

# Microcrustacean community structure in the different water bodies of the Lake Fertő/Neusiedler See (Fertő-Hanság National Park, Hungary): new invaders, recurring and missing taxa

A. KISS, E. ÁGOSTON-SZABÓ and M. DINKA,

Dr. Anita Kiss, Dr. Edit Ágoston-Szabó & Dr. Mária Dinka, MTA Centre for Ecological Research,  
Danube Research Institute 2163 Vácrátót, Hungary. E-mails: [kiss.anita@okologia.mta.hu](mailto:kiss.anita@okologia.mta.hu),  
[agoston-szabo.edit@okologia.mta.hu](mailto:agoston-szabo.edit@okologia.mta.hu), [dinka.maria@okologia.mta.hu](mailto:dinka.maria@okologia.mta.hu)

**Abstract.** The composition and community parameters of the microcrustacean assemblages were studied at twenty one sampling sites located in different water bodies/habitats (open water, inner ponds, canal, reed belt) of the shallow turbid alkaline Lake Fertő/Neusiedler See. 53 taxa (24 Cladocera, 9 Ostracoda, 20 Copepoda) were recorded from the lake, *Alona affinis* (Leydig, 1860) and *Eurytemora velox* (Lilljeborg, 1853) were detected for the first time. Including these two species, the microcrustacean fauna of the lake increased to 112 (49 Cladocera, 27 Ostracoda, 36 Copepoda) species on the basis of 15 published faunistic studies. Variations in composition, species richness, density, and diversity of communities of the different water bodies of the lake became obvious. In the reed belt, significant differences were detected between the species composition of the healthy and degraded reed stands. The long-term changes in the microcrustacean fauna are in accordance with the high instability and spatial variability of lake habitats and with several factors which are consequences of the extreme shallowness (water level fluctuations, extensive reed belt, high turbidity, wind effects, periodic anoxic conditions).

**Keywords.** Cladocera, Copepoda, Ostracoda, Neusiedler See

## INTRODUCTION

Lake Fertő/Neusiedler See (47°42' N, 16°46' E) is the westernmost and largest steppe lake in Eurasia. It is situated on the Hungarian-Austrian border with a surface area of 309 km<sup>2</sup> (Hungarian part: 75 km<sup>2</sup>), and a mean depth of 1.1 m. 54% of the whole lake and 85% of the Hungarian part is covered by reed. There are numerous reedless areas (inner ponds) of various sizes within the reed belt, which is intersected by artificial canals connecting the inner ponds with the open water areas. The Lake Fertő is a permanent, but extremely shallow lake with regulated outflow. According to the characteristic ionic ratios, the water of the lake is a mixed hydrogencarbonate-sulphate and sodium-magnesite water type. Its conductivity is 1.3–3.5 mS cm<sup>-1</sup>, pH is 7.7–9.5 and its sulphate concentration is 350–500 mg l<sup>-1</sup>. The water volumes and levels of the lake fluctuate significantly. Life conditions are highly influ-

enced by the stirring effects of the primarily north and northwest winds. A detailed description of the lake is given in Löffler (1979).

The investigation of the microcrustacean fauna in the lake started in the 1890s by Daday (1890, 1891, 1897, 1900), who described 46 species (25 Cladocera, 11 Ostracoda, 10 Copepoda). Later Pesta (1954) recorded 18 cladoceran species and Zakovsek (1961) 16 microcrustacean species. Pesta established the importance of planktonic crustaceans in the lake, whereas Zakovsek was the first publishing quantitative results about the zooplankton. 1979 was a prominently significant year for the microcrustacean studies. In the Austrian side of the lake, detailed investigations of the microcrustacean communities in the open water (Herzig 1979) and the reed belt (Löffler 1979) took place, whereas in the Hungarian part of the lake Ponyi & Dévai (1979) characterized the microcrustacean assemblages in the typical habi-

tats of the lake. Herzig (1979) carried out a long-term (between 1968 and 1974) and intensive sampling design and provided a detailed description about the distribution, population and production biology of 7 Cladocera and 4 Copepoda species.

Between 1980 and 1982 Forró & Metz (1987) recorded 20 Cladocera and 14 Copepoda species from the reed belt of the Austrian part and revealed quantitative data of the assemblages. Kiss (2007a) summarized the faunistic works of the microcrustacean fauna, and reported 63 microcrustacean taxa in the period between 2002 and 2005. Out of the detected taxa 24 occurred in the inhomogeneous reed patches, situated near the Fertőrákos Bay, after the introduction of pre-treated wastewater. On the basis of the 15 studies on the microcrustacean fauna of the lake, 110 (48 Cladocera, 27 Ostracoda, 35 Copepoda) species were recorded between 1890 and 2005.

Between 2005 and 2012, our investigations continued, and our main objectives were to study the microcrustacean assemblages in the different habitats of the lake, and to examine the possible long-term changes in the composition of the fauna during the whole period (2002–2012).

