

Thamnotettix malaya Stål, 1855: 192.

Male terminalia. Pygofer (Fig. 37) with caudal margin of lobe membranous; ventrocaudal process elongate evenly curved and tapered, spiniform, produced posteriorly beyond pygofer lobe apex. Subgenital plates (Fig. 37) extending posteriorly beyond pygofer lobe apex by approximately one-third of lobe length, dorsal surface with numerous long, fine setae evenly distributed throughout length and three macrosetae in longitudinal row near midlength. Connective (Fig. 38) H-shaped, arms subparallel; without dorsal median keel or median anterior lobe. Style (Fig. 38) slender and elongate; apex globose, directed laterally, with few small denticuli. Aedeagus (Fig. 38, 39) with ventral paraphyses-like structure with pair of robust, tapered, recurved distal processes; dorsal part consisting of pair of round basolateral lobes and tubular shaft. Anal tube (Fig. 37) with segment X without basal processes and distal margin thickened, terminating ventrally in short lobe.

Notes. Identification based on Stål's (1859) illustration and collecting locality. Male genitalia previously undescribed.

Distribution. W. Malaysia (Stål 1855), Philippines (Baker 1915), and Singapore (Baker 1923).

Material examined. Malaysia: male, Selangor, Kuala Lumpur, IX 1964, N. L. H. Krauss on *Melastoma malabathricus*, USNM.

Signoretia pacifica (Walker, 1858)

http://species-id.net/wiki/Signoretia_pacifica

Tettigonia pacifica Walker, 1858: 357.

Notes. Identification based on Anufriev's (1971, Figs 1–5) and Linnavuori's (1978, Figs 4b, c, d) illustration of the male genitalia. The male holotype is deposited in the BMNH (M. Webb, pers. com.).

Distribution. Cameroon [**new record**]; Democratic Republic of Congo, Guinea, Liberia (Linnavuori 1978); Ivory Coast, Nigeria, and Sierra Leone (Anufriev 1971).

Material examined. Cameroon: male, Litteral, nr. Limbe on road to Bimbia Village, 03°58'192."N, 009°14'16.7"E, 15–30 III 2009, J. R. Cryan & G. J. Svenson, INHS.

Signoretia yangi Li, 1995

http://species-id.net/wiki/Signoretia_yangi
Figs 40–42

Signoretia yangi Li, 1995: 6.

Notes. Identification based on illustrations in original description, although male specimens studied differ from original illustration in the shape of the connective. Additionally, distinctive features not mentioned or illustrated in the original publication include the: highly membranous, small and tubular aedeagal shaft; ventral aedeagal processes being separately articulated and densely clothed with microtrichia; and pair of slender ventral spines on segment X extending basad.

Distribution. China: Fujian (Li 1995) and Taiwan [**new record**].

Material examined. Taiwan: male, Nantou Hsien, Tungpu, 1200m, 18–21.x.1982, K. C. Chou & S. C. Lin, TARI; male, Nantou Hsien, Sungkang, 2100m, XI.1985, Malaise trap, K. S. Lin, TARI.

Signoretia spp.

Material examined. Malaysia: female, Sabah, 1km S. Kundasang, 1530m, 11 IX 1983, G. F. Hevel & W. E. Steiner, USNM. Nigeria: female, Kaduna, Kagoro forest, 29–30 VIII 1973, R. Linnavuori, AMNH [This specimen is similar in external morphology and coloration with the type specimen of *S. astraea* imaged by the AMNH]. Philippines: Mindanao, Davao, Santa Cruz, Badiang, 2000ft, 10 XII 1946, M. Celeston, FMNH. Vietnam [**new genus record**]: female, Thua Thien-Hue: Bach Ma Natl. Pk., edge of stream, ca. 1km along Five Lakes trail 4–16 VI 2000 B. Hubley, Malaise trap, 1200m, subtropical evergreen forest, 16°11'20.1"N, 107°51'08.5"E, DNA voucher PR173, ROM. Zambia [**new genus record**]: female, Northwestern Province, ~15 km N Mwinilunga Lwakera National Forest, 11°34'28.2"S, 24°23'40.1"E, 1445m, 5 XI 2007, Hg-vapor light, J. N. Zahniser, INHS.

Discussion

As mentioned in the introduction, despite sharing some features unique among Cicadellidae, the two recognized tribes of Signoretiinae show striking differences in major characters of the external morphology. Likewise, the male genitalia also show differences between the two groups. All described Signoretiini have the valve not fused laterally to the pygofer, a strongly developed ventrocaudal process on the pygofer lobe, and long subgenital plates. Males of Phlogisini have, on the other hand, the valve fused laterally to the pygofer, pygofer without processes, and shorter subgenital plates. Furthermore, the aedeagus is articulated with the anal tube by an additional sclerite, the dorsal connective (Hamilton 1983). Signoretiines tend to have one or two pairs of processes arising from the ventral margin of segment X of the anal tube. The presence of these processes is variable within the tribes, and they can originate in different positions and have different shapes, which indicate they may not be homologous structures. For example, all African *Signoretia* and *Preta gratiosa* have processes at the base, while *Signoretia aureola* and *Phlogis mirabilis* bear modifications at a more apical position. However, *Chouious tianzeus* and the remaining Oriental Signoretiini with male genitalia described, *S. delicata* sp. n. and *S. malaya*, have processes strongly reduced or absent.

Linnavuori (1978) in his revision of the African Signoretiini (as Signoretiinae) divided the species of *Signoretia* into two groups: the *pacifica* group including species with the aedeagus shaft “reduced, membranous and more or less concealed by the fused, scoop-shaped appendages” and the *karaseki* group including species with the aedeagus shaft “long and sclerified, distinctly separated from the appendages”. Furthermore, in the key to species, Linnavuori (1978) added that in species of the *karaseki* group the paired basal appendages are long and separate, while in the *pacifica* group they are fused both to each other and, more or less, to the membranous shaft. The definition of these groups based on the sclerotization of the shaft can be confusing, because the degree of apparent sclerotization can vary due to differences in procedures used for preparing the genitalia for study. However, whether the paraphyses-like structure (=basal appendages) is completely fused or not to the base of the shaft seems to be an important taxonomic character, as previously noted by Anufriev (1971). At that the time Anufriev published his study, this character would separate Oriental signoretiines (with an articulated shaft to the basal appendages) from the Afrotropical ones (with a fused shaft and basal appendages). The genitalia of at least some of Linnavuori’s (1978) species from the *karaseki* group do resemble the genitalia of Oriental Signoretiini because of the membranous connection of the highly sclerotized basal appendages to the lightly sclerotized aedeagus shaft. In Oriental species, the shaft can be so short and lightly sclerotized that previous authors have not illustrated it in their genitalia descriptions (Anufriev 1971, Li 1995, see comments above). Although the membranous shaft of members of the Linnavuori’s (1978) African *pacifica* group can be variable, the complete fusion of the paraphyses-like structure to the aedeagal shaft (Fig. 29), seems to be a better character to define this group and has not so far been found in Oriental signoretiines. Additional paired sclerotized cuticular processes were seen associated to this membranous connection in *S. yangi* as triangular tooth-like projections (Fig. 35) and in *P. gratiosa* (Fig. 23) as curved elongate spiniform projections.

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RESEARCH ARTICLE

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Two new species of *Vertomannus* Distant, 1903 (Heteroptera, Rhyparochromidae, Ozophorini), with proposal of a new subgenus

Katinka Varga[1,†], Előd Kondorosy[1,‡]

[1] *Pannon University, Georgikon Faculty, Department of Animal Science, Deák F. Str. 16, H-8360 Keszthely, Hungary*

† *urn:lsid:zoobank.org:author:BC2BD125-F943-4FEC-9B7B-B4AB23EB5126*
‡ *urn:lsid:zoobank.org:author:637ACD73-2A1F-41CA-918D-1C37D1B0F341*

Corresponding author: *Katinka Varga* (vrgktnk@gmail.com)

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Abstract

Two new *Vertomannus* species, *V. flavus* **sp. n.** (south Vietnam) and *V. borneensis* **sp. n.** (Borneo) are described. *Vertomannus* (*Elongatomannus*), **subgen. n.** (type species: *V. flavus*) is proposed.

Keywords

Heteroptera, Rhyparochromidae, Ozophorini, *Vertomannus*, new species, distribution, Oriental Region

Introduction

Rhyparochromidae is the largest family of Lygaeoidea containing more than half of the described species of the superfamily. Species of the rhyparochromid tribe Ozophorini are distributed all over the world (Slater 1964; Slater and O'Donnell 1995). The diversity of Ozophorini is highest in tropical America and southeast Asia, however, the Oriental Region is the least investigated area.

The ozophorine genus *Vertomannus* Distant, 1903 was described as monotypic, containing *V. capitatus* Distant, 1903 from Assam and Burma (Distant 1903). Breddin (1905) described *V. tener* Breddin, 1905 from Java, but Bergroth (1916) subsequently transferred it to *Omacrus* Bergroth, 1916. Later Zheng (in Zheng and Zou 1981) described five new species from China and provided a key for the Chinese species. Thus, there are six described species of *Vertomannus* at present.

This paper contains descriptions of two new species of *Vertomannus* from Vietnam and Borneo. One of the new species is morphologically strikingly different from all other species of the genus: therefore, a new subgenus is proposed for its accommodation.

Material and methods

Abbreviations for depositories: NHMW: Natural History Museum, Vienna, Austria; ZMAN: Zoological Museum, Amsterdam, The Netherlands; MMBC: Moravian Museum, Brno, Czech Republic.

Examination of the specimens was carried out using an ALPHA STO-4-65 Zoom and a Zeiss Disovery V8 stereomicroscopes. Measurements were taken using a micrometer eyepiece. Pictures were made using a Panasonic DMC G2 digital camera (12 Mpixel).

Taxonomy

Genus *Vertomannus* Distant, 1903

http://species-id.net/wiki/Vertomannus

Redescription. Body elongate. Head not punctured behind ocelli, posterior part slender, forming a long neck. Postocular part of head with neck longer than anteocular part. Eyes prominent. Ocelli situated close to eyes. Neck exserted. Antenna and legs slender, long. Antennal segment I and femora thickened apically. Fore femur often thick, always with spines. Pronotum with transversal furrow usually well developed, anterior and posterior lobes well separated. Anterior lobe of pronotum narrower than posterior one. Lateral margins of pronotum not flattened, humeri without spines. Middle of scutellum slightly elevated. Clavus with three or four rows of punctures. Scent gland ostiole with prominent and short peritreme curving posteriorly. Evaporatorium indistinct. Basal part of abdomen dorsoventrally constricted, not or weakly punctured. Intersegmental sutures between abdominal sterna 4 and 5 usually not curving cephalad, reaching lateral margin of abdomen.

Discussion. The genus *Vertomannus* is similar to *Cervicoris* Slater, 1982, but the latter genus is different in having the anterior lobe of the pronotum globose, and the presence of a pair of long humeral spines. Additionally, *Cervicoris* has the intersegmental sutures between abdominal sterna 4 and 5 curving cephalad, not reaching the lateral margin of abdomen, which is a typical rhyparochromid character.

Descriptions of new taxa

Vertomannus (*Elongatomannus*) subgen. n.

urn:lsid:zoobank.org:act:AD5A59AD-B19E-4F92-ABA8-AD2F55C6AE4C
http://species-id.net/wiki/Vertomannus_(Elongatomannus)

Description. Head elongate, anteocular part distinctly longer than postocular part without neck, nearly horizontal, weakly declivous, antennifers not closer to eyes than longitudinal diameter of eye. Head, especially neck, with sparse long and dense short pilosity, neck transversely wrinkled. Humeral angles of pronotum prominent, posterior lobe medially elevated. Apex of labium surpassing mid coxa. Scutellum triangular, with faint Y-shaped elevation. Clavus with four full rows of punctures.

Discussion. The new subgenus can readily be separated from the nominotypical subgenus based on the above mentioned characters: all known members of *Vertomannus* (*Vertomannus*) have a globose head with only sparse long pilosity (without short hairs) and with a relatively short anteocular part, a smooth neck; humeral angles of pronotum not prominent, labium not surpassing fore coxa, scutellum without a distinct elevation and clavus with only three rows of punctures.

Type species (by present designation): *Vertomannus* (*Elongatomannus*) *flavus*, sp. n.

Etymology. Formed by the combination of the Latin prefix *elongato-* 'elongate' and *–mannus*, the former referring to the strikingly elongate head and neck characteristic for the subgenus, the latter referring to the genus *Vertomannus*. Gender masculine.

Vertomannus (*Elongatomannus*) *flavus* sp. n.

urn:lsid:zoobank.org:act:8687A7A6-CB96-4C94-BADF-C5ADB6981D24
http://species-id.net/wiki/Vertomannus_flavus

Type material. Holotype: female, pinned. Original label: "S Vietnam, 14°10'N, 108°30'E 40km NW of An Khe, Buon Luoi, 650–750m 28.3.–12.4. 1995, Pacholátko & Dembicky leg." [printed] (NHMW).

Paratype: 1 female, pinned. Original labels: "Laos, 24–29. IV. 2001, 18°07'N, 104°29'E, Khammouan pr. Ban Khoun Ngeun ca 200m, V. Kubáň lgt.", "Collectio Petr Baňař, Moravian Museum Brno" (MMBC).

Measurements (in mm). Body length: 9.75; head length with neck: 2.75, width: 1.0, interocular space: 0.55, anteocular length: 0.7, postocular length: 0.55, neck length 1.15; pronotum: length: 1.5, humeral width: 1.55; scutellum: length: 1.0, width: 0.9; length of claval commissure: 2.0; lengths of antennal segments: I 0.95, II 2.9, III 2.35, IV 2.45; lengths of labial segments: 5.05 = I 1.5, II 1.6, III 1.4, IV 0.55.

Description. Body elongate, dorsum moderately shiny, thoracic sternum dull (Fig. 1). Head, neck and ventral side of body with short semidecumbent hairs, long erect hairs present only on head (Fig. 2).

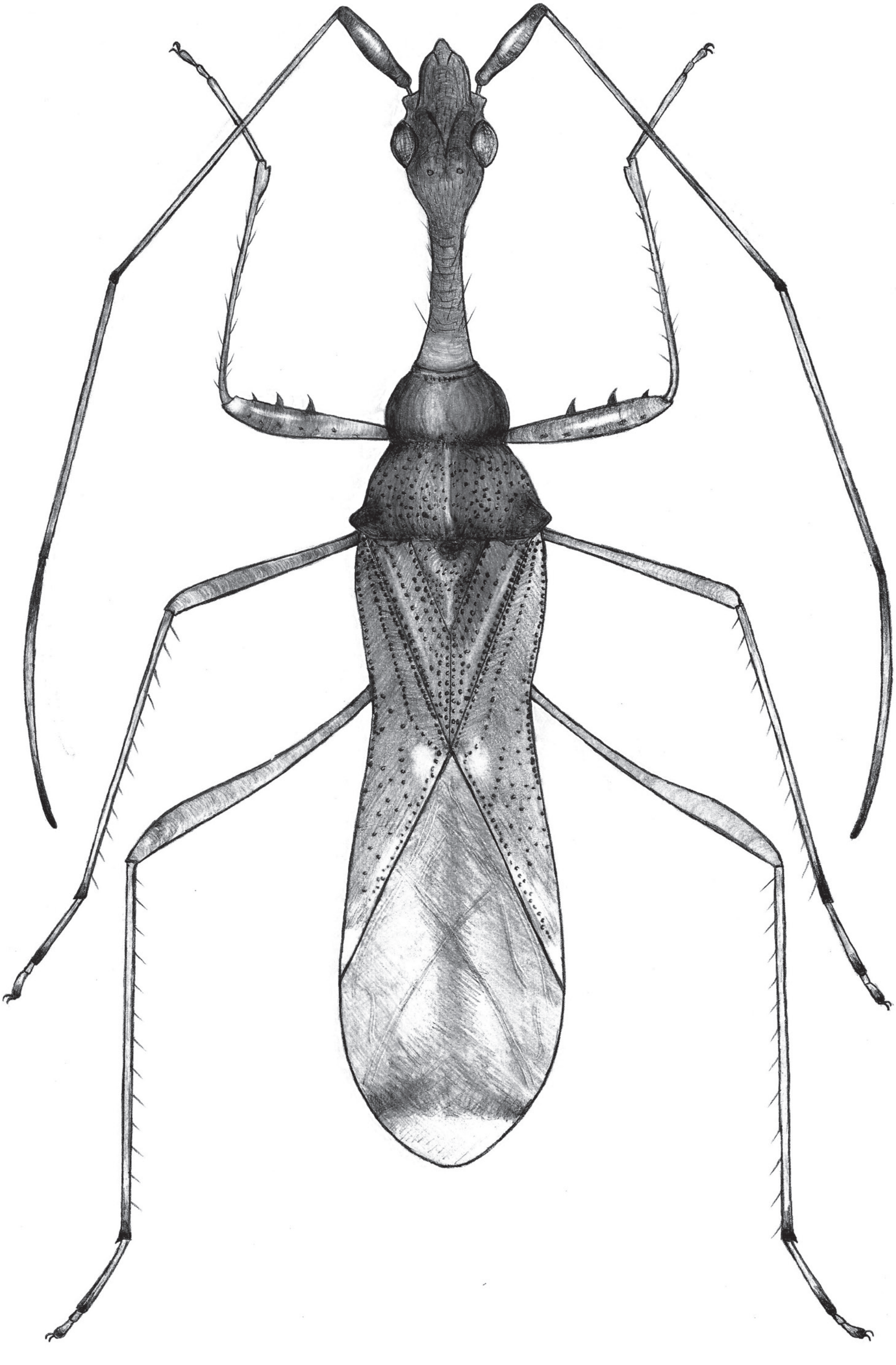

Figure 1. *Vertomannus* (*Elongatomannus*) *flavus*, sp. n., dorsal view

Head: head-neck transition very gradual. Antennal segment I thickened apically, remaining segments long and filiform.