## MATERIALS AND METHODS

The study was carried out between 2002 and 2012, without sampling in 2007, 2008, and 2011. Sampling took place once a year, in the vegetation period, except for 2004, when four samplings (April, June, August, and October) were carried out. This sampling design is obviously unsuitable for the exploration of seasonal patterns, but it is capable of revealing the spatial differences of the habitats.

A total of 21 sampling sites were selected from all the typical water bodies of the lake: open water (sites 11, 20, 23, and 25), inner ponds (sites 41, 42, 44, 45, 46, 47, and 48), Bozi-canal (sites B1, B8, and B9), reed belt (sites 2, 3, 4, 5, 6, 7, and 9) (Fig. 1). The inner ponds are reedless areas within the reed belt. Their size varies between 0.5 and 42

ha, and their distance from the shore is also various. In the Hungarian part of the lake, the reed belt is intersected by canals (width max. 3 m), which connect the inner lakes with the open water areas (Dinka *et al.* 2004). For our research, we choose the longest (5.9 km), 2.5–3.0 m wide Bozi-canal, which crosses the whole reed belt. From the sampling sites in the reed belt, 2, 4, 5 and 9 are homogeneous, closed, healthy reed stands, while sites 3, 6 and 7 are degraded, loose reed stands.

Microcrustaceans were collected with plankton net (mesh size 70  $\mu$ m, N = 1), by filtering 5 X 10 l of water then preserved in 4% formalin. The three examined groups of crustaceans were enumerated by using inverted microscopy, and with the exception of the harpacticoid copepods, were identified to species level. Microcrustacean abundance, including copepodids, was evaluated by enumerating individuals in the whole sample. Gulyás & Forró (1999, 2001), Meisch (2000) and the nomenclature of Dussart (1967, 1969) were used for species identification.

For comparing zooplankton assemblages, relative frequency and density for each species, the species richness (S), Shannon–Weaver diversity index ( $H'$ ), dominance (D) and density of the assemblages were calculated. Microcrustacean composition, abundance, Shannon diversity, and dominance in the different water bodies were compared by Mann-Whitney test. The difference was considered to be significant when  $P < 0.05$ . The composition of the healthy and degraded reed stands were compared by Detrended Correspondence Analysis using the PAST software (Hammer *et al.* 2001).