Thorax: pronotum trapeziform, lateral margin concave, anterior lobe narrower than posterior, anterior lobe without punctures except at margins, posterior lobe distinctly punctured, punctures with very short inconspicuous setae, posterior lobe a little more declivous than anterior lobe in lateral view. Scutellum triangular, width and length subequal, with dense punctures except faint Y-shaped elevation, with very fine, hardly visible hairs.

Legs slender and long, fore femur distally with two large spines and one small spine, with hairs as long as diameter of femur. Corium less punctured, not pubescent. Abdomen: densely pubescent with silvery hairs.

Colouration. Body stramineous, punctures brown. Head and antennal segment I reddish brown, antennal segments II-III stramineous with reddish apex, segment IV brown with basal third reddish. Lateral margin of anterior lobe of pronotum darker than disk, punctures on posterior part brown. Scutellum slightly darker than ground colour of body. Membrane honey-coloured, apical part translucent, subapically with a transverse stripe connected with a longitudinal stripe.

Discussion. The long and stramineous body and the features in the diagnosis of the subgenus easily separate this species from all known *Vertomannus* species.

Etymology. The species is named after the unique colouration. The epithet "flavus" is a Latin adjective in nominative case, meaning "yellow".

***Vertomannus* (*Vertomannus*) *borneensis* sp. n.**

urn:lsid:zoobank.org:act:ADA68F97-E0A8-4A6D-9D06-9BF7813922E8
http://species-id.net/wiki/Vertomannus_borneensis

Type material. Holotype: female, pinned. Original label: "C. Borneo, Long Nawang, leg. Mjöberg 1925" [printed] (ZMAN).

Measurements (in mm). Body length: 5.85; head length with neck: 1.63, width: 0.95, interocular space: 0.6; anteocular length: 0.3, postocular length: 0.5, neck length 0.53; pronotum: length: 0.95, width: 1.55; scutellum: length: 0.95, width: 0.6; length of claval commissure: 1.4; Length of antennal segments: I 0.75, II 1.8, III 1.5, IV missing; lengths of labial segments: 1.65 = I 0.5, II 0.35, III 0.5, IV 0.3

Description. Head globose, shiny, frons smooth, not wrinkled, not punctured (Fig. 3). Anteocular part shorter than postocular part without neck. Long hairs present on head and neck. Labium surpassing anterior margin of prosternum but ending before fore coxae, segment I reaching hind margin of eyes (Fig. 4).

Thorax: Pronotum trapezoidal, with long hairs, lateral margin concave, anterior lobe impunctate, narrower than posterior lobe which is punctured, posterior lobe a little more declivous than anterior lobe in lateral view. Scutellum longer than wide, sparsely punctured, with some long hairs.

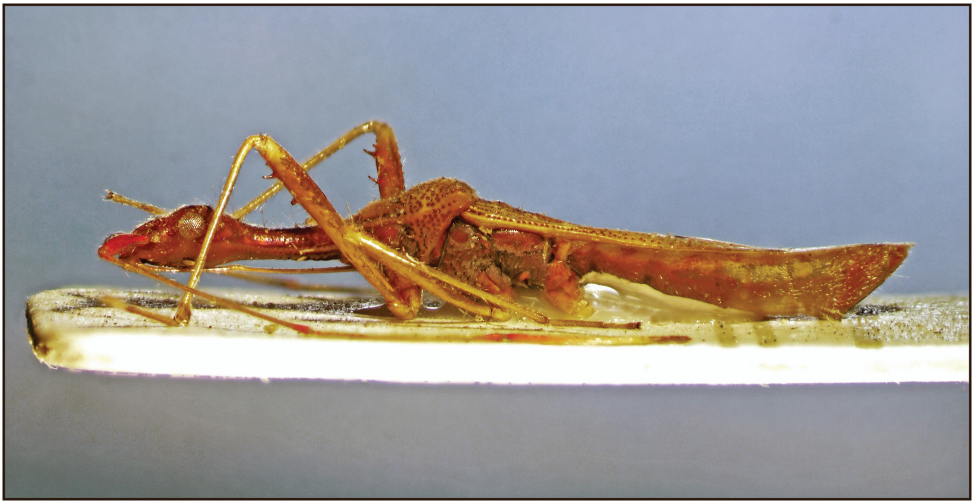

Figure 2. *Vertomannus* (*Elongatomannus*) *flavus* sp. n., lateral view.

Figure 3. *Vertomannus* (s. str.) *borneensis* sp. n., dorsal view.

Legs slender and long, fore femur with a single spine, provided with hairs which are longer than diameter of femur. Corium with two rows of punctures along claval suture and with irregular punctures on apical half of mesocorium, not pubescent. Membrane with four distinct veins, not forming cells.

Abdomen: densely pubescent with decumbent silvery hairs.

Colouration. Body fuscous. Posterior lobe of pronotum pale- brown except middle part, antenna pale. Bases of femora pale stramineous, apical halves brown, tibiae basally pale yellowish brown, gradually lightening towards apex, tarsi faint light brown. Scutel-

Figure 4. *Vertomannus* (s. str.) *borneensis* sp. n., lateral view

lum with tiny stramineous spot at apex. Corium with extensive pale colouration, basal half pale except punctures, behind this area a wide stripe mostly ochraceous with brown spots and a tiny rounded white spot at apex of claval commissure; apex of corium brown with extensive white subapical spot. Membrane pale brownish, with some white spots.

Discussion. *Vertomannus borneensis* sp. n. is smaller than the other described species of the genus. The rounded, shining anteocular part of head (without wrinkles) is diagnostic value. The long pilosity on head is more sparse than for other species. *V. crassus* Zheng, 1981 and *V. validus* Zheng, 1981 are clearly different in multispinose and thick fore femora and large globose anterior pronotal lobe. *V. brevicollum* Zheng, 1981 has a very short neck, shorter than postocular part, and the apical part of abdomen is yellowish brown. *V. capitatus, V. emeia* Zheng, 1981 and *V. ophiocephalus* Zheng, 1981 have a longer labium reaching the fore coxae and have at least two spines on fore femora. Additionally, *V. ophiocephalus* has a longer neck than the postocular part of head; and moderately shortened hemelytra, not reaching the end of the abdomen. The pale subapical spot of corium has concave fore margin at *V. capitatus*, however, *V. borneensis* has this spot with straight fore margin.

Etymology. The name of the species refers on the type locality, "borneensis" is a Latin adjective in nominative case with meaning "origin from island Borneo" (now Kalimantan).

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RESEARCH ARTICLE

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Monitoring of aphid flight activities in seed potato crops in Serbia

Andja Vučetić[1], Tanja Vukov[2], Ivana Jovičić[1], Olivera Petrović-Obradović[1]

1 *University of Belgrade, Faculty of Agriculture, Nemanjina 6, Zemun, Belgrade, Serbia* **2** *University of Belgrade, Institute for Biological Research "Siniša Stanković", Belgrade, Serbia*

Corresponding author: *Andja Vučetić* (avucetic@agrif.bg.ac.rs)

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Abstract

Aphid flight activities in seed potato fields have been studied by the yellow water traps. It is a good method for monitoring aphids as vectors of viruses, but this study also showed it is a suitable method for insect-diversity research. During the four-year studies, over 11.500 specimens were collected and a total of 107 different taxa of aphids were identified. The most abundant species were polyphagous species, such as: *Acyrthosiphon pisum* (Haris), *Aphis fabae* Scopoli, *Aphis gossypii* Glover and *Brachycaudus helichrysi* (Kaltenbach). The results of the studies show that diversity of aphids in different regions of Serbia is similar regardless of the altitude and the diversity of terrain. At most sites it ranged from 2 to 3. The highest value was recorded in Begeč, locality in northern part of Serbia, in year 2008, and it was 2.92. The maximum values of the Shannon-Weaver diversity index at all sites were recorded in the first weeks of the monitoring of aphid flight activities. Morisita-Horn similarity index shows no significant differences between sites regardless of altitudes. The sites are grouped by year, not by similarity of relief. In spite of these results, the Chi-square analysis showed highly significant difference in vector frequencies among seasons and sites with more pronounced differences for PVY. As a consequence of differences in vector frequencies, the vector pressure index in some regions was different also. The number of vectors and vector pressure index vary depending on the altitude of localities. At localities at altitudes under 1000 m, they were high. The highest index was at Kotraža, locality in central part of Serbia, in 2007, when PVY index exceeded the value of 180, while for PLRV it was 60. At high altitudes on mountain Golija, above 1100 m, the number of aphids was low, as well as the vector pressure index which indicates that these regions are suitable for producing virus-free seed potato.

Keywords

Aphids, potato, Shannon-Weaver index diversity, Morisita-Horn similarity index, vectors of viruses

Introduction

Aphids (Aphididae, Hemiptera) are the most efficient vectors of plant pathogenic viruses therefore they cause serious problems in potato growing. Production of healthy seed potatoes is possible in conditions of reduced number of aphids and their ability to come into contact with the plant and transfer the virus (Robert and Bourdin 2001). Two most important potato viruses are Potato Virus Y (PVY) and Potato Leafroll Virus (PLRV). Seed quality depends directly on the infection level (Salazar 1996).

After infection of leaves, the virus is translocated into the tubers. In some countries, earlier sowing and haulm destruction is carried out at critical period of virus infection (Van Harten 1983). It is a good way to stop virus transmission from leaves to tubers. In Serbia the maximum aphid flight activities and at the same time the maximum vector activities occur end of May-early June (Petrović-Obradović 2003). In that period, potato is at early stages of growth and desiccation is not possible. That can completely interrupt plant's vegetation and the yield would be lost. Because of similar vegetation complexity, relief, climate and aphid fauna, situation is similar in neighboring countries in southeastern Europe. In this region, it is necessary to find some other way for the production of healthy seed potato. One possibility is to find localities with a lower number of aphids and inoculum sources. The success of agricultural production depends on the biodiversity of an area, the number of present organisms, which may have a positive or a negative impact (Dueli 1997, Laznik et al. 2010). Diversity of aphids is just a segment of biodiversity of an area, but significant in the aspect of ecology and crop production, in this case production of seed potatoes.

The aim of these studies was to determine the biodiversity of aphids and similarity in aphid composition between different regions of Serbia. Also, the aim of these studies was to determine differences in vectors frequency among different sites in Serbia and to calculate the pressure of vectors for the two most important potato viruses (Potato Virus Y – PVY and Potato Leafroll Virus – PLRV), and thus determine which areas are suitable for the cultivation of healthy seed potatoes.

Material and methods

Aphid flight activity was studied in different areas of Serbia in twenty sites for four years (2007–2010). These 20 sites belong to the three major potato growing areas in Serbia. The first area is in northern part of Serbia under the altitudes of 80 m (localities: Begeč, Stanišić, Kupusina). The second one is in central part at altitudes of 400 – 900 m (localities: Kotraža, Zablaće, Prijevor, Glumač), and the third one is in southern part at altitudes above 1100 m (localities on mountain Golija) (Fig. 1). Monitoring of aphid flight activity was conducted by using yellow water traps. Yellow water traps were placed in potato crops (4traps/1ha) immediately after the emergence of potato. Traps have been raised gradually to be visible for aphids during the growth of the crop. Samples were taken once per week until drying of the above-ground mass. Aphids were

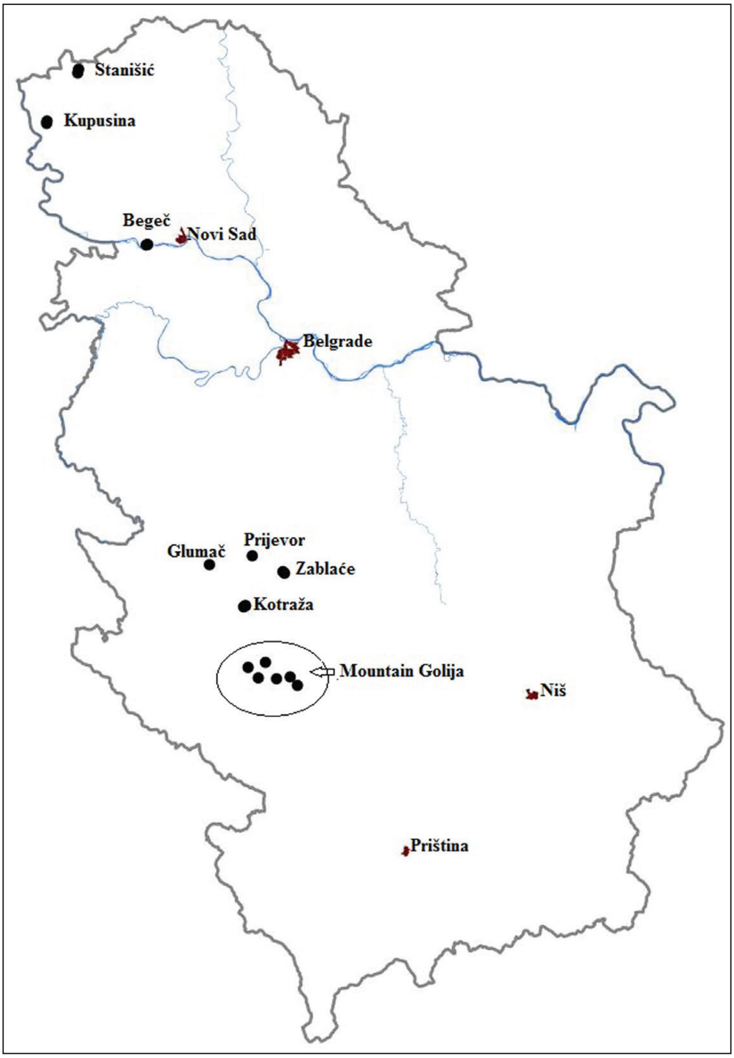

Figure 1. Map of Serbia with monitored aphid flight activities sites. Coordinates of localities: Begeč 2007 (45°13'26"N, 19°36'53"E), Begeč 2008 (45°13'34"N, 19°37'23"E), Glumač 2008 (43°52'27"N, 20°1'1"E), Golija 1 2007 (43°27'45"N 20°20'58"E), Golija 2 2007 (43°21'58"N, 20°32'12"E), Golija 1 2008 (43°26'25"N, 20°14'56"E), Golija 2 2008 (43°23'36"N, 20°24'53"E), Golija 1 2009 (43°24'6"N, 20°29'38"E), Golija 2 2009 (43°23'48"N, 20°18'31"E), Kotraža 2007 (43°42'7"N, 20°13'49"E), Kotraža 2008 (43°42'17"N, 20°13'34"E), Kotraža 2010 (43°41'49"N, 20°13'9"E), Kupusina 2008 (45°44'24"N, 19°0'6"E), Kupusina 2009 (45°43'49"N, 18°59'58"E), Stanišić 2008 (45°56'48"N, 19°10'51"E), Stanišić 2009 (45°57'7"N, 19°9'10"E), Stanišić 2010 (45°57'46"N, 19°11'6"E), Prijevor (43°54'49"N, 20°16'2"E), Zablaće 2 2009 (43°50'51"N, 20°26'51"E), Zablaće 1 2010 (43°50'27"N, 20°27'25"E).

identified using a stereoscopic microscope (Bio-optica, Italy, Type: 1000) and keys for identification of alatae aphids (Taylor 1984, Jacky and Bouchery 1988, Remaudiere and Seco Fernandez 1990).