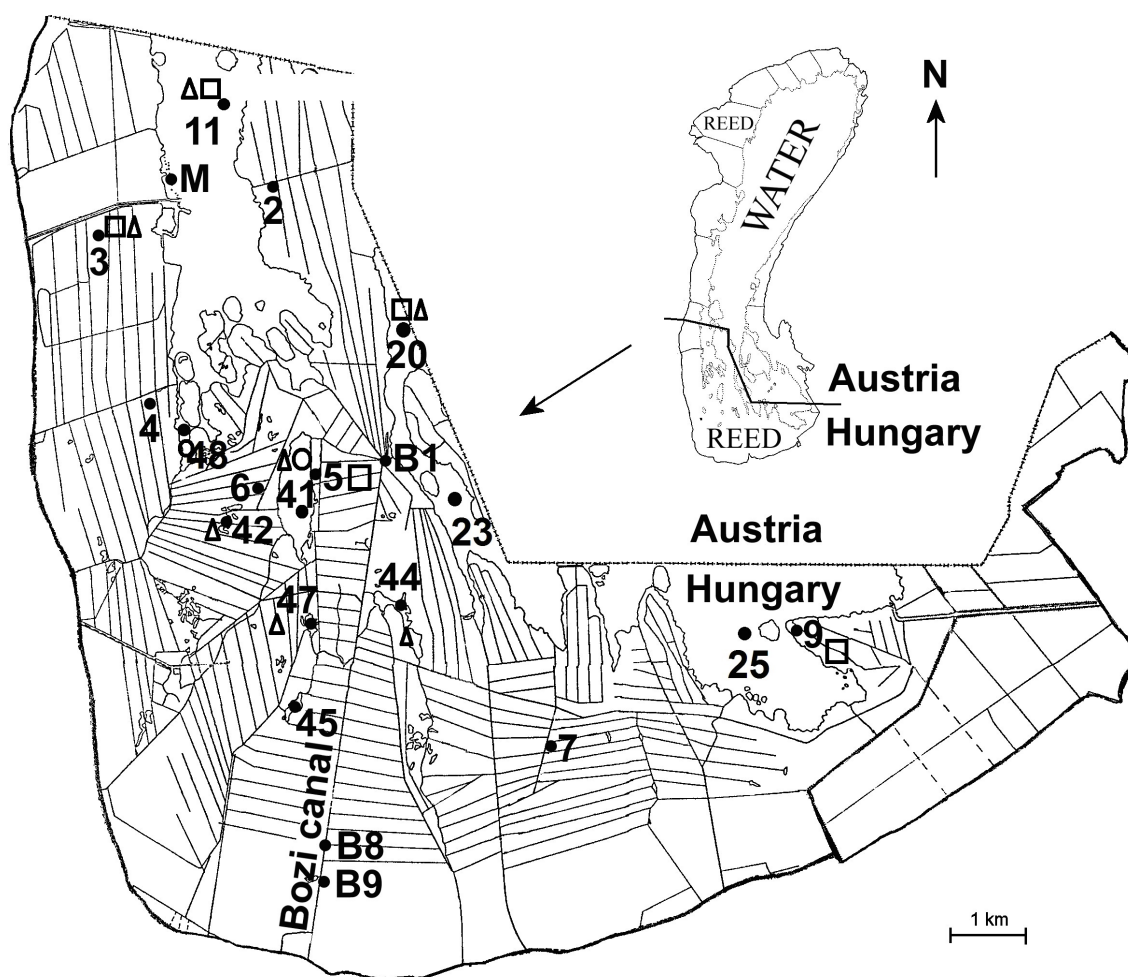
## RESULTS AND DISCUSSION

### Faunistic results

53 taxa (24 Cladocera, 9 Ostracoda, 20 Copepoda) were recorded, *Alona affinis* (Leydig, 1860) and *Eurytemora velox* (Lilljeborg, 1853) were recorded for the first time from the Lake Fertő (Appendix 1). Between 2002 and 2012, altogether

13 species were reported (see this survey and Kiss 2007a), which had not been mentioned earlier from the lake: 5 Cladocera (*Alona affinis*, *Alona intermedia* Sars, 1862, *Alonella nana* Baird, 1850, *Bunops serricaudata* (Daday, 1888), *Macrotrix rosea* (Liévin, 1848), *Pleuroxus truncatus* (O. F. Müller, 1785)), 4 Ostracoda (*Candona weltneri* Hartwig, 1899, *Fabaeformiscandona fragilis*

(Hartwig, 1898), *Fabaeformiscandona holzkampfi* (Hartwig, 1900), *Pseudocandona compressa* (Koch, 1838)) and 4 Copepoda (*Eucyclops macruiroides* (Lilljeborg, 1901), *Eurytemora velox*, *Macrocyclus distinctus* (Richard, 1887), *Paracyclops affinis* (Sars, 1863)). Out of the 13 taxa 9 occurred only in the inhomogeneous reed patch, after the introduction of pre-treated wastewater.



**Figure 1.** Sampling sites at the Lake Fertő/Neusiedler See and the distribution of *Eurytemora velox* in the different habitats in 2009 (○), 2010 (□) and 2012 (△).

M = Meteorological Station. Open water: sites 11, 20, 23, 25. Inner ponds: sites 41, 42, 44, 45, 46, 47. Bozi-canal: sites B1, B8, B9. Healthy reed stands: 2, 4, 5, 9. Degraded reed stands: 3, 6, 7.

Among the newly detected species, *Macrotrix rosea* (Löffler 1959, Metz & Forró 1991), *Eucyclops macruiroides* (Löffler 1959) and *Paracyclops affinis* (Metz & Forró 1991) were known from the nearby Seewinkel (Eastern Austria), and

*Candona weltneri*, *Pseudocandona compressa* and *Fabaeformiscandona fragilis* were detected in the neighbouring Lake Fehér in the Hanság (Kiss 2002a). In Hungary, the calanoid copepod *Eurytemora velox* has been known since 1992 (Forró

& Gulyás 1992), firstly from the area of the Szigetköz (Northwest Hungary) then it became widely distributed, for example in the Gemenc floodplain (Southern Hungary) (Kiss & Schöll 2009). In the Neusiedler See, this species occurred for the first time in 2009 then spread gradually and in 2012 a total of 492 specimens were collected (Fig. 1.)

The most abundant species of the lake were *Diaphanosoma mongolianum* and *Arctodiaptomus spinosus*. 17 out of the 53 species were found in all of the water bodies, while 12 occurred only in one type of habitat. Most taxa were detected from the Bozi-canal (39) and the reed belt (40). The composition, density, and diversity of the communities differed notably in the various water bodies of the lake (Fig. 2 and Appendix 1). These differences can be explained by the synergetic effects of physico-chemical and biological factors. Dinka *et al.* (2004) reported basic differences in the water chemistry of the different water type areas. The degree of these differences is essentially determined by distance from the open water areas and the water level of the given years. Somogyi *et al.* (2010) revealed the differences of phytoplankton composition and biomass of the open water, the inner ponds, and the canals. The inner ponds and the canals are more sheltered from wind-induced mixing, and therefore exhibit higher transparency. The presence of submerged and emerged macrophytes in the canals and the

reed belt provide food and shelter against predators, but fish predation should not be ignored as an important eliminating factor in the lake (Herzig 1979).

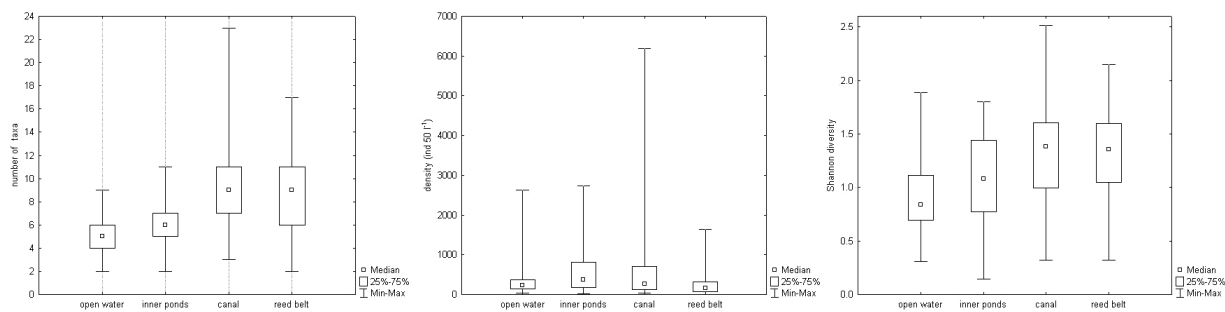
The mean density of the communities was significantly higher in the inner ponds and canal sites than in the open water and the reed belt sites. Species richness and diversity increased from the open water sites to the canal and reed belt sites, while the values of dominance showed an opposite trend decreasing from open water to reed belt (Tab. 1.)

The mean annual density of the assemblages was significantly lower in 2002 (1.54 ind l<sup>-1</sup>), 2009 (2.70 ind l<sup>-1</sup>) and 2010 (3.57 ind l<sup>-1</sup>) than the other years (2004: 13.56, 2005: 13.02, 2006: 22.01 and 2012: 10.62 ind l<sup>-1</sup>). The extremely low water level of 2002 may explain the lowest recorded mean density. In the last years of the study, an interesting phenomenon were observed in the lake. Besides microcrustaceans, the abundance of fish assemblages also decreased and the colour of the lake water developed a reddish tinge, which is especially visible on the open lake on sunny days (pers. comm. of Dinka, M & Török, J.). This observed phenomenon supposedly refers to changes in the structure of the phytoplankton communities and in the bottom-up regulation, but further studies are needed to prove this relationship.

**Table 1.** Mean, minimum and maximum values of community parameters in the different water bodies of the Lake Fertő/Neusiedler See

	OPEN WATER (N=33)			INNER PONDS (N=41)			BOZI CANAL (N=22)			REED BELT (N=25)		
	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX	MEAN	MIN	MAX
<b>density (ind 50 l<sup>-1</sup>)</b>	376.9	33	2629	667.1	30	2739	768.3	33	6196	277.5	2	1633
<b>Species richness</b>	4.97	2	9	6.36	2	11	9.72	3	23	8.6	2	17
<b>Shannon diversity (H)</b>	0.92	0.31	1.88	1.07	0.3	1.79	1.37	0.31	2.51	1.34	0.31	2.15
<b>Dominance (D)</b>	0.49	0.17	0.77	0.46	0.19	0.95	0.37	0.12	0.86	0.38	0.14	0.85





**Figure 2.** Microcrustacean species richness, density, and Shannon diversity at different water bodies of the Lake Fertő/Neusiedler See between 2002 and 2012.

### Microcrustacean community structure in the different water bodies of the lake

#### Open water

30 taxa were recorded from the sampling sites of the open water (N=33). The mean density did not differ significantly between the four examined sampling sites. Similarly to the results of previous studies (Herzig 1979), the assemblages of the open water were characterized by the significant dominance of *Arctodiaptomus spinosus* and *Diaphanosoma*, and *Acanthocyclops vernalis* was also frequent in the Hungarian part of the lake (Ponyi & Dévai 1977, 1979). The presence and distribution of the *Diaphanosoma* genus in the lake is an interesting faunistic problem. Before 1990, *Diaphanosoma brachyurum* has been mentioned (Löffler 1979, Herzig 1979, Ponyi & Dévai 1977, 1979, Forró & Metz 1987), but Forró (1990) has already reported *Diaphanosoma mongolianum* as well. According to N. Korovchinsky (pers. comm., Forró 1990), only *D. mongolianum* is present in the lake.

Our results show that the abundance of *Diaphanosoma mongolianum* and *Arctodiaptomus spinosus* were the highest in the open water and these two species accounted for 57.4–99.5 per cent of the total microcrustacean standing stock, but notable differences could be found between the investigated years (Fig. 3). Interestingly, no specimens from the *Arctodiaptomus* genus occurred in the samples of 2009 and 2010. With the exception of *A. spinosus*, *D. mongolianum* and

*Acanthocyclops vernalis*, the abundance of the other species of the open water was low, and the disappearance or low density of the phytophilous species was obvious in this water body type. Interestingly, one specimen of the rare benthic copepod, *Paracyclops fimbriatus* and the phytophilous cladoceran, *Pleuroxus truncatus* were collected at sampling sites of the open water.

The communities of the open water are primarily affected by the extreme turbidity and wind effects, which are typical features of the Lake Fertő. Increasing turbulence and turbidity have a negative influence on the feeding and development of zooplankton in the lake (Herzig & Koste 1989) and among extreme wind situations, the animals are crushed by the sediment particles. The direct effects of wind on plankton distribution have been demonstrated by Herzig (1979). According to his results, the major plankton density gradients were recorded along the wind axis.