Shannon–Weaver index was used for the analysis of biodiversity (Krebs 1989). A diversity index is a quantitative measure that reflects how many different species there are in a dataset, and simultaneously takes into account how evenly individuals are distributed among those types. It is always ranging between 0 (indicating low community complexity) and 4 (indicating high community complexity). Morisita–Horn similarity index was used to calculate the similarities in aphid composition among the sites (Magurran 2004). This index takes into account composition and richness of fauna and successfully compares samples of different size. The maximum value of this index is 1. The cluster analysis on the basis of Morisita–Horn index after the UPGA method was conducted. Comparisons of number of aphids that are vectors for PVY and PLRV viruses among localities were performed with Chi-square analysis. Similarity Percentage analysis (SIMPER) (Clarke 1993) was applied for determination of the contribution of each aphid species, which are identified as virus vectors, to the similarity (the dissimilarity) between all localities and years of collections. The Bray-Curtis measure was calculated after logarithmic transformation of the data. The risk of infection of potato by viruses was shown as a cumulative index vector pressure which was calculated using the Relative Transmission Efficiency value of aphids, known vectors of potato viruses (http://aphmon.csl.gov.uk/info.cfm).

Results

During the four-year studies, over 11.500 specimens were collected and a total of 107 different taxa of aphids were identified. Seventy five different taxa were identified to the species level, thirty two to genus level. Thirty six heteroecious species and thirty nine monoecious species were identified (Table 1). According to the data Petrović-Obradović (2003), 60 aphid species, which is about 17% of identified species in Serbia, are heteroecious. During these researches, almost 50% of identified species were heteroecious, which are commonly polyphagous species and some of them are the most important vectors of potato viruses. Two invasive species were found during this research, *Trichosiphonaphis polygonifoliae* (Shinji), which had been recently discovered on its host plant (Petrović-Obradović et al. 2010) and *Macrosiphum albifrons* Essig which had been found for the first time in Serbia during this research.

Results from 20 different localities were used for the analysis of biodiversity using Shannon–Weaver index. The maximum values of the Shannon–Weaver index diversity at all sites were recorded in the first weeks of the monitoring of aphid flight activities (Fig. 2).

The results of studies show that diversity of aphids in different regions of Serbia is similar regardless of the altitude and the diversity of terrain. At most sites, it ranged from 2 to 3. The highest value was recorded in Begeč in 2008, where it was 2.92. The lowest values were on the mountain Golija in 2008, where on the locality at the lower altitudes was 0.69 and at the higher altitudes was 1.098. In that year, in two localities on this mountain, a total of 5 aphid specimens were caught (Fig. 3).

Table 1. Identified aphid taxa (^{PVY} vectors of PVY, ^{PLRV}vectors of PLRV).

Monoecious species	Heteroecious species	Genus
Acyrthosiphon cyparissiae (Koch)	*Anoecia corni* (F.)	*Acyrthosiphon* spp.
Acyrthosiphon malvae (Mosley)	*Aphis fabae* Scopoli $^{PVY/PLRV}$	*Amphorophora* spp.
Acyrthosiphon pisum (Haris) ^{PVY}	*Aphis gossipii* Glover^{PLRV}	*Anoecia* spp.
Amphorophora rubi (Kaltenbach)	*Aphis nasturtii* Kaltenbach	*Aphis* spp.
Aphis craccivora Koch	*Aphis spiraecola* Patch	*Brachycaudus* spp.
Aphis idaei van der Goot	*Aphis sambuci* L.	*Capitophorus* spp.
Aphis pomi De Geer	*Aulacorthum solani* (Kaltenbach) $^{PVY/PLRV}$	*Cavariella* spp.
Atheroides serrulatus Haliday	*Brachycaudus cardui* (L.)	*Chaitophorus* spp.
Brevycorinae brassicae (L.)	*Brachycaudus helichrysi* (Kaltenbach) ^{PVY}	*Cinara* spp.
Callipterinela calliptera (Hartig)	*Capitophorus eleagni* (del Guercio)	*Dysaphis* spp.
Callipterinela tuberculata (von Heyden)	*Cavariella theobaldi* (Gillete and Bragg)	*Eriosoma* spp.
Chaitophorus populialbe (Boyer de Fonscolombe)	*Cryptomyzus galeopsidis* (Kaltenbach)	*Euceraphis* spp.
Cinara tujafilina (del Guercio)	*Cryptomyzus ribis* (L.)	*Forda* spp.
Ctenocallis setosus (Kaltenbach)	*Dysaphis plantaginea* (Passerini)	*Hyadaphis* spp.
Drepanosiphum aceris Koch	*Eriosoma ulmi* (L.)	*Hyperomyzus* spp.
Eucalipterus tiliae (L.)	*Forda marginata* Koch	*Macrosiphoniella* spp.
Euceraphis betulae (Koch)	*Hyadaphis foeniculi* (Passerini)	*Microlophium* spp.
Eriosoma lanigerum (Hausmann)	*Hyalopterus pruni* complex	*Myzocallis* spp.
Hyadaphis polonica Szelegiewicz	*Hyperomyzus lactuce* (L.)	*Myzus* spp.
Lachnus roborus (L.)	*Hyperomyzus pallidus* Hille Ris Lambers	*Ovatus* spp.
Lipaphis erysimi (Kaltenbach)	*Hyperomyzus picridis* (Börner and Blunck)	*Pemphigus* spp.
Macrosiphum albifrons Essig	*Macrosiphum euphorbiae* (Thomas) $^{PVY/PLRV}$	*Periphyllus* spp.
Macrosiphum funestrum (Macchiati)	*Macrosiphum rosae* (L.)	*Protaphis* spp.
Megoura viciae Buckton	*Metopolophium dirhodum* (Walker) ^{PVY}	*Protrama* spp.
Megourella purpurea Hille Ris Lambers	*Myzus cerasi* (Fabricus)	*Rhopalosiphum* spp.
Myzocallis castanicola Baker	*Myzus persicae* (Sulzer) $^{PVY/PLRV}$	*Semiaphis* spp.
Myzocallis occidentalis Remaudie et Nieto Nafria	*Nasonovia ribis-nigri* (Mosley)	*Sipha* spp.
Myzodium modestum (Hottes)	*Phorodon humuli* (Schrank) ^{PLRV}	*Subsaltusaphis* spp.
Myzus ligustri (Mosley)	*Rhopalomyzus poae* (Gill)	*Tetraneura* spp.
Ovatus inulae (Walker)	*Rhopalosiphoninus staphylleae* (Koch) ^{PLRV}	*Therioaphis* spp.
Phyllaphis fagi (L.)	*Rhopalosiphum maidis* (Fitch)	*Tuberculatus* spp.
Pterocallis alni (de Geer)	*Rhopalosiphum nimfaeae* (L.)	*Uroleucon* spp.
Schizaphis graminum (Rondani)	*Rhopalosiphum padi* (L.) ^{PVY}	
Sipha elegans del Guercio	*Sitobion fragariae* (Walker)	
Sipha maydis Passerini	*Smynthurodes betae* Westwood	
Sitobion avenae (Fabricius)	*Trichosiphonaphis polygonifoliae* (Shinji)	
Therioaphis trifolii (Monell)		
Tinocallis platani (Kaltenbach)		
Wahlgreniella ossiannilssoni Hille Ris Lambers		

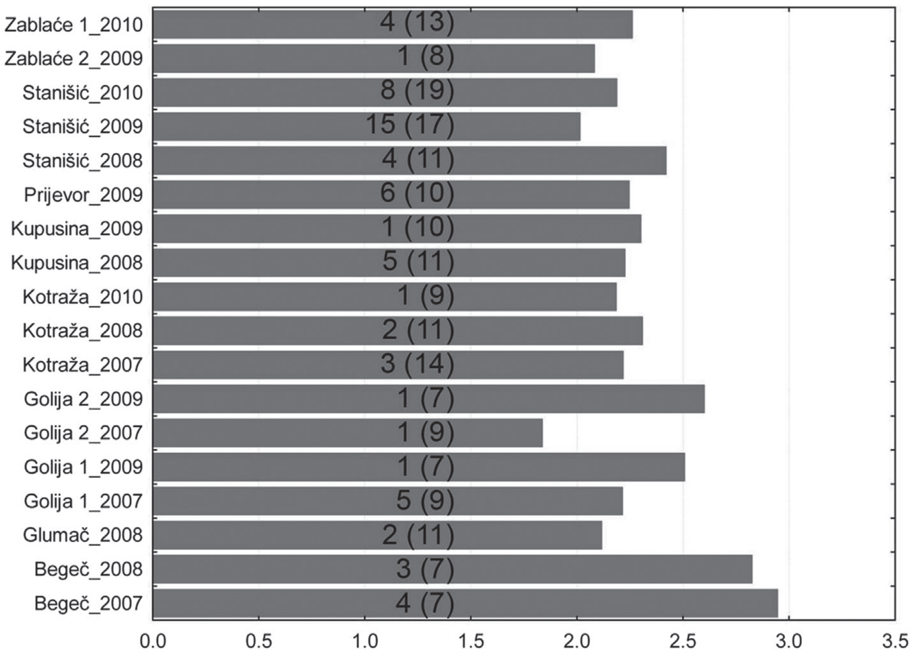

Figure 2. Maximum of Shannon–Weaver index per locality (number in brackets - number of weeks of monitoring aphid flight activities, number without brackets - week with maximum value of Shannon–Weaver index).

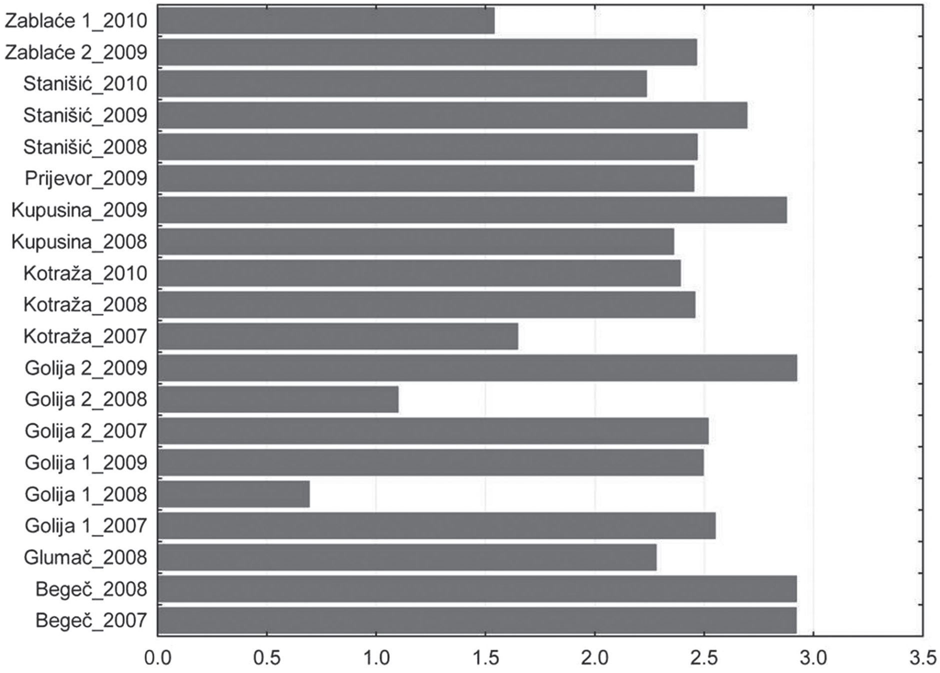

Figure 3. Total Shannon–Weaver index diversity per locality.

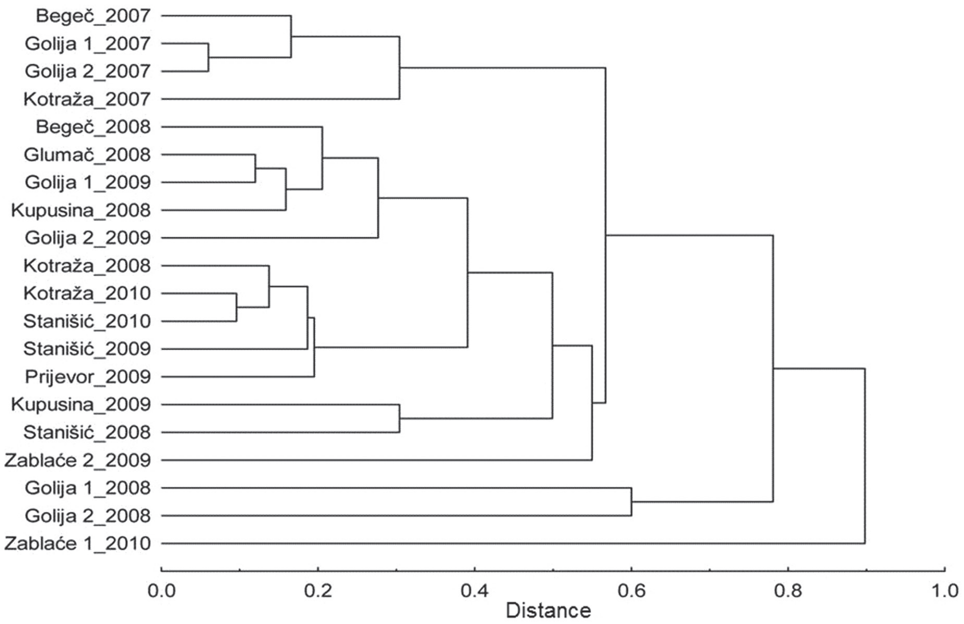

Figure 4. Dendrogram shows similarity between the sites, constructed on the basis of Morisita–Horn similarity index.

Also, Morisita–Horn similarity index shows no significant differences in aphid composition between sites regardless of altitudes. The cluster analysis on the basis of this index was carried out (Fig. 4). The sites are grouped by year, not by similarity of relief. Sites on the mountain Golija were clearly separated from the rest because of the low number of aphids in the year 2008. In the locality Zablaće, five aphid species were caught which were not recorded previously in other localities during these studies. These species are: *Chaitophorus populialbae* (Boyer de Fonscolombe), *Myzocallis castanicola* Baker, *Myzocallis occidentalis* Remaudie et Nieto Nafria, *Protrama* spp. and *Sminthuroides betae* Westwood.

Important potato virus vectors such as: *Acyrthosiphon pisum* (Haris), *Aphis fabae* Scopoli, *Aphis gossypii* Glover, *Aulacorthum solani* (Kaltenbach), *Brachycaudus helichrysi* (Kaltenbach), *Macrosiphum euphorbiae* (Thomas), *Metapolophium dirhodum* (Walker), *Myzus persicae* (Sulzer) and *Rhopalosiphum padi* (L.) were found in almost all localities, but in different numbers. The most important vector of potato viruses *M. persicae*, was found in all localities, but in high number just in localities Begeč and Kotraža in 2007.

The Chi–square analysis showed highly significant difference in vector frequencies among seasons and sites, with more pronounced differences for PVY (Table 2).

Similarity Percentage analysis shown that similarities in presence of PVY vectors between localities in 2007 year was almost 60%. In that year the most common species was *Br. helichrysi*, which was dominant species in all localities, but in localities

Table 2. Results from Chi–square analysis used to compare the different sites by the number of vectors for PVY and PLRV viruses.

PVPLRV	Begec 2007	Begec 2008	Glumac 2008	Golija 1 2007	Golija 1 2009	Golija 2 2007	Golija 2 2009	Kotraza 2007	Kotraza 2008	Kotraza 2010	Kupusina 2008	Kupusina 2009	Prijevor 2009	Stanisic 2008	Stanisic 2009	Stanisic 2010	Zablace 1 2010	Zablace 2 2009
Begec 2007		***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Begec 2008	***		ns	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Glumac 2008	***	*		***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Golija 1 2007	***	***	***		***	ns	ns	***	**	ns	***	ns	*	ns	*	ns	ns	**
Golija 1 2009	***	***	***	***		***	***	***	***	***	ns	***	***	***	***	***	***	***
Golija 2 2007	***	***	***	ns	***		ns	***	*	ns	*	ns	ns	ns	ns	ns	ns	*
Golija 2 2009	***	***	***	***	***	***		***	***	ns	**	ns	*	ns	*	ns	ns	**
Kotraza 2007	***	***	***	***	***	***	***		***	***	***	***	***	***	***	***	***	***
Kotraza 2008	***	***	***	***	***	***	*	***		*	***	***	*	***	**	*	***	**
Kotraza 2010	***	***	***	*	***	***	ns	***	**		***	***	ns	**	ns	ns	**	*
Kupusina 2008	***	***	***	***	**	***	***	***	**	***		***	***	***	***	***	ns	***
Kupusina 2009	***	***	***	***	***	***	ns	***	***	***	***		**	ns	ns	ns	*	***
Prijevor 2009	***	***	***	ns	***	ns	ns	***	***	ns	***	***		***	ns	ns	***	***
Stanisic 2008	***	***	***	**	***	*	***	***	***	**	***	**	**		ns	*	ns	*

PVPLRV	Begec 2007	Begec 2008	Glumac 2008	Golija 1 2007	Golija 1 2009	Golija 2 2007	Golija 2 2009	Kotraza 2007	Kotraza 2008	Kotraza 2010	Kupusina 2008	Kupusina 2009	Prijevor 2009	Stanisic 2008	Stanisic 2009	Stanisic 2010	Zablace 1 2010	Zablace 2 2009
Stanisic 2009	***	***	***	***	***	***	**	***	***	*	***	***	***	***		***	***	***
Stanisic 2010	***	***	***	*	***	**	ns	***	***	ns	***	***	ns	***	***		ns	*
Zablace 1 2010	***	***	***	***	***	***	*	***	*	ns	*	**	ns	***	***	ns		ns
Zablace 2 2009	***	***	***	***	***	***	**	***	***	*	***	***	***	***	***	**	***	

* - significant differences at a level of significance α = 0.05

** - significant differences at a level of significance α = 0.01

*** - significant differences at a level of significance α = 0.001

ns - not significant differences

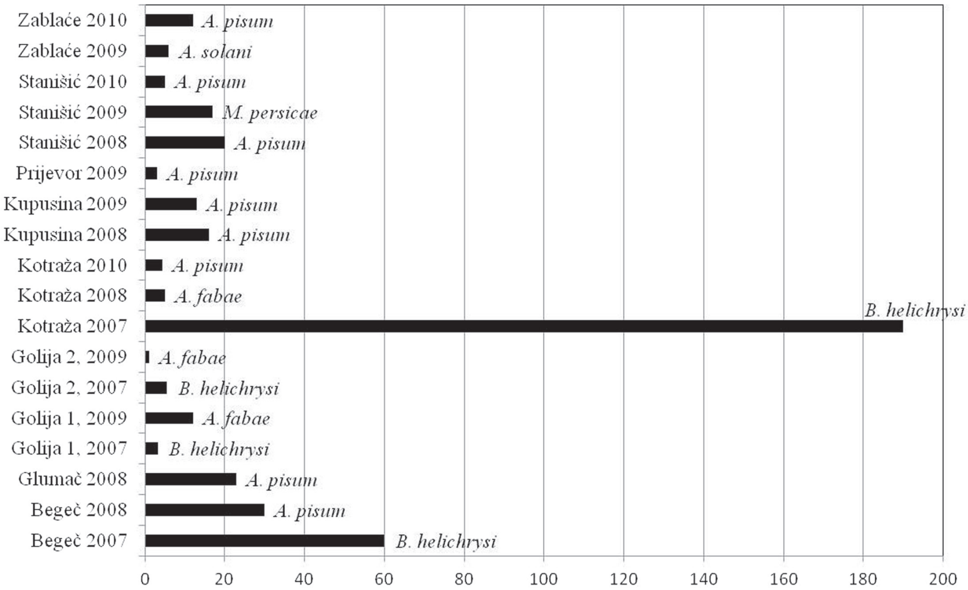

Figure 5. Vector pressure index for PVY and most important vector per locality.

Begeč and Kotraža it was found in large number. In the locality Kotraža over 1500 specimens were caught during the monitoring period. In the next years, large number of the specimens of this species has not been repeated, and because of that there was low similarity percent between localities in this year and localities in the fallowing years. In 2008 and 2010 similarity percent between localities were 70%, but in 2009 it was 50%. In all those years the most common vector species were *A. fabae* and *A. pisum* which were most responsible for high percent of similarities between localities. In all years the least number of aphids was recorded in localities in mounting Golija at altitudes above 1100m. There were recorded no significant differences between these localities and locality Prijevor because of low number of aphids in this locality and similar number of species *A. fabae* and *A. solani*. Similarity between localities in presence of PLRV vectors was around 70% in 2008 and 2010. In 2007 it was 51% and in 2009 just 44%. In all years the most common vector species was *A. fabae*. The best average dissimilarity was recorded between localities Begeč in 2007 and 2008 and all others localities because of constantly high number of vectors in this area. Especially high percent was recorded between this locality and localities Golija 2 in all three years, and it was 60%.

As a consequence of differences in diversity among sites and difference in vector frequencies, the vector pressure index in some regions was different also. The lowest vector number and the lowest vector pressure were observed in Golija mountain area during the study. In localities at above 1100m in Golija, vector pressure index newer exceeded 10. The highest value was recorded in locality Kotraža in 2007 (at altitudes of 850m), when pressure of vectors for PVY exceeded 180, and for PLRV exceeded 60. In the following years,

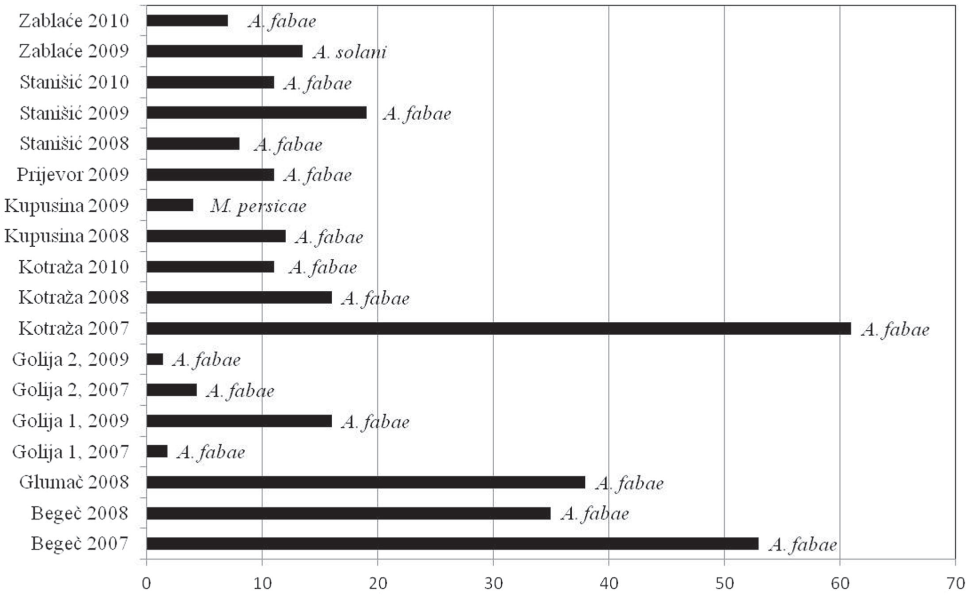

Figure 6. Vector pressure index for PLRV and most important vector per locality.

these high values were not repeated. Pressure of vectors for both viruses was constantly high in locality Begeč. In other localities, at the lowest altitudes, Kupusina and Stanišić, values of pressure vectors were low, but reached their maximums early in the season (Figs 5, 6).

Discussion

In the studies of biodiversity, in order to obtain a result with a scientific value, it is necessary to standardize sampling method, i.e. adapt it to target organisms. Different types of traps are the best known and the most widely used methods of sampling (Duelli 1997). Yellow water traps are often used for monitoring of aphid flight activities in potato fields (Sigvald 1989, Milošević and Petrović 1997, Kuroli and Lantos 2006, Kotzampigikis et al. 2008), but had not been used before for the studies of biodiversity of aphids. During these studies, they proved to be a good method, giving valid results. Shannon-Weaver diversity index is not an absolute indicator of the diversity of a certain area, it is used to compare different localities or the same locality in different years or weeks of a year. For this purpose it was used in these researches.

The values of Shannon–Weaver diversity index varied during the growing season. Temperature changes and rain influence the abundance of aphids (Morgan 2000), which also results in changes in the values of this index. However, in most localities the highest values were recorded in the first half of the monitored period, i.e. in spring. The total values of the index were similar among different sites, regardless of altitude. Due to the fact that Shannon–Weaver index takes into account the number of species and frequency of each species' individuals, localities with large differences in the number of aphids had similar index values. The highest values were recorded in locality Begeč, at an altitude of 80 m. Morisita–Horn index takes into account the diversity of species and number of individuals, and it showed that there are not large differences between different localities, i.e. different localities have similar richness of the species. Locality Zablaće was clearly separated from other localities because of the five species which were recorded only in this locality during investigations.

In spite of similar values of Shannon–Weaver diversity index among different localities, participation of the vectors in it is different. The Chi–square analysis showed highly significant difference in vector frequencies among seasons and sites, with more pronounced differences for PVY. As a consequence of differences in vector frequencies, the vector pressure index in some regions was different also. In areas at lower altitudes such as Begeč, a higher number of vector species was registered, as well as more individuals of each present species. *M. persicae*, the most important vector of viruses was found in most localities, but in high number only in localities Begeč and Kotraža, while at the localities above 1100 m it was registered very rarely and in a low number. In localities under 900m, potato sowing is usually done in April, while there is an intensive growth of potato in May when aphid flight is at maximum and virus infection risk is the highest. Potato is the most sensitive in the first development phases, until flowering (DiFonso et al. 1994). Production of virus free seed potatoes is possible if the pressure of vectors does not exceed the value of 10–15 by the end of June – early July (Basky 2002). In localities above 1000m, potato sowing is usually done at the end of May or beginning of Jun, depending on the ambient temperature. Except a lower number of aphids at higher altitudes, later sowing leads to avoiding the periods of aphid maximum flight and the risk of virus infection is reduced. Also, at higher altitudes, agricultural production is not intensive and the possibilities for isolated production are stronger.

Results of these studies show that only in localities at high altitudes, such as mountain Golija, it is possible to grow healthy, virus free seed potato. This research indicated that the potential of other mountainous regions of Serbia is also high and that Serbia has the capacity for production of quality seed potato. Also, this research may have relevance and application in other neighboring countries, too, because of similar relief, vegetation composition, composition of the fauna of aphids, and the possibility of crop production.

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RESEARCH ARTICLE

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Aphids (Hemiptera, Aphididae) on ornamental plants in greenhouses in Bulgaria

Mariya Yovkova[1], Olivera Petrović-Obradović[2], Elena Tasheva-Terzieva[3], Aneliya Pencheva[1]

1 *Faculty of Ecology and Landscape Architecture, University of Forestry, 10 Kliment Ohridski Blvd, 1756 Sofia, Bulgaria* **2** *Faculty of Agriculture, University of Belgrade, 6 Nemanjina str., 11080 Beograd–Zemun, Serbia* **3** *Faculty of Biology, Sofia University "St. Kliment Ohridski", 8 Dragan Tsankov Blvd, 1164 Sofia, Bulgaria*

Corresponding author: *Mariya Yovkova* (mariya_yovkova@abv.bg)

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Abstract

Investigations on the species composition and host range of aphids on ornamental greenhouse plants in Bulgaria was conducted over a period of five years, from 2008 to 2012. Twenty greenhouses, growing ornamentals for landscaping, plant collections and other purposes were observed. They were located in the regions of Sofia, Plovdiv, Smolyan, Pavlikeni, Varna and Burgas. The total number of collected aphid samples was 279. Their composition included 33 aphid species and one subspecies from 13 genera and 5 subfamilies. Twenty-eight species were found to belong to subfamily Aphidinae. Almost 70 % of all recorded species were polyphagous. The most widespread aphid species was *Myzus persicae*, detected in 13 greenhouses all year round, followed by *Aulacorthum solani* (10 greenhouses) and *Aphis gossypii* (9 greenhouses). The widest host range was shown by *Myzus persicae* (43 hosts), *Aulacorthum solani* (32 hosts) and *Aulacorthum circumflexum* (23 hosts).

The list of host plants includes 114 species from 95 genera and 58 families. The greatest variety of aphid species was detected on *Hibiscus* (9 species). Out of all aphid samples 12.9 % were collected on *Hibiscus* and 6.8 %, on *Dendranthema*. The greatest variety of aphid species was detected on *Hibiscus* (9 species).

Periphyllus californiensis and *Aphis* (*Aphis*) *fabae mordvilkoi* are reported for the first time for Bulgaria. Furthermore, *Aphis spiraecola* has been found in new localities and has widened its host range in this country.

Keywords

Aphididae, aphids, ornamental plants, greenhouses, Bulgaria

Introduction

Aphids cause serious damage in greenhouses, where conditions are favorable for their development throughout the year and where they can reach high density over a short period of time. The damage caused by aphids may lead to deterioration of the ornamental qualities of infested plants and sometimes even death. One of the most important and serious consequences is virus transmission.

Currently, there is no extensive research on ornamental plants in greenhouses in Bulgaria, which prompted the current study. The only survey on this topic was conducted by Tashev (1962). He reported 6 aphid species: *Aulacorthum* (*Neomyzus*) *circumflexum* (Buckton, 1876); *Macrosiphoniella sanborni* (Gillette, 1908); *Macrosiphum euphorbiae* (Thomas, 1878); *Myzus* (*Myzus*) *ornatus* Laing, 1932; *Myzus* (*Nectarosiphon*) *ascalonicus* Doncaster, 1946; *Myzus* (*Nectarosiphon*) *persicae* (Sulzer, 1776).

The results of our survey contribute to the scientific knowledge in the investigated field, but also have a practical application, benefitting producers of ornamental crops. The purpose of this study was to identify the species composition of aphids on greenhouse ornamentals, their host range and the most frequently infested ornamental species in Bulgaria.

Material and methods

The investigation was conducted over a period of five years, from 2008 to 2012. Twenty greenhouses, located in the regions of Sofia, Plovdiv, Smolyan, Pavlikeni, Varna and Burgas, were observed. Several types of greenhouses were included: for growing and propagation of ornamentals, for landscaping (annuals, perennials, rooting cuttings), for acclimatization of imported plants, for winter preservation of cold-tender species and for plant collections.

The observed greenhouses are designated as follows:

Greenhouses with a permanent plant composition: Greenhouses of University of Forestry (GL); Greenhouses of Bulgarian Academy of Science (GB); Greenhouses of the University Botanic Gardens (GS); Greenhouses of Euxinograd park (GE); Greenhouses of Vrana park (GV); Greenhouses of Krichim park (GK); Ravda (R1);

Greenhouses with a constant circulation of plant species: private greenhouses in Sofia (S1, S2, S3, S4, S5, S6); Varna (V1, V2); Burgas (B1); Ravda (R2); Pavlikeni (PV); Plovdiv (PL); Smolyan (SM).

Aphids were collected in plastic bags together with the infested plant parts. Larvae were reared in laboratory conditions to the stage of adults.

The species identification was carried out using permanent microscope slides, after the traditional method of Hille Ris Lambers (1950). Identification keys included Blackman and Eastop (1994, 2000, 2006), Shaposhnikov (1964) and Stroyan (1984).

Results

The total number of collected samples of aphids on ornamental plants during the observed five-year period was 279.

In total, 33 aphid species and one subspecies from 13 genera and 5 subfamilies (Lachninae, Chaitophorinae, Calaphidinae, Aphidinae and Eriosomatinae) were identified. Four species were identified only to the generic level but they are included in a total number of species because of the presence of clear distinguishing characters proving that they are separate species. Fourteen species belong to genus *Aphis* (42 %) and three species belong to genus *Myzus* (9 %). Genera *Aulacorthum, Brachycaudus, Macrosiphum* and *Rhopalosiphum* are represented by 2 species. Genera *Cinara, Idiopterus, Macrosiphoniella, Ovatus, Periphyllus, Prociphilus* and *Tinocallis* are represented by 1 species.

All aphid species and their host plants, including the data of Tashev (1962), are presented in alphabetical order in Table 1.