#### Inner ponds

29 taxa were reported from the five examined inner ponds (N=41). Taxon richness was similar at the different sites. The new species of the lake, *Alona affinis* was only found in the inner ponds (in 2009, sites 47). The most frequent species were *Bosmina longirostris* (37 per cent of the total abundance in inner ponds), *Thermocyclops crassus* (15%) and, similarly to the open water sites, *Diaphanosoma mongolianum* (17%) and *Arctodiaptomus spinosus* (11%). The species rich-

ness and density of ostracods (the most frequent of them was *Limnocythere inopinata*) were higher than at the open water sites.

The abundance of the species varied in the different inner ponds. The density and relative frequency of *Thermocyclops crassus* was significantly higher in sites 47 and 48, *Acanthocyclops vernalis* in site 48 and *Ceriodaphnia quadrangula* in site 42. Ponyi & Dévai (1977, 1979) also mentioned the significant dominance of *Bosmina longirostris* in the inner ponds, but according to our results, *Thermocyclops crassus* was also frequent.

The inner ponds proved to be various in their physical and chemical aspects (Dinka *et al.* 2004) and this could partly explain the variation in the dominant species. Compared to the open water area, electrical conductivity and salt concentration were lower, and there are great differences in the transparency of the sites.

### Canal

From the three sampling sites of the canal 38 taxa were detected (N=22). *Macrothrix hirsuticornis*, *Ectocyclops phaleratus*, *Eucyclops macrurus*, *E. macruroides* and *Microcyclops varicans* were only found at the sampling sites of the Bozi-canal. The abundance of *Daphnia pulex* was significantly higher in the canal than in the other water bodies. It should be noted, that all the three Hungarian representatives of the genus *Macrocyclus* were recorded from the canal. During the sampling period, the mean taxon richness, density and diversity as well as the maximum number of taxa (23 taxa, site B8, 05. 2005), the maximum density (123.9 ind l<sup>-1</sup>, site B8, 07. 2006) and maximum diversity (2.51, site B8, 05. 2005) were the highest in the canal. The number of collected species in the canal increased from open water to reed belt (21, 29, 32 taxa).

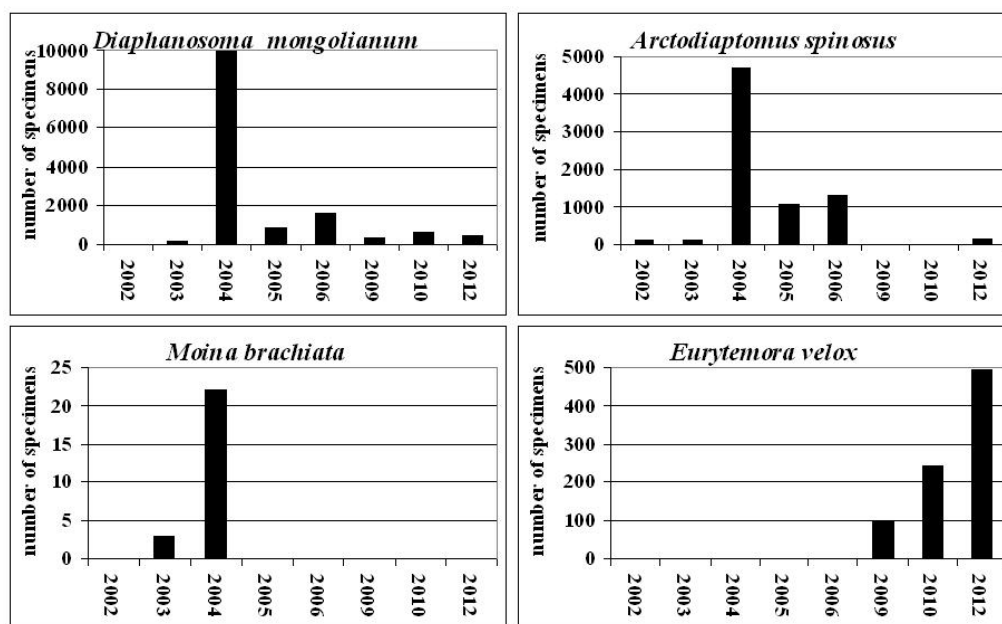
The composition of the communities was different in the three sampling sites of the canal. A few specimens of *Moina brachiata* and *Leydigia acanthocercoides* occurred only at the entrance of

the canal (site B1). *Moina brachiata* was collected only in 2003 and 2004 in very low density (Fig. 3.). At the inner sites of the canal (sites B8, B9), the species richness of the phytophilous taxa (especially cladocerans and ostracods) was higher than at the entrance of the canal. At the entrance of the canal (B1), the mean density and relative frequency of the pelagic *Diaphanosoma mongolianum* (mean: 11.08 ind l<sup>-1</sup>, 65.73%), *Acanthocyclops vernalis* (mean: 1.26 ind l<sup>-1</sup>, 7.48%) and *Arctodiaptomus spinosus* (mean: 1.54 ind l<sup>-1</sup>, 9.17%) were notably higher than at the other sites of the canal. Opposing to this, the mean density of *Simocephalus vetulus*, *Megacyclops viridis* and *Notodromas monacha* increased gradually from the open water to the shore. The mean density and relative frequency of *Ceriodaphnia laticaudata* (mean: 2.6 ind l<sup>-1</sup>, 11.96 %) and *Daphnia pulex* (mean: 13.05 ind l<sup>-1</sup>, 59.85 %) were the highest in the middle part of the canal (B8).