Discussion

Twenty three of all recorded aphid species (69.7 %) have been reported on indoor ornamental plants (Weiss 1916, Cichocka and Goszczynski 1975, Achremowicz et al. 1986, Cichocka 1992, Łabanowski 2008, Rafi et al. 2010) and only six (18.2 %) have been found on ornamentals in Bulgarian greenhouses (Tashev 1962).

Twenty one of all recorded aphid species are polyphagous, 9 are oligophagous and only one is monophagous (Blackman and Eastop 1994, 2000, 2006). Seven of the polyphagous species were observed more frequently (Fig. 1).

During the survey, the most common species, represented by the highest numbers of samples, was *Myzus persicae*, found throughout the year in 13 greenhouses (61 samples, 21.9 %) (Fig. 1), followed by *Aulacorthum solani* (10 greenhouses, 51 samples, 18.3 %), *Aulacorthum circumflexum* (3 greenhouses, 33 samples, 11.8 %), *Aphis gossypii* (9 greenhouses, 26 samples, 9.3 %), *Aphis spiraecola* (4 greenhouses, 11 samples, 3.9 %), *Macrosiphum euphorbiae* (3 greenhouses, 9 samples, 3.2 %) and *Aphis fabae*

Table 1. Aphid species on greenhouse ornamental host plants recorded in Bulgaria.

Aphid species	Host plant family	Host plant species	Green-house	Date
Aphis (*Aphis*) *craccivora* Koch, 1854	Fabaceae	*Robinia pseudoacacia* L.	GL	27.07.2010
		Wisteria chinensis Siebold	R1	17.07.2009
	Malvaceae	*Hibiscus rosa-sinensis* L.	GL	11.07.2011
	Nyctaginaceae	*Bougainvillea glabra* Choisy	GE	27.05.2009
	Portulacaceae	*Portulaca umbraticola* Kunth	B1	17.08.2010
Aphis (*Aphis*) *fabae* Scopoli, 1763*	Agavaceae	*Yucca elephantipes* Hort. ex Regel	S1	05.07.2011
	Aizoaceae	*Aptenia cordifolia* (L.f.) Schwantes	GL	18.09.2009
				30.06.2009
	Araceae	*Anthurium andraeanum* Linden	GE	01.06.2010
	Asteraceae	*Cosmos bipinnatus* Cav.	GL	11.07.2011
	Nyctaginaceae	*Bougainvillea glabra* Choisy	GE	13.07.2009
	Solanaceae	*Datura hybrida* Ten.	GE	27.05.2009
Aphis (*Aphis*) *fabae mordvilkoi* Börner & Janich, 1922	Tropaeolaceae	*Tropaeolum majus* L.	GE	01.06.2010
Aphis (*Aphis*) ex gr. *fabae*	Araceae	*Anthurium andraeanum* Linden	GE	01.06.2010
Aphis (*Aphis*) *farinosa* Gmelin, 1790	Salicaceae	*Salix matsudana* Koidz.	GB	26.05.2010
Aphis (*Aphis*) ex gr. *frangulae*	Asteraceae	*Gazania heterophylla* Willd. ex Steud.	S2	06.08.2010
Aphis (*Aphis*) *gossypii* Glover, 1877	Acanthaceae	*Aphelandra squarrosa* Nees	S1	13.03.2009
				18.03.2009
				26.05.2010
			S3	28.04.2010
	Araliaceae	*Schefflera arboricola* (Hayata) Merr.	GS	05.03.2010
	Asteraceae	*Chrysanthemum hybridum* Guss.	S1	17.02.2009
				25.11.2008
		Dendranthema sp.	S1	13.02.2009
				13.03.2009
				25.11.2008
			S6	26.11.2009
	Malvaceae	*Hibiscus rosa-sinensis* L.	GL	05.11.2010
				08.10.2010
				11.07.2011
				18.09.2009
				20.07.2011
				31.08.2010
			GV	28.10.2008
			R1	01.06.2010
				19.07.2010
		Hibiscus syriacus L.	GB	04.08.2010
			GL	20.08.2010
				30.07.2010
	Primulaceae	*Cyclamen persicum* Mill.	S4	03.08.2010
	Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	R1	17.07.2009
	Scrophulariaceae	*Hebe* sp.	S1	01.07.2010

Aphid species	Host plant family	Host plant species	Green-house	Date
Aphis (*Aphis*) *hederae* Kaltenbach, 1843	Araliaceae	*Hedera helix* L.	GE	23.07.2010
			S2	06.08.2010
				12.07.2011
				27.05.2010
Aphis (*Aphis*) *nasturtii* Kaltenbach, 1843	Malvaceae	*Hibiscus rosa-sinensis* L.	GL	05.11.2010
				31.08.2010
		Hibiscus syriacus L.	GL	31.08.2010
			R1	20.08.2010
	Primulaceae	*Cyclamen persicum* Mill.	S4	03.08.2010
Aphis (*Aphis*) *nerii* Boyer de Fonscolombe, 1841	Apocynaceae	*Nerium oleander* L.	R1	17.07.2009
				19.07.2010
	Asclepiadaceae	*Asclepias curassavica* L.	R1	17.07.2009
Aphis (*Aphis*) *sedi* Kaltenbach, 1843	Crassulaceae	*Sedum adolphi* Raym.-Hamet	GE	27.05.2009
		Sedum glaucophyllum R. T. Clausen	GE	27.05.2009
Aphis (*Aphis*) *spiraecola* Patch, 1914	Aizoaceae	*Aptenia cordifolia* (L.f.) Schwantes	GL	14.07.2010
				31.08.2010
	Caprifoliaceae	*Viburnum tinus* L.	R1	01.06.2010
	Malvaceae	*Hibiscus rosa-sinensis* L.	GL	05.11.2010
				08.10.2010
	Rosaceae	*Aronia melanocarpa* Nutt. ex Elliott	R1	17.07.2009
				29.05.2009
		Spiraea douglasii Hook.	PV	14.07.2010
		Spiraea japonica L. f.	PV	14.07.2010
		Spiraea vanhouttei (Briot) Carrière	PV	14.07.2010
	Scrophulariaceae	*Hebe* sp.	S1	01.07.2010
Aphis (*Aphis*) *spiraephaga* F. P. Müller, 1961	Rosaceae	*Spiraea douglasii* Hook.	S2	06.08.2010
Aphis (*Aphis*) *verbasci* Schrank, 1801	Buddlejaceae	*Buddleja davidii* Franch.	GB	04.08.2010
Aphis (*Aphis*) sp.	Begoniaceae	*Begonia semperflorens* Hook.	PL	19.08.2010
Aulacorthum (*Aulacorthum*) *solani* (Kaltenbach, 1843)	Acanthaceae	*Aphelandra squarrosa* Nees	R2	01.06.2010
			S1	28.04.2010
	Aceraceae	*Acer palmatum* Thunb.	GB	05.11.2010
	Apocynaceae	*Mandevilla sanderii* (Hemsl.) Woodson	S5	12.07.2011
		Nerium oleander L.	GL	08.06.2011
		Vinca major L.	GL	08.06.2011
				28.03.2011
	Araceae	*Anthurium andraeanum* Linden	GE	23.07.2010
			S1	28.04.2010
		Syngonium podophyllum Schott	GL	08.06.2011
		Syngonium sp.	R2	01.06.2010
	Araliaceae	*Aralia japonica* Thunb.	GL	14.03.2012
		Hedera helix L.	GL	28.03.2011
		Schefflera arboricola (Hayata) Merr.	GL	08.06.2011
			R1	01.06.2010

Aphid species	Host plant family	Host plant species	Green-house	Date
Aulacorthum (*Aulacorthum*) *solani* (Kaltenbach, 1843)	Asteraceae	*Chrysanthemum hybridum* Guss.	S4	12.07.2011
		Dahlia x *cultorum* Thorsrud & Reisaeter	S5	26.05.2010
		Dendranthema sp.	S4	12.07.2011
		Gerbera jamesonii Adlam	GL	08.06.2011
		Senecio macroglossus DC.	GV	28.10.2008
	Begoniaceae	*Begonia elatior* Hort. ex Steud.	S5	01.07.2010
	Caesalpiniaceae	*Gleditsia triacanthos* L.	GL	08.06.2011
	Caprifoliaceae	*Weigela floribunda* C. A. Mey	R1	01.06.2010
		Weigela florida A. DC.	GL	08.06.2011
	Geraniaceae	*Pelargonium peltatum* (L.) L'Hèr.	GL	05.11.2010
				14.03.2012
				28.03.2011
			S2	19.05.2011
		Pelargonium roseum Ehrh.	GL	08.06.2011
		Pelargonium zonale (L.) L'Hèr.	GL	01.04.2010
				05.11.2010
				14.07.2010
				18.09.2009
				21.03.2011
				27.04.2010
			S2	19.05.2011
				24.01.2011
	Lamiaceae	*Coleus* x *hybridus* Hort.	GL	08.06.2011
		Mentha sp.	GB	05.11.2010
		Thymus sp.	GB	05.11.2010
	Lauraceae	*Persea americana* Mill.	GL	08.06.2011
	Liliaceae	*Tulipa* sp.	S5	26.05.2010
	Malvaceae	*Hibiscus rosa-sinensis* L.	GB	07.10.2010
			GL	08.06.2011
				11.07.2011
				28.03.2011
				28.05.2011
	Onagraceae	*Fuchsia hybrida* Hort.	GL	08.06.2011
	Solanaceae	*Calibrachoa* sp.	S5	26.05.2010
				28.04.2010
	Verbenaceae	*Verbena* x *hybrida* Hort. ex Vilm.	S5	26.05.2010
Aulacorthum (*Neomyzus*) *circumflexum* (Buckton, 1876)	Acanthaceae	*Acanthus* sp.	GB	Tashev (1962)
		Ruellia speciosa Lindau	GB	Tashev (1962)
	Adiantaceae	*Adianthum capillus-veneris* L.	GL	21.03.2011
	Amaryllidaceae	*Nerine* sp.	GB	Tashev (1962)
	Anthericaceae	*Chlorophytum comosum* (Thunb.) Jacques	GL	17.02.2009
				26.05.2010

Aphid species	Host plant family	Host plant species	Green-house	Date
Aulacorthum (*Neomyzus*) *circumflexum* (Buckton, 1876)	Apocynaceae	*Catharanthus* sp.	GL	28.03.2011
		Vinca major L.	GL	01.04.2010
				08.06.2011
				11.07.2011
	Araceae	*Alocasia macrorrhizos* (L.) G. Don	GB	Tashev (1962)
			GL	28.03.2011
		Anthurium andraeanum Linden	GE	30.06.2009
		Calla sp.	GB	Tashev (1962)
		Colocasia antiquorum Schott	GB	Tashev (1962)
		Syngonium podophyllum Schott	GL	01.04.2010
				03.12.2008
				17.02.2009
				28.03.2011
				30.06.2009
		Zantedeschia aethiopica (L.) Spreng.	GL	08.06.2011
	Asteraceae	*Chrysanthemum hybridum* Guss.	S5	28.04.2010
		Chrysanthemum indicum L.	GB	Tashev (1962)
		Cineraria sp.	GB	Tashev (1962)
		Dendranthema sp.	S5	28.04.2010
		Gerbera jamesonii Adlam	GL	28.03.2011
		Tagetes patula L.	GL	21.03.2011
	Begoniaceae	*Begonia semperflorens* Hook.	GL	28.03.2011
	Bombacaceae	*Ceiba pentandra* Gaertn.	GL	21.03.2011
				28.03.2011
	Commelinaceae	*Tradescantia* sp.	GB	Tashev (1962)
	Corylaceae	*Carpinus betulus* L.	GL	08.06.2011
	Ericaceae	*Erica arborea* L.	GB	Tashev (1962)
	Hyacinthaceae	*Scilla maritima* L.	GB	Tashev (1962)
		Scilla peruviana L.	GB	Tashev (1962)
	Hydrocharitaceae	*Hydrilla verticillata* (L.f.) Royle	GB	Tashev (1962)
	Iridaceae	*Tritonia fenestrata* Ker Gawl.	GB	Tashev (1962)
	Lamiaceae	*Coleus* x *hybridus* Hort.	GB	Tashev (1962)
	Malvaceae	*Abutilon hybridum* Hort.	GL	08.06.2011
			GB	Tashev (1962)
		Hibiscus rosa-sinensis L.	GL	03.12.2008
				30.06.2009

Aphid species	Host plant family	Host plant species	Green-house	Date
Aulacorthum (*Neomyzus*) *circumflexum* (Buckton, 1876)	Nymphaeaceae	*Nymphaea coerulea* Lam.	GB	Tashev (1962)
		Nymphaea sp.	GB	Tashev (1962)
	Oxalidaceae	*Oxalis floribunda* Lehm.	GB	Tashev (1962)
		Oxalis sp.	GL	28.03.2011
			GB	Tashev (1962)
		Oxalis violacea L.	GB	Tashev (1962)
	Polypodiaceae	*Polypodium vulgare* L.	GB	Tashev (1962)
	Primulaceae	*Cyclamen persicum* Mill.	GL	28.03.2011
		Cyclamen sp.	GB	Tashev (1962)
		Primula obconica Hance	GL	28.03.2011
	Ranunculaceae	*Aquilegia vulgaris* L.	GL	08.06.2011
	Rosaceae	*Aronia melanocarpa* Nutt. ex Elliott	GL	08.06.2011
	Rubiaceae	*Hoffmannia refulgens* Hemsl.	GE	23.07.2010
	Salviniaceae	*Salvinia auriculata* Aubl.	GB	Tashev (1962)
	Saxifragaceae	*Saxifraga sarmentosa* L.f.	GB	Tashev (1962)
	Tiliaceae	*Sparmannia palmata* Hort. ex Lindl.	GB	Tashev (1962)
Brachycaudus (*Acaudus*) *cardui* (Linnaeus, 1758)	Asteraceae	*Chrysanthemum frutescens* L.	GB	05.11.2010
		Dahlia x *cultorum* Thorsrud & Reisaeter	SM	05.09.2011
		Senecio cineraria DC.	GL	08.06.2011
				11.07.2011
				28.03.2011
Brachycaudus (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843)	Asteraceae	*Senecio mikanioides* Otto ex Walp.	GB	04.08.2010
Cinara (*Cinara*) *neubergi* (Arnhart, 1930)	Pinaceae	*Pinus pinaster* Aiton	R1	29.05.2009
Idiopterus nephrelepidis Davis, 1909	Adiantaceae	*Adianthum capillus-veneris* L.	S1	25.05.2011
	Araceae	*Syngonium podophyllum* Schott	GL	23.03.2011
	Aspleniaceae	*Asplenium nidus* L.	V1	13.07.2009
	Blechnaceae	*Blechnum* sp.	S1	25.05.2011
	Davalliaceae	*Nephrolepis exaltata* (L.) Schott	GL	25.04.2012
				30.03.2012
			S1	13.03.2009
				25.05.2011
			S3	06.08.2010
				19.05.2011
	Piperaceae	*Peperomia clusiifolia* Hook.	GL	28.03.2011
	Polypodiaceae	*Platycerium bifurcatum* (Cav.) C. Chr.	V1	13.07.2009

Aphid species	Host plant family	Host plant species	Green-house	Date
Idiopterus nephrelepidis Davis, 1909	Pteridaceae	*Pteris cretica* L.	GL	28.03.2011
		Pteris sp.	S1	25.05.2011
Macrosiphoniella (*Macrosiphoniella*) *sanborni* (Gillette, 1908)	Asteraceae	*Chrysanthemum hybridum* Guss.	S1	20.10.2010
			S4	12.07.2011
			S5	07.10.2010
				18.12.2008
				26.05.2010
				28.04.2010
			S6	01.11.2011
				26.11.2009
		Chrysanthemum indicum L.	GB	Tashev (1962)
		Dendranthema sp.	GE	27.05.2009
			GV	28.10.2008
			R1	23.07.2010
				29.05.2009
			S1	20.10.2010
			S4	12.07.2011
			S5	07.10.2010
				18.12.2008
				26.05.2010
				28.04.2010
			S6	01.11.2011
				26.11.2009
Macrosiphum (*Macrosiphum*) *euphorbiae* (Thomas, 1878)	Acanthaceae	*Aphelandra squarrosa* Nees	R2	01.06.2010
	Anthericaceae	*Chlorophytum comosum* (Thunb.) Jacques	R2	01.06.2010
	Apocynaceae	*Mandevilla sanderii* (Hemsl.) Woodson	R2	01.06.2010
		Vinca major L.	R1	29.05.2009
	Araliaceae	*Schefflera arboricola* (Hayata) Merr.	R1	01.06.2010
	Asteraceae	*Cineraria* sp.	GB	Tashev (1962)
	Hydrangeaceae	*Hydrangea hortensis* Sm.	GB	Tashev (1962)
	Malvaceae	*Hibiscus rosa-sinensis* L.	GL	28.03.2011
				30.06.2009
			R2	01.06.2010
Macrosiphum (*Macrosiphum*) *rosae* (Linnaeus, 1758)	Rosaceae	*Rosa hybrida* Vill.	GE	27.05.2009
		Rosa rugosa Thunb.	GB	05.11.2010
Myzus (*Myzus*) *ornatus* Laing, 1932	Acanthaceae	*Acanthus* sp.	GB	Tashev (1962)
		Fittonia argyroneura E. Coem.	GB	Tashev (1962)
		Ruellia speciosa Lindau	GB	Tashev (1962)
	Amaranthaceae	*Iresine herbstii* Hook.	GV	25.05.2009
	Araliaceae	*Aralia sieboldii* Hort. ex K. Koch	GB	Tashev (1962)

Aphid species	Host plant family	Host plant species	Green-house	Date
Myzus (*Myzus*) *ornatus* Laing, 1932	Asparagaceae	*Asparagus* sp.	GB	Tashev (1962)
	Asteraceae	*Centaurea macrocephala* Muss. Pushk. ex Willd.	GB	Tashev (1962)
		Chrysanthemum indicum L.	GB	Tashev (1962)
		Cineraria sp.	GB	Tashev (1962)
	Begoniaceae	*Begonia* sp.	GB	Tashev (1962)
	Brassicaceae	*Arabis alpina* L.	GB	Tashev (1962)
	Ericaceae	*Erica australis* L.	GB	Tashev (1962)
		Erica lusitanica Rudolphi	GB	Tashev (1962)
		Erica sp.	GB	Tashev (1962)
	Fabaceae	*Lupinus* sp.	GB	Tashev (1962)
	Gesneriaceae	*Saintpaulia ionantha* H. Wendl.	GB	Tashev (1962)
	Hydrangeaceae	*Hydrangea hortensis* Sm.	GB	Tashev (1962)
	Lamiaceae	*Coleus* x *hybridus* Hort.	GV	25.05.2009
			GB	Tashev (1962)
	Mimosaceae	*Acacia floribunda* Willd.	GB	Tashev (1962)
	Oxalidaceae	*Oxalis floribunda* Lehm.	GB	Tashev (1962)
	Primulaceae	*Primula* sp.	GB	Tashev (1962)
	Saxifragaceae	*Heuchera* sp.	GB	Tashev (1962)
	Scrophulariaceae	*Digitalis purpurea* L.	GB	Tashev (1962)
	Urticaceae	*Laportea gigas* Wedd.	GB	Tashev (1962)
	Valerianaceae	*Valeriana montana* L.	GB	Tashev (1962)
	Violaceae	*Viola* sp.	GB	Tashev (1962)
Myzus (*Nectarosiphon*) *ascalonicus* Doncaster, 1946	Cucurbitaceae	*Lagenaria vulgaris* Ser.	GB	Tashev (1962)
	Geraniaceae	*Pelargonium* sp.	GB	Tashev (1962)
	Hydrangeaceae	*Hydrangea hortensis* Sm.	GB	Tashev (1962)
	Lamiaceae	*Salvia* sp.	GB	Tashev (1962)

Aphid species	Host plant family	Host plant species	Green-house	Date
Myzus (*Nectarosiphon*) *ascalonicus* Doncaster, 1946	Malvaceae	*Hibiscus rosa-sinensis* L.	GL	28.03.2011
	Resedaceae	*Reseda odorata* L.	GB	Tashev (1962)
	Scrophulariaceae	*Hebe* sp.	S1	01.07.2010
Myzus (*Nectarosiphon*) *persicae* (Sulzer, 1776)	Acanthaceae	*Aphelandra aurantiaca* Lindl.	GB	07.10.2010
		Thunbergia coccinea Wall.	GB	09. 03.2009
				20.12.2008
	Agavaceae	*Cordyline terminalis* Kunth.	GS	05.03.2010
	Aizoaceae	*Aptenia cordifolia* (L.f.) Schwantes	GL	24.01.2011
	Amaranthaceae	*Pleuropetalum darwinii* Hook. f.	GS	17.03.2009
	Anthericaceae	*Chlorophytum comosum* (Thunb.) Jacques	GK	31.05.2010
			GL	11.07.2011
	Apocynaceae	*Catharanthus* sp.	GL	28.03.2011
		Mandevilla sanderii (Hemsl.) Woodson	S5	01.07.2010
				03.08.2010
				26.05.2010
	Araceae	*Anthurium andraeanum* Linden	V2	14.07.2009
		Syngonium podophyllum Schott	GL	24.01.2011
		Zantedeschia aethiopica (L.) Spreng.	GV	28.10.2008
	Araliaceae	*Hedera helix* L.	GL	14.03.2012
		Schefflera arboricola (Hayata) Merr.	GB	02.09.2010
				04.08.2010
				07.10.2010
			R1	01.06.2010
	Asteraceae	*Bellis perennis* L.	GB	20.10.2010
		Chrysanthemum hybridum Guss.	S1	13.03.2009
		Chrysanthemum indicum L.	GB	Tashev (1962)
		Cineraria sp.	GB	Tashev (1962)
		Dendranthema sp.	S1	13.03.2009
		Gazania heterophylla Willd. ex Steud.	S4	26.05.2010
		Senecio hybridus Scheidw.	S1	13.03.2009
		Senecio rowleyanus H. Jacobsen	GB	18.12.2008
		Zinnia elegans Jacq.	GE	01.06.2010
	Bignoniaceae	*Campsis radicans* (L.) Seem.	S5	30.08.2010
	Bombacaceae	*Ceiba pentandra* Gaertn.	GL	14.03.2012
	Brassicaceae	*Arabis alpina* L.	GB	20.10.2010
			GL	24.01.2011
	Cactaceae	*Zygocactus truncatus* K.Schum.	GS	05.03.2010
	Caprifoliaceae	*Viburnum tinus* L.	GB	02.09.2010
				07.10.2010
	Caryophyllaceae	*Dianthus hybridus* Schmidt ex Tausch	S6	31.05.2011

Aphid species	Host plant family	Host plant species	Green-house	Date
Myzus (*Nectarosiphon*) *persicae* (Sulzer, 1776)	Convolvulaceae	*Dichondra repens* J. R. Forst & G. Forst	S4	01.07.2010
				26.05.2010
				28.04.2010
		Ipomoea purpurea (L.) Roth	S4	28.04.2010
	Droseraceae	*Dionea* sp.	S3	06.08.2010
	Gesneriaceae	*Aeschynanthus radicans* Jack	GB	05.03.2010
	Hydrangeaceae	*Hydrangea hortensis* Sm.	GB	Tashev (1962)
	Lamiaceae	*Thymus* sp.	GB	05.11.2010
	Malvaceae	*Hibiscus rosa-sinensis* L.	GB	07.10.2010
				09.03.2009
			GL	24.01.2011
			S6	04.11.2009
		Hibiscus sp.	GS	17.12.2008
		Hibiscus syriacus L.	GL	28.05.2011
	Nyctaginaceae	*Bougainvillea glabra* Choisy	GB	04.08.2010
			R1	01.06.2010
			S4	28.04.2010
	Oleaceae	*Jasminum officinale* L.	GB	09.03.2009
	Primulaceae	*Cyclamen persicum* Mill.	S1	13.03.2009
	Solanaceae	*Calibrachoa* sp.	S5	26.05.2010
		Datura hybrida Ten.	GE	27.05.2009
		Solandra maxima (Sessè & Moc.) P. S. Green	GB	04.08.2010
				05.03.2010
				07.10.2010
		Solandra sp.	GB	26.05.2010
		Solanum sp.	GB	26.05.2010
	Zamiaceae	*Zamia pumila* L.	GB	18.12.2008
Ovatus (*Ovatus*) *crataegarius* (Walker, 1850)	Lamiaceae	*Monarda didyma* L.	R1	01.06.2010
Periphyllus californiensis (Shinji, 1917)	Aceraceae	*Acer palmatum* Thunb.	GB	20.10.2010
Prociphilus (*Meliarhizophagus*) *fraxinifolii* (Riley in Riley & Monell, 1879)	Oleaceae	*Fraxinus* sp.	R1	01.06.2010
Prociphilus sp.	Oleaceae	*Fraxinus excelsior* L.	GL	17.02. 2009
Rhopalosiphum nymphaeae (Linnaeus, 1761)	Nymphaeaceae	*Nymphaea alba* L.	GV	28.10.2008
Rhopalosiphum padi (Linnaeus, 1758)	Asphodelaceae	*Kniphophia uvaria* (L.) Hook.	R1	29.05.2009
	Poaceae	*Agrostis stolonifera* L.	S4	18.11.2010
		Festuca ovina L. subsp. *glauca* (Vill.) O. Bolòs & Vigo	R1	29.05.2009
Tinocallis (*Sarucallis*) *kahawaluokalani* (Kirkaldy, 1907)	Lythraceae	*Lagerstroemia indica* L.	R1	01.06.2010
				29.05.2009

* The specimens of *Aphis* (*Aphis*) *fabae* are not identified to the subspecies level.

(3 greenhouses, 8 samples, 2.9 %). All other species were found very rarely and were represented by 5 or less samples (< 1.8 %).

The present study indicates that in greenhouses with a permanent plant composition, aphid infestations are more frequent, more widespread, and are caused by a greater variety of species compared to infestations in greenhouses with a constant circulation of plant species (Fig. 2).

The widest host range was shown by *Myzus persicae* (43 hosts, 38 %), *Aulacorthum solani* (32 hosts, 28 %), *Aulacorthum circumflexum* (23 hosts, 20 %), *Aphis gossypii* (9 hosts, 8 %), *Aphis spiraecola* (8 hosts, 7 %), *Aphis fabae* (7 hosts, 6 %) and *Macrosiphum euphorbiae* (6 hosts, 5 %).

Periphyllus californiensis and *Aphis* (*Aphis*) *fabae mordvilkoi* are reported for the first time for Bulgaria. Furthermore, *Aphis spiraecola* has been found in new localities and has widened its host range in this country. So far, this species had been reported only on apple by Rasheva and Andreev (2007). All hosts reported in the present study for *Aphis spiraecola* are new for Bulgaria.

The list of host plants includes 114 species from 95 genera and 58 families. The most frequently infested plant species belong to Asteraceae (50 samples) and Malvaceae (37 samples). Eighteen samples were collected from Araceae; 16 samples from Apocynaceae; 15 samples from Araliaceae; 13 samples from Geraniaceae; and 10 samples from Acanthaceae, Solanaceae and Rosaceae.

The most frequently infested plants belong to the genera *Hibiscus* (12.9 %, 36 samples), *Dendranthema* (6.8 %, 19 samples), *Chrysanthemum* (5 %, 14 samples) and *Pelargonium* (4.7 %, 13 samples).

The highest diversity of aphid species was observed on *Hibiscus rosa-sinensis* and consists of 9 species (from 29 samples). Five species were identified on *Dendranthema* sp. (19 samples), *Chrysanthemum hybridum* (13 samples) and *Anthurium andreanum*

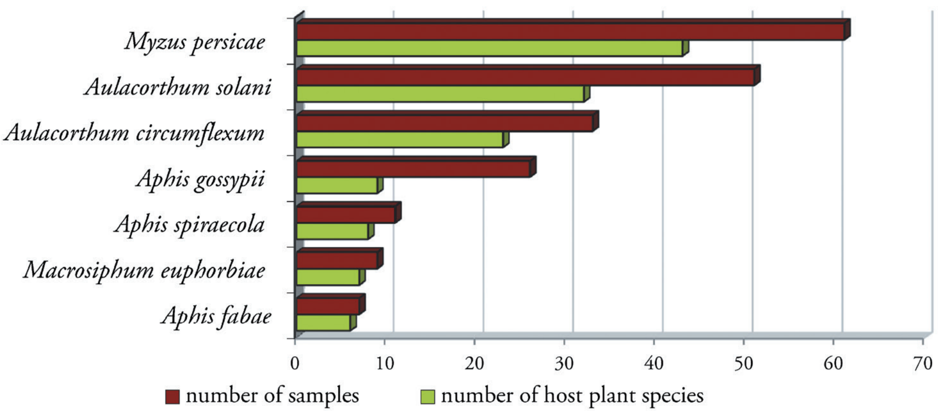

Figure 1. Number of samples and number of host plant species found by polyphagous aphid species.

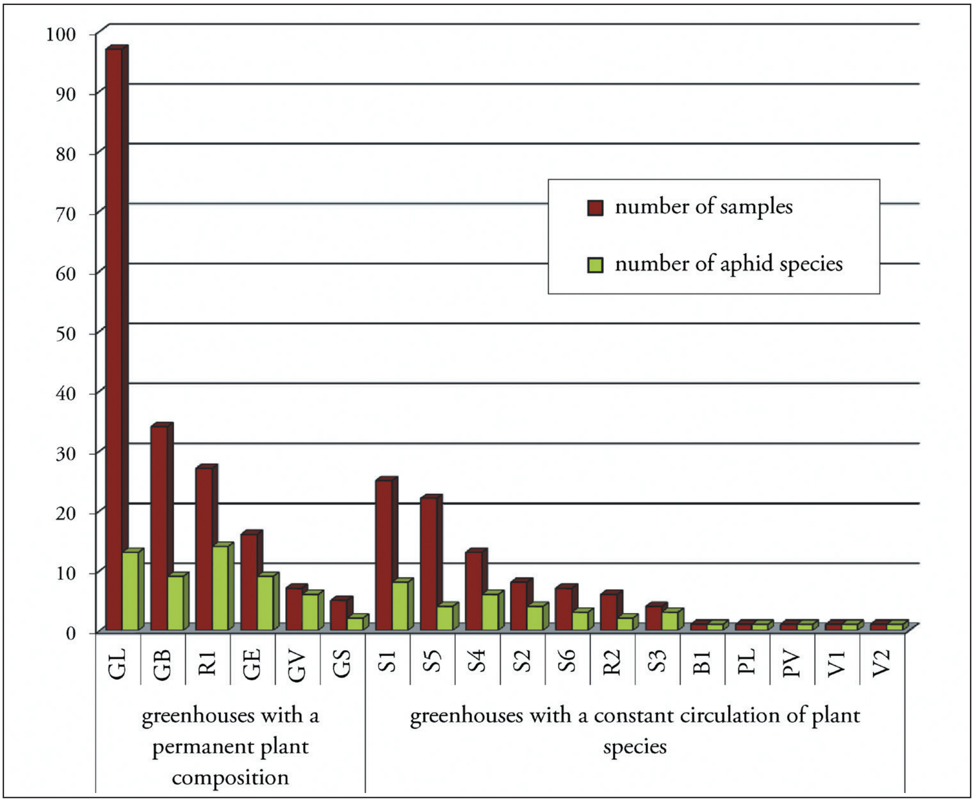

Figure 2. Distribution of number of samples and number of aphid species by greenhouses.

(6 samples). Four species were found on *Cyclamen persicum*, *Shefflera arboricola* and *Syngonium podophyllum*. Three species were recorded on *Aptenia cordifolia*, *Bougainvillea glabra*, *Chlorophytum comosum*, *Hebe* sp., *Hedera helix*, *Hibiscus syriacus*, *Mandevilla sanderi* and *Vinca major*.

Conclusion

The aphids established on ornamental plants in greenhouses in Bulgaria comprise 33 species and one subspecies from 13 genera and 5 subfamilies. The most widespread aphid species is *Myzus persicae*, followed by *Aulacorthum solani* and *Aphis gossypii*. The widest host ranges were shown by *Myzus persicae*, *Aulacorthum solani* and *Aulacorthum circumflexum*.

The list of host plants includes 114 species from 95 genera and 58 families. The most infested plants belong to the genera *Hibiscus* and *Dendranthema*. The largest number of aphid species was detected on *Hibiscus* (9 species).