Dinka *et al.* (2004) reported similar trends in the aspect of the chemical parameters of the water along the Bozi-canal: for example, the electric conductivity and pH increased from shore to open water. In the canal, the presence of submerged macrophytes and the reduced effect of wind offer favourable life conditions for microrustaceans, but in the dense *Utricularia vulgaris* stands, the density of microcrustaceans, as they are prey animals for the carnivorous *Utricularia*, could notably decrease (Andrikovics *et al.* 1988).

### Reed belt

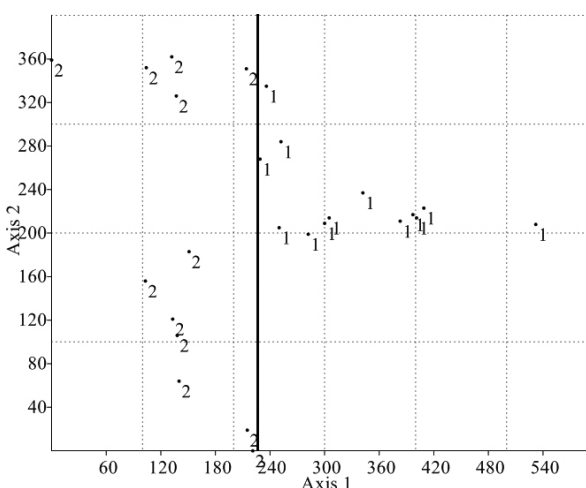
39 taxa were collected at the seven examined sites of the reed belt (N=25). *Macrothrix rosea*, *Scapholeberis mucronata* and the juvenile individuals of *Candona* sp. occurred only in the reed belt sites (Appendix 1). The density of the open lake species was low, these species only occasionally drift into the reed belt. The density and relative frequency of 10 taxa (especially *Ceriodaphnia quadrangula*, *C. reticulata*, *Scapholeberis rammneri*, and *Megacyclops viridis*) were the highest in the reed belt. The mean species richness and diversity were lower than those of the canal, but the ratio of phytophilous taxa (75%)



**Figure 3.** Number per year of collected specimens of *Moina brachiata*, *Diaphanosoma mongolianum* and *Arctodiaptomus spinosus*, the two most frequent species of the lake, and the newly found *Eurytemora velox*.

and ostracods were the highest. The mean density was 5.55 ind  $l^{-1}$ , the lowest among the examined habitats. Before our study, quantitative data about the microcrustacean communities of the reed belt in the Lake Fertő were scarce, but the quantitative studies of Forró (1990) from the Austrian side of the lake revealed significantly higher numbers. Kiss (2002b) also reported higher values from the reed belt of the Lake Fehér in Hanság (mean: 83.7 ind  $l^{-1}$ ).

There were no considerable differences in the species richness (30 and 29 taxa, mean: 8 and 9.15) and Shannon diversity (mean: 1.31 and 1.37) between the healthy (sites 2, 4, 5, 9) and degraded (sites 3, 6, 7) reed stands, but the mean density was higher in the degraded (7.31 ind  $l^{-1}$ ) than the healthy (3.64 ind  $l^{-1}$ ) reed stands. The composition of the assemblages was completely different in the healthy and in the degraded reed stands, only 20 out of the 39 taxa occurred at both types of the reed stands. Based on the DCA analysis, the microcrustacean composition of the healthy and degraded reed stands formed well-separated groups (Fig. 4).



**Figure 4.** Detrended Correspondence Analysis of the microcrustacean composition in the degraded (1) and the healthy (2) reed stands between 2002 and 2012.

Among cladocerans, *Leydigia acanthocercoides*, *Megafenestra aurita* and *Tretoccephala ambigua* were found in the healthy stands, whereas *Daphnia longispina*, *D. magna*, *Macrothrix rosea* and *Polyphemus pediculus* only in the degraded reed stands. *Daphnia magna* (a total of eight specimens) has not been found since the

study of Pesta (1954), but in the pools of Seewinkel this species is common (Löffler 1959, Metz & Forró 1991). The density of *Scapholeberis* was notably higher in the degraded reed than in the healthy reed stands. The most significant difference appeared in the Ostracoda fauna: in the healthy reeds 4 taxa (*Cyclocypris ovum*, *Cypridopsis vidua*, *Notodromas monacha*, *Pseudocandona pratensis*), whereas in the degraded reeds 3 taxa (*Candona* sp., *Limnocythere inopinata*, *Potamocypris unicaudata*) occurred. In case of the copepods, *Cyclops vicinus*, *Macrocyclus distinctus* and *Harpacticoida* sp. were reported only from the healthy, whereas *Arctodiaptomus bacillifer* and *Cyclops strenuus* only from the degraded reed stands. These results confirmed the study of Löffler (1979) about the distinct habitat preferences of the species in the reed belt. Kiss (2007b) reported similar significant differences in the composition of assemblages comparing the healthy and degraded macrophyton communities in Lake Fehér.