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RESEARCH ARTICLE

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Secondary structure models of 18S and 28S rRNAs of the true bugs based on complete rDNA sequences of *Eurydema maracandica* Oshanin, 1871 (Heteroptera, Pentatomidae)

Shasha Yu[1], Yanhui Wang[1], Dávid Rédei[1], Qiang Xie[1], Wenjun Bu[1]

[1] *Institute of Entomology, College of Life Sciences, Nankai University, 94 Weijin Road, Tianjin 300071, China*

Corresponding author: *Qiang Xie* (qiangxie@nankai.edu.cn); *Wenjun Bu* (wenjunbu@nankai.edu.cn)

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Abstract

The sequences of 18S and 28S rDNAs have been used as molecular markers to resolve phylogenetic relationships of Heteroptera for two decades. The complete sequences of 18S rDNAs have been used in many studies, while in most studies only partial sequences of 28S rDNAs have been used due to technical difficulties of amplifying the complete lengths. In this study, we amplified the complete 18S and 28S rDNA sequences of *Eurydema maracandica* Oshanin, 1871, and reconstructed the secondary structure models of the corresponding rRNAs. In addition, and more importantly, all of the length variable regions of 18S rRNA were compared among 37 families of Heteroptera based on 140 sequences, and the D3 region of 28S rRNA was compared among 51 families based on 84 sequences. It was found that 8 length variable regions could potentially serve as molecular synapomorphies for some monophyletic groups. Therefore discoveries of more molecular synapomorphies for specific clades can be anticipated from amplification of complete 18S and 28S rDNAs of more representatives of Heteroptera.

Keywords

rRNA, secondary structure, Heteroptera, molecular synapomorphy, *Eurydema maracandica*

Introduction

Each cluster of rDNA in turn contains external transcribed spacer (ETS), 18S rDNA, internal transcribed spacer 1 (ITS1), 5.8S rDNA, ITS2 and 28S rDNA (Hillis, Dixon 1991). These genes and spacer regions, separately or in combination, have been used as molecular markers for resolving phylogenetic relationships of Heteroptera for two decades from Wheeler et al. (1993). Among them, the length-conservative regions of 18S rDNA and 28S rDNA have been mostly used for resolving phylogenetic relationships between higher level groups (Wheeler et al. 1993, Xie et al. 2005, Schuh et al. 2009), while the length-variable regions (LVRs), ITS1 and ITS2 have always been used at species level (Marcilla et al. 2001, Hebsgaard et al. 2004, Damgaard et al. 2005, Calleros et al. 2010).

As far as the rDNAs are concerned, complete sequences of 18S rDNA have been used in various phylogenetic studies on Heteroptera (Tian et al. 2008, Jung, Lee 2011). Comparatively, so far only partial sequences of 28S rDNAs have been involved in phylogenetic studies on Heteroptera due to technical difficulties of amplifying the complete lengths. These difficulties are twofold. First, the amplification of 28S rDNA is more likely interfered by the hairpin structures, or tandem replicates of single nucleotides or oligonucleotides. Second, universal primers are unavailable for amplifying the 28S rDNA of Heteroptera.

Reconstruction of the complete secondary structure model of 28S rRNA can only be achieved by full sequencing of 28S rDNA. According to the results of comparative studies of 18S rRNAs of Insecta (Xie et al. 2009) and Hemiptera (Xie et al. 2008), the secondary structure model can have significance in two aspects. First, the alignment results of rDNAs can be corrected based on the secondary structure models of the corresponding rRNAs (Kjer et al. 2006). Further, it is possible to evaluate the potential influences to the results of phylogenetic reconstruction. Second, the secondary structure model provides a novel view and datasets to discover synapomorphies, such as group-specific insertions or deletions (indels), exactly the same length of some LVRs, and length expansions. In this study, the secondary structure models of 18S and 28S rRNAs of Heteroptera were reconstructed based on corresponding rDNA sequences of the pentatomid species *Eurydema maracandica* Oshanin, 1871. Additionally, all LVRs of complete 18S rRNA and the Divergent region 3 (D3) of 28S rRNA were compared based on data of nearly all available families of Heteroptera from GenBank (www.ncbi.nlm.nih.gov/Genbank), with exception of a few problematic sequences.

Methods

Taxon sampling

According to the currently accepted classification of Heteroptera (Schuh and Slater 1995, Schuh et al. 2008), heteropterans are divided into 7 infraorders, 23 superfamilies and 76 families. In this study, the 18S rDNA dataset comprises 140 sequences representing 7 infraorders, 16 superfamilies and 37 families of Heteroptera. The 28S rDNA dataset, which only included the D3 region, comprises 84 sequences of 7 infraorders, 21 superfamilies and 51 families.

Molecular experiments

The specimen was collected from Yining, Xinjiang Uyghur Autonomous Region, China (43°56'N, 81°19'E, 570m) on July 26, 2011 by Qiang Xie. In the alcohol-kept insects' collection of Nankai University, the ID number for the voucher specimen is NKU0150177. The species was identified based on the available literature and comparative material, its identity was confirmed by P. Kment. The specimen perfectly fits the original description (Oshanin 1871) and the available detailed redescriptions and illustrations (Stichel 1961, Putshkov 1965, Zheng 1983, Nonnaizab 1988) of *E. maracandica*.

Genomic DNA was extracted from thoracic tissue of ethanol-preserved specimen. Total genomic DNA was isolated using the CTAB-based method (Reineke et al. 2002). The primers Ns1 and Ns8 used for amplifying the 18S rDNA were those used by Barker et al. (2003). The others were designed by the software Primer Premier 5.00 (Lalitha 2000). These primer sets were used to amplify six overlapping fragments of 28S rDNA and two overlapping fragments of 18S rDNA. All of the sequences were sequenced in both directions. In addition, 18S rDNA was cloned, which used pEASY-T3 (TransGen, Beijing, China) as vector, following the manufacturer's instructions. Amplification was carried out in a 50 µL volume reaction, with 1.5 units of *LA Taq* DNA Polymerase, 2.5 mM of dNTP and 10 µM of each primer. The thermal cycling program of PCR consisted of an initial denaturation at 94°C for 1 min, followed by 35 cycles (94°C for 30 s, 49–57°C for 30 s, 72°C for 1 min), and ending with a final extension at 72°C for 8 min. Colony PCR was carried out in a 25 µL volume reaction, and consisted of 30 amplification cycles. All of the primer pairs and annealing temperatures are listed in Supplementary File 1. The GenBank accession numbers of 18S and 28S rDNAs of *Eurydema maracandica* are JX997807 and JX997806 respectively.

Reconstruction of secondary structure and Sequence alignment

The secondary structure of 18S rRNA was slightly revised from the universal model of insects (Xie et al. 2009) based on the sequence of *Drosophila melanogaster* (GenBank accession number M21017). In the group specific optimization of the universal model according to the sequences of Heteroptera, secondary structures of LVRs were reconstructed using the thermodynamics folding method of the software RNAstructure 5.4 (Reuter and Mathews 2010). The secondary structure of 28S rRNA was revised from the model of insects (Wang et al. 2013) based on the sequence of *Drosophila mela-*

nogaster (GenBank accession number M21017). The numbering system for LVRs of 28S rRNA followed the D system (Hassouna et al. 1984, Ellis et al. 1986). In the optimization of the previous model of insects, secondary structures of LVRs were reconstructed using RNAstructure 5.4 as well. The re-calculated results in this study were selected under the principle of co-variation: the fewer the secondary structural elements, especially the paired regions, are destroyed by each sequence, the better the model is (Gutell et al. 2002). We simplified the principle in this study as: the longer the stems are kept by each sequence, the better the model is. Sequence alignment was performed by ClustalW, which is imbedded within BioEdit 7.1.3 (Hall 2011). Manual alignments were based on the rRNA secondary structure models reconstructed in this study.

Data resources

The data underpinning the analyses reported in this paper are deposited in the Dryad Data Repository at doi: 10.5061/dryad.j8kp5

Results and discussion

General description of secondary structures

The complete sequence of 18S rDNA of *Eurydema maracandica* is 1,894 bp. In the secondary structure of the corresponding rRNA (Fig. 1) the LVRs L and X regions were specifically optimized. The 18S rDNA sequence of *Eurydema maracandica* was aligned with other 140 orthologous sequences of 37 families in Heteroptera. The alignment result suggested that the local length variations of 18S rDNA are localized in 13 independent LVRs except for various indels. Most LVRs were restrained in three domains, which were previously named as V2, V4 and V7 (Neefs et al. 1993). Among all of the 13 LVRs, LVR L is the most variable one in length.

The complete sequence of 28S rDNA of *Eurydema maracandica* is 4,030 bp. In the secondary structure of corresponding rRNA (Figs 2, 3), the LVRs D2, D3, D7, D8, D10, and D11 were specifically optimized. Compared with the secondary structure of the universal model of insect 28S rRNA, LVRs of heteropteran 28S rRNAs are distributed in 10 regions (D2–D11). Only D3 region of most superfamilies has corresponding data in GenBank, therefore only this region was comparatively analyzed and the results may serve as an inspiring case for the other LVRs of 28S rRNA. Alignment results suggested that in the D3 region, LVRs can be further divided into three sections (D3-1, D3-2 and D3-3), which are interspaced by several short length-conservative regions. Among these three separate LVRs, D3-2 is the most variable one in length.

According to the above results, the local length variations of heteropteran rRNAs are moderate in comparison with the length variations of eukaryotic rRNAs (Xie et

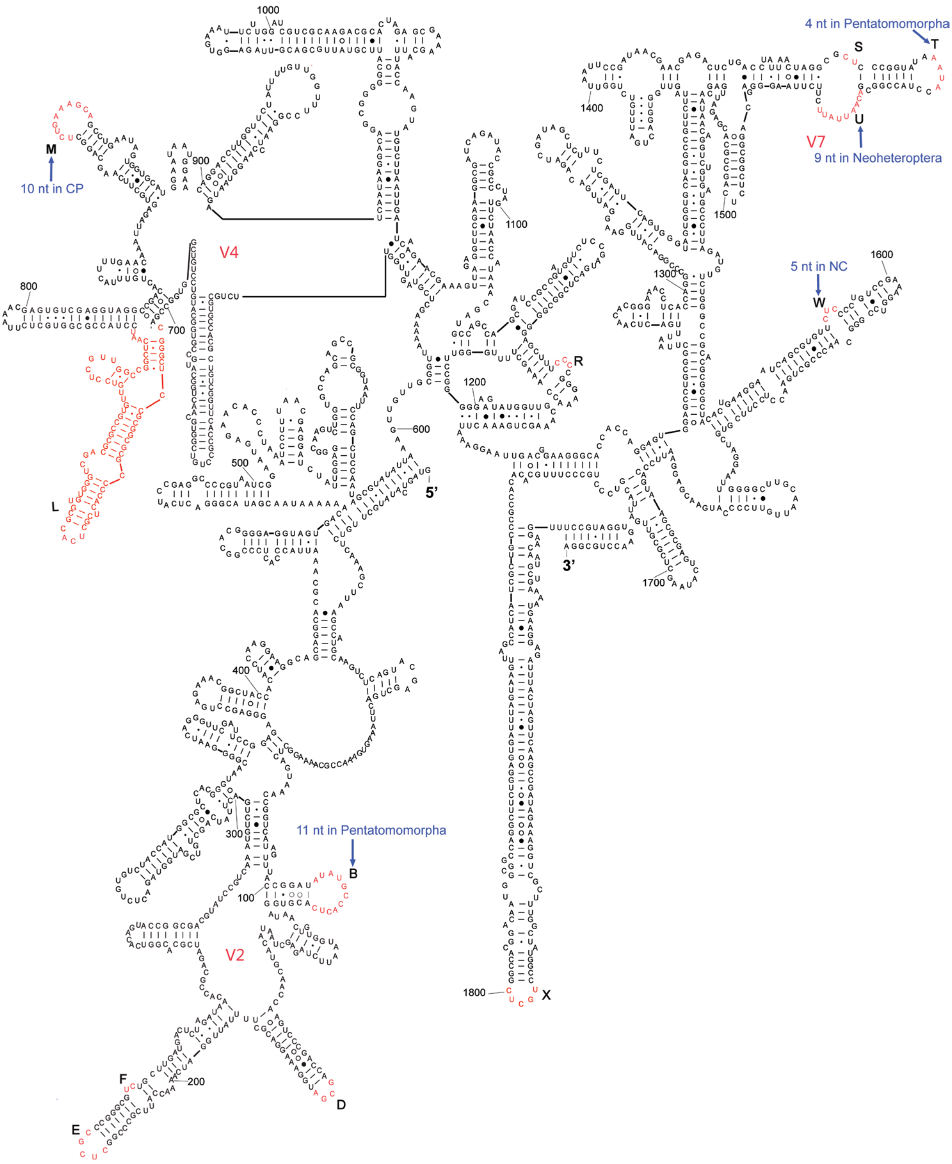

Figure 1. Secondary structure model of 18S rRNA of *Eurydema maracandica*. The bases marked in black represent length-conservative regions, and the bases labeled as capital letters **B** to **W** in red represent 13 LVRs. CP and NC represent monophyletic groups Cimicomorpha+Pentatomomorpha and Naboidea+Cimicoidea, respectively. Base pairing is indicated as follows: standard canonical pairs by lines (G–C, A–U), wobble G:U pairs by dots (G·U), A:G or A:C pairs by open circles (A○G, A○C), and other non-canonical pairs by filled circles (e.g., A●A).

al. 2011). The local length variations of heteropteran rRNAs did not cause overlap between adjacent regions (See Supplementary Files 2, 3) like it was documented in the suborder Sternorrhyncha of Hemiptera (Xie et al. 2008) and some other insect orders

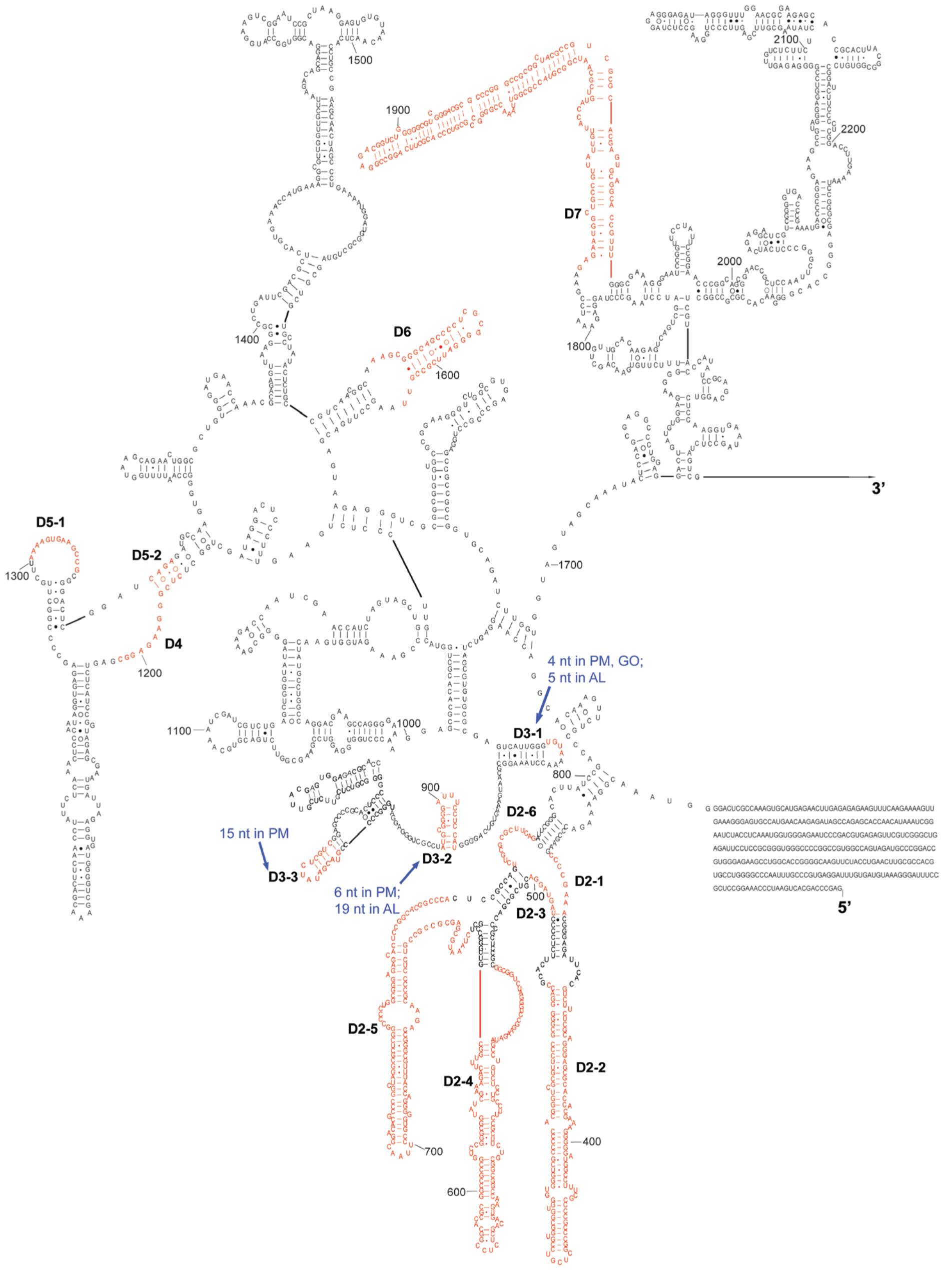

Figure 2. The 5'-half part of secondary structure model of 28S rRNA of *Eurydema maracandica*. The numbers D2 to D7 represent six LVRs. PM, GO and AL represent monophyletic groups Paraphrynoveliidae+Macroveliidae, Gelastocoridae+Ochteridae and Acanthosomatidae+Lestoniidae, respectively.