Löffler (1979) reported 56 taxa (19 Cladocera, 13 Ostracoda and 24 Copepoda) from the reed belt. Out of the 56 taxa 26 also occurred at our sampling sites. Similarly to his findings, the fauna of the reed belt was characterized by a great variety of composition of the communities, but in our study the genera *Diaphanosoma*, *Macrothrix* and *Limnocythere* were not absent from the reed belt. Ponyi & Dévai (1977, 1979) described the assemblages of the various reed communities. In the *Scirpeto-Phragmitetum utriculariosum* reed belt, which is typical in Lake Fertő, the dominance of *Chydorus sphaericus*, *Pleuroxus aduncus*, *Megacyclops viridis* and *Ceriodaphnia reticulata* was typical, whereas *Ceriodaphnia reticulata*, *Chydorus sphaericus*, *Megacyclops viridis* and *Daphnia curvirostris* were the most frequent species in *Scirpeto-Phragmitetum phragmitetosum*. In our study, the dominance of *Ceriodaphnia* spp., and *Scapholeberis rammneri* has been shown, the density of *Chydorus sphaericus*, *Pleuroxus aduncus* and *Megacyclops viridis* were insignificant, and *D. longispina* and *D. pulex* were collected instead of *Daphnia curvirostris*.

The typical feature of this habitat is the rich spatial structure, combined with rapidly changing environmental parameters. Food and physical-chemical parameters, especially the fluctuations of oxygen concentration are of great importance to the microcrustaceans. In the reed belt of the Lake Fertő anoxic conditions were often detected (Dinka *et al.*, 2004), which together with the accumulation of H<sub>2</sub>S have a significant negative influence on the assemblages. Opposing to this, reduced wind effects and water movements, and the presence of emerged and submerged macrophytes offer favourable life conditions to phytophilous and tychoplanktonic species.

### Long-term changes in the microcrustacean fauna of the Lake Fertő/Neusiedler See

Based on the 15 published faunistic studies of the Lake Fertő, 110 (48 Cladocera, 27 Ostracoda, 35 Copepoda) taxa were reported. This study added *Alona affinis* and *Eurytemora velox*. The results of these studies revealed changes in the fauna of the lake. Daday (1890, 1891, 1897, 1900) found 46 taxa, 16 of these taxa have not been mentioned from the lake later (eg. *Sida crystallina*, *Eurycercus lamellatus*, *Heterocypris salina*). Ponyi & Dévai (1977, 1979) collected 44 (22 Cladocera, 8 Ostracoda, 14 Copepoda) taxa from the Hungarian part of the lake and described the typical assemblages of the different water bodies. In our studies, 71 (30 Cladocera, 17 Ostracoda, 24 Copepoda) taxa were detected between 2002 and 2012 and from this, only 31 taxa were mentioned by Ponyi & Dévai (1977, 1979). Compared to other studies, the number of the collected species was relatively high, but the sampling area was more extensive, and the duration of the survey was longer than those of the other studies. Between 2002 and 2005, we also investigated the inhomogeneous reed patches, situated near the Fertőrákos Bay, after the introduction of pre-treated wastewater. 54 taxa were recorded and out of them 12 were new faunistic records to the fauna of the lake. In the further period of our long-term study between 2005 and 2012, among the new faunistic records, *Macrothrix rosea*, *Pleuroxus truncatus*, *Macrocyclus distinctus* and *Eucyclops macruroides*

have also been found in the other water bodies of the lake. *Macrothrix rosea* (Löffler 1959, Metz & Forró 1991) and *Eucyclops macruroides* (Löffler 1959) were collected in the nearby Seewinkel, but the cosmopolitan *Macrocyclus distinctus* and the holarctic *Pleuroxus truncatus* have not been detected from the area of the Fertő-Hanság yet. The density of the newly detected species was usually very low, indicating the lack of stable populations and the possibility of passive dispersion by waterbirds.

Similarly to the results of Ponyi & Dévai (1977, 1979), the composition of assemblages differed completely in the various habitats. Compared to the Cladocera and Copepoda fauna of the lake, the Ostracoda fauna is less known. Among the 17 detected Ostracoda species of our study, *Potamocypris unicaudata* was first mentioned from the Lake Fertő by Ponyi & Dévai (1977, 1979), and Löffler (1959) found this species in some pools of the Seewinkel. Instead of *Limnocythere sanctipatricii* (Daday, 1900) later *Limnocythere inopinata* was mentioned (Schiemer *et al.* 1969, Jungwirth 1979), which is an indicator of high alkalinity (Löffler 1990). In the Austrian part of the lake, *L. inopinata* showed a distinct distribution pattern (Jungwirth 1979), but in the course of our study, this species occurred only in 2012, and the collected 57 specimens were found in the inner ponds (sites 41, 42, and 47) and the reed belt (site 3). *L. sanctipatricii* seems to have been restricted to oligotrophic habitats (Meisch 2000), and along with the eutrophication processes apparently disappeared from the lake. *Pseudocandona pratensis* was first mentioned by Löffler (1979), just as *Candona pratensis*. Kiss (2007a) reported four Ostracoda species (*Candona weltneri*, *Fabaeformiscandona fragilis*, *F. holzkampfi*, *Pseudocandona compressa*) for the first time from the inhomogeneous reed patches, after the introduction of pre-treated wastewater. *Candona weltneri*, *Fabaeformiscandona fragilis* and *Pseudocandona compressa* are common ostracods in the reed belt of the neighbouring Lake Fehér in the Hanság region (Kiss 2007b), while *Fabaeformiscandona holzkampfi* was de-

scribed from Lake Balaton (Daday 1903) and Lake Velence (Györe 1985).

From the cladocerans, *Moina brachiata* was only found in two years (2003, 2004) of our study and of very low density: only 25 specimens were collected (Fig. 3). This species has been mentioned earlier by Daday (1890, 1891) and Forró & Metz (1987) and *M. brachiata* was very abundant until 1950 (Pesta 1954). Herzig (1979) and Löffler (1979) have not found *M. brachiata* in the Austrian part of the lake, but in the pools of the neighbouring Seewinkel this cladoceran is one of the most abundant crustaceans (Löffler 1959; Metz & Forró 1991). According to Herzig (1979) *M. brachiata* formerly inhabited the lake, but disappeared in the past forty years because of the increasing water level and decreasing salt concentration of the water. *Diaphanosoma* has taken over the niche previously occupied by *Moina*.

In our survey the most frequent *Daphnia* species was *D. pulex* which accounted for an average of 34 percent in the assemblages of the Bozi-canal. Pesta (1954) described this species as a typical member of the ponds in the reed belt, and it was very rare in the plankton of the open lake. Since 1975, *D. pulex* has been replacing *D. longispina* in the open lake community (Herzig 1979). According to our study supported by the results of Pesta (1954), *D. pulex* had a distinct distribution pattern and appeared only in the sampling sites of the reed belt. In the Bozi-canal and the open water this species did not occur. *D. longispina* appeared in all types of water bodies, but its density was very low everywhere.

Ponyi & Dévai (1977, 1979) revealed that since Daday the species richness of Copepoda showed an increasing tendency. Daday (1891) mentioned 10 species, while Pesta (1954) 15, Ponyi & Dévai (1977, 1979) 14, and Löffler (1979) 24 species. Forró & Metz (1987) reported 14 species and detected *Cyclops vicinus* for the first time. In our study, between 2002 and 2012, 24 taxa were recorded, however in these studies the number of sampling sites and the duration of the survey were different.

Herzig (1979) established a general decline in the *Cyclops* genus in the assemblages of the open lake. He recorded only 3 species (*Acanthocyclops robustus*, *Mesocyclops leuckarti*, *Thermocyclops crassus*) and the majority of the animals found were in the nauplius stage. The reasons for this phenomenon were supposedly the wind situation and the rapid decrease of the macrophytes in the Austrian part of the lake (Schiemer & Prosser 1976). In our investigation, 10 *Cyclops* species were recorded from the open lake and 9 from the inner ponds. Similarly to the results of Herzig (1979) the density of the species was insignificant, except for *Acanthocyclops vernalis*. The decline of macrophytes has not been confirmed in the Hungarian part of the lake, but the extreme wind effects could actually decrease the abundance of *Cyclops* species.

## CONCLUSION

Between 2002 and 2012, 53 taxa (24 Cladocera, 9 Ostracoda, 20 Copepoda) were recorded from different water bodies of the Lake Fertő. Thus, the microcrustacean fauna of the lake increased to 112 (49 Cladocera, 27 Ostracoda, 36 Copepoda) species together with *Alona affinis* and *Eurytemora velox*, detected for the first time in the lake. Since the study of Ponyi & Dévai (1977, 1979), there were no intensive, long-term studies in the Hungarian part of the lake investigating the composition and spatial differences of the three microcrustacean groups. In our studies, we confirmed some faunistic changes in the microcrustacean fauna of the lake, which were established in the 1970s, especially the significant reduction of *Moina* and *Cyclops* populations in the assemblages of the open lake.

Significant differences were revealed in the community parameters between the different water bodies of the lake. The mean density of the assemblages was significantly higher in the inner ponds and canal sites than in the open water and reed belt sites. The species richness and the diversity of the assemblages were the highest in the Bozi-canal. This specific fragmentation

caused by the canal system may be supporting high habitat diversity.

The microcrustacean fauna of the Lake Fertő has been investigated for approximately 120 years. On the basis of the results the fauna of the lake changes dynamically, some species disappear, old species reappear and new species occur. These