(Xie et al. 2009). However, the ambiguity in alignment caused by length variations might have impact on the results of phylogenetic reconstruction of Heteroptera, and it deserves further evaluation.

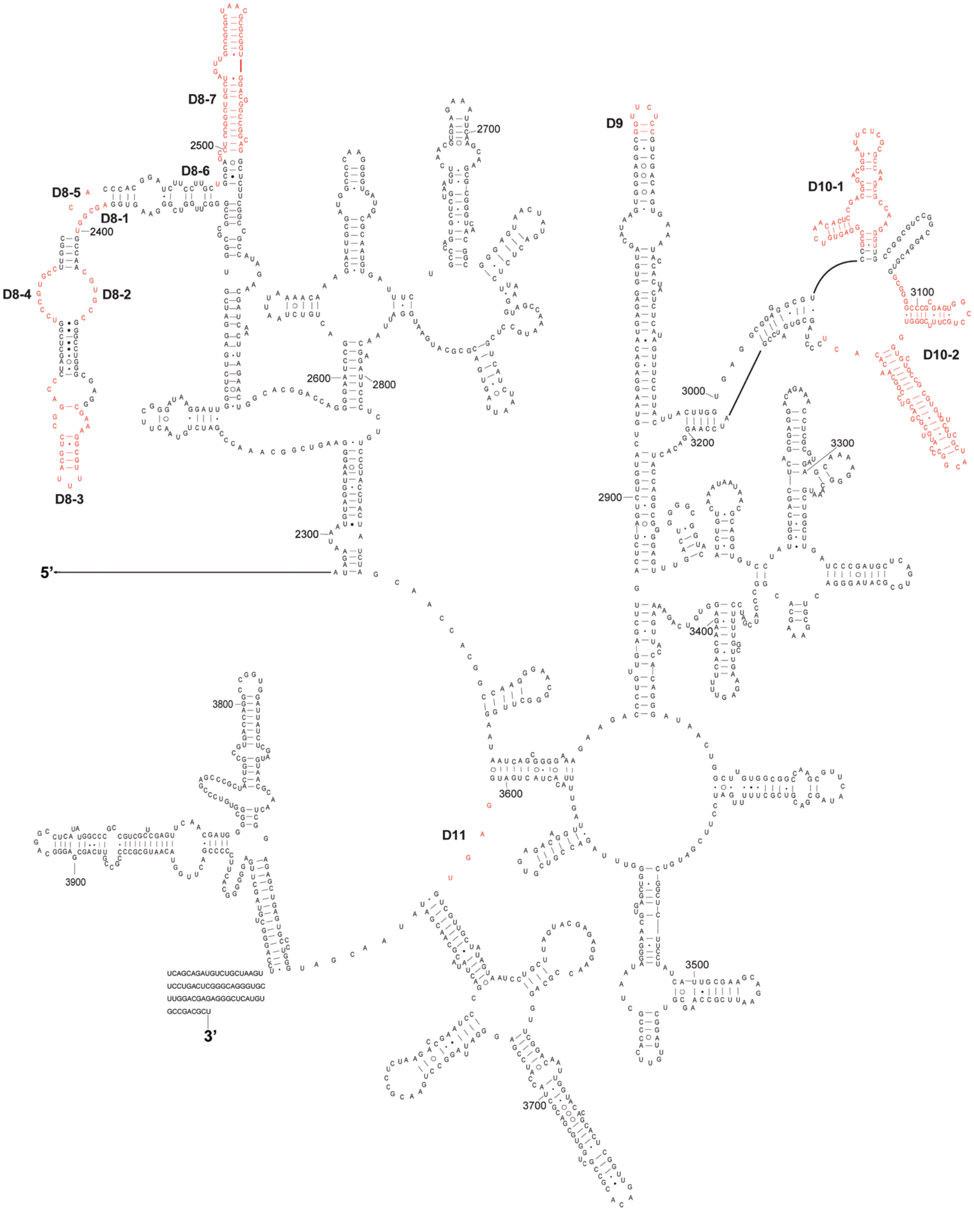

Figure 3. The 3'-half part of secondary structure model of 28S rRNA of *Eurydema maracandica*. The numbers D8 to D11 represent four LVRs.

The LVRs potentially serving as synapomorphies

Campbell et al. (1994) hypothesized that length expansion in 18S rDNA could serve as synapomorphy for Sternorrhyncha. Later, the concepts of "molecular morpho-metrics" (Billoud et al. 2000) and "morpho-molecular structures" (Ouvrard et al. 2000) were introduced. It was found that length variation and indels could serve as synapomorphies for specific monophyletic groups of insects (Xie et al. 2009). The results of this study indicate that, the LVRs B, M, T, U and W of 18S rDNA, and D3-1, D3-2 and D3-3 of 28S rDNA could potentially serve as molecular synapomorphies (Table 1). According to the lengths of LVRs B and T of 18S rDNA, there only a few exceptions exist within Pentatomomorpha. Therefore, the 11nt length of LVR B and the 4nt length of LVR T very likely originate from the last ancestor of Pentatomomorpha and are the synapomorphies of this infraorder. In the same sense, the 10nt length of LVR M is a dominant state in the clade (Cimicomorpha+Pentatomomorpha), and the 9nt length of LVR U is very conservative within Neoheteroptera. Fig. 4 shows the secondary structure models of LVR W of Naboidea and Cimicoidea. Within Heteroptera, Naboidea and Cimicoidea have the same unique length of 5nt in this region. Taking the problem of the phylogeny within the superfamily Pentatomoidea for more instances, the 5nt length of LVR D3-1 and 19nt length of LVR D3-2 in 28S rRNA could possibly serve as synapomorphies for an Acanthosomatidae+Lestoniidae clade (Grazia et al. 2008). Additionally, the Paraphrynoveliidae+Macroveliidae clade shares the same length of LVR D3-1, D3-2 and D3-3. Gelastocoridae and Ochteridae have the same length of 4nt in D3-1 region. Therefore amplification of complete 18S and 28S rDNAs of more representatives very likely will result in more representative dataset for reconstruction of ancestral states and discoveries of more molecular synapomorphies for specific clades within Heteroptera.

Table 1. Monophyletic groups within Heteroptera with some LVRs serving as potential synapomorphies.

Monophyletic group	Reference	LVR (number of sequences examined)	
		18S rDNA	28S rDNA
Neoheteroptera	Štys et al. (1975) Schuh (1979) Wheeler et al. (1993)	9nt U (131)	
Paraphrynoveliidae + Macroveliidae	Damgaard (2008)		4nt D3-1 (3) 6nt D3-2 (3) 15nt D3-3 (3)
Gelastocoridae + Ochteridae	Hebsgaard (2004)		4nt D3-1 (4)
Cimicomorpha + Pentatomomorpha	Štys et al. (1975) Schuh (1979) Schaefer (1993) Wheeler et al. (1993)	10nt M (117)	
Naboidea + Cimicoidea	Schuh et al. (2009)	5nt W (36)	
Pentatomomorpha	Leston et al. (1954) Schuh (1979) Schaefer (1993) Wheeler et al. (1993)	11nt B (39) 4nt T (37)	
Acanthosomatidae+Lestoniidae	Grazia et al. (2008)		5nt D3-1 (8) 19nt D3-2 (8)

Note: Detailed information see Supplementary Files 4 and 5.

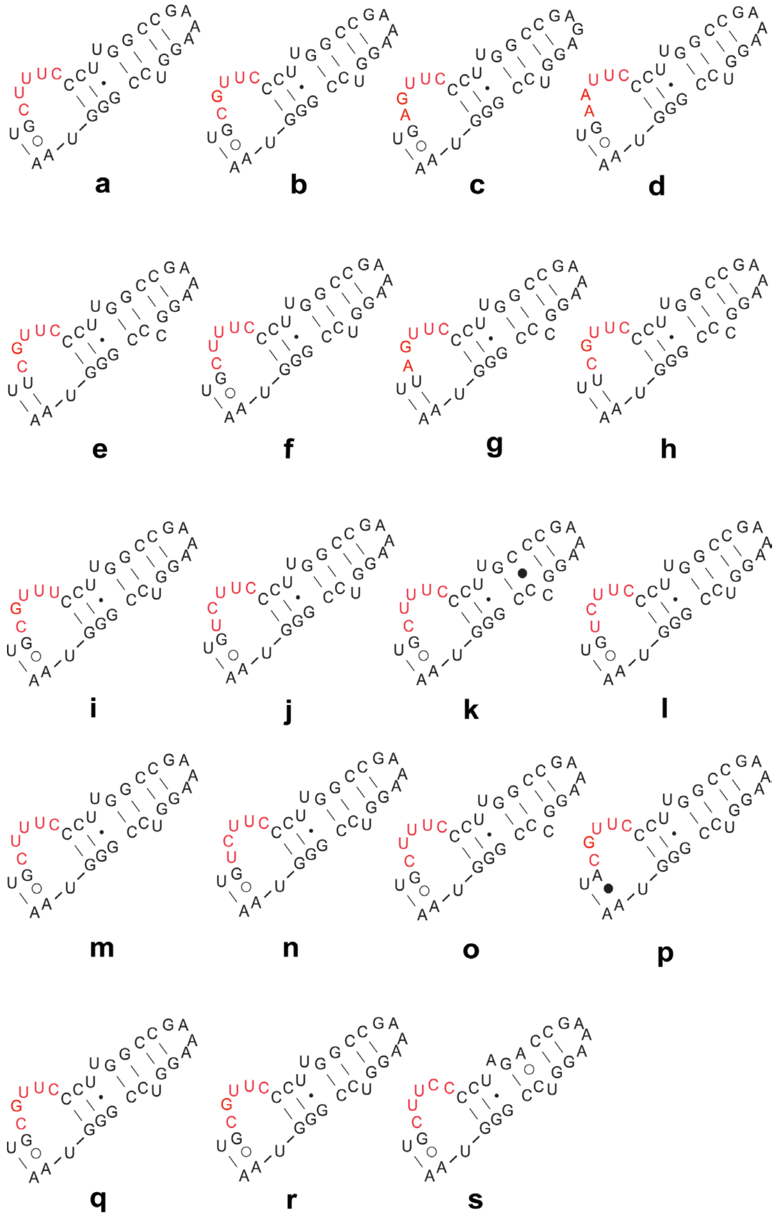

Figure 4. Secondary structure models of LVR W of Naboidea and Cimicoidea. These sequences are from 15 genera, 19 species of Naboidea and Cimicoidea. The species names and GenBank Accession numbers are as follow: Nabidae (**a**) *Nabis ferus* EF487300 (**b**) *Nabis flavomarginatus* GQ258424 (**c**) *Himacerus apterus* GQ258425; Lyctocoridae (**d**) *Lyctocoris beneficus* EF487298; Anthocoridae (**e**) *Anthocoris* sp. AY252319 (**f**) *Anthocoris confusus* EF487297 (**g**) *Anthocoris montanus* EF487307 (**h**) *Tetraphleps aterrimus* EF487295 (**i**) *Amphiareus obscuriceps* EF487301 (**j**) *Orius agilis* EF487296 (**k**) *Physopleurella armata* EF487308 (**l**) *Montandoniola moraguesi* EF487310 (**m**) *Xylocoris cerealis* GQ258395 (**n**) *Bilia* sp. GQ258406 (**o**) *Buchananiella crassicornis* GQ258407 (**p**) *Lasiochilus japonicus* GQ258410 (**q**) *Lasiochilus luceonotatus* GQ258411; Cimicidae (**r**) *Cimex lectularius* GQ258396; Curaliidae (**s**) *Curalium cronini* EU683128.

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Appendix 1

Primer pairs and the annealing temperatures for amplifying rDNAs of *Eurydema maracandica*. (doi: 10.3897/zookeys.319.4178.app1) File format: Mircrosoft Word Document (doc).

Explanation note: List of primer pairs and annealing temperatures.

Citation: Yu S, Wang Y, Rédei D, Xie Q, Bu W (2013) Secondary structure models of 18S and 28S rRNAs of the true bugs based on complete rDNA sequences of *Eurydema maracandica* Oshanin, 1871 (Heteroptera, Pentatomidae). In: Popov A, Grozeva S, Simov N, Tasheva E (Eds) Advances in Hemipterology. ZooKeys 319: 363–377. doi: 10.3897/zookeys.319.4178.app1

Appendix 2

Alignment of 18S rDNA sequence of Heteroptera. (doi: 10.3897/zookeys.319.4178.app2) File format: DNA and Protein Sequence Alignment (fas).

Explanation note: The alignment of *Eurydema maracandica* 18S rDNA sequence with other 140 orthologous sequences of Heteroptera.

Citation: Yu S, Wang Y, Rédei D, Xie Q, Bu W (2013) Secondary structure models of 18S and 28S rRNAs of the true bugs based on complete rDNA sequences of *Eurydema maracandica* Oshanin, 1871 (Heteroptera, Pentatomidae). In: Popov A, Grozeva S, Simov N, Tasheva E (Eds) Advances in Hemipterology. ZooKeys 319: 363–377. doi: 10.3897/zookeys.319.4178.app2

Appendix 3

Alignment of D3 region in 28S rDNA sequence of Heteroptera. (doi: 10.3897/zookeys.319.4178.app3) File format: DNA and Protein Sequence Alignment (fas).

Explanation note: The alignment of *Eurydema maracandica* D3 region in 28S rDNA sequence with other 84 orthologous sequences of Heteroptera.

Citation: Yu S, Wang Y, Rédei D, Xie Q, Bu W (2013) Secondary structure models of 18S and 28S rRNAs of the true bugs based on complete rDNA sequences of *Eurydema maracandica* Oshanin, 1871 (Heteroptera, Pentatomidae). In: Popov A, Grozeva S, Simov N, Tasheva E (Eds) Advances in Hemipterology. ZooKeys 319: 363–377. doi: 10.3897/zookeys.319.4178.app3

Appendix 4

The summarization of length variation in 18S rDNA sequence of Heteroptera. (doi: 10.3897/zookeys.319.4178.app4) File format: Microsoft Excel Worksheed (xls).

Explanation note: The length of 12 LVRs in all currently known 18S rDNA sequences of Heteroptera.

Citation: Yu S, Wang Y, Rédei D, Xie Q, Bu W (2013) Secondary structure models of 18S and 28S rRNAs of the true bugs based on complete rDNA sequences of *Eurydema maracandica* Oshanin, 1871 (Heteroptera, Pentatomidae). In: Popov A, Grozeva S, Simov N, Tasheva E (Eds) Advances in Hemipterology. ZooKeys 319: 363–377. doi: 10.3897/zookeys.319.4178.app4

Appendix 5

The summarization of length variation in D3 region of 28S rDNA sequence of Heteroptera. (doi: 10.3897/zookeys.319.4178.app5) File format: Microsoft Excel Worksheed (xls).

Explanation note: The length of 3 LVRs in all currently known sequences of D3 region of 28S rDNA of Heteroptera.

Citation: Yu S, Wang Y, Rédei D, Xie Q, Bu W (2013) Secondary structure models of 18S and 28S rRNAs of the true bugs based on complete rDNA sequences of *Eurydema maracandica* Oshanin, 1871 (Heteroptera, Pentatomidae). In: Popov A, Grozeva S, Simov N, Tasheva E (Eds) Advances in Hemipterology. ZooKeys 319: 363–377. doi: 10.3897/zookeys.319.4178.app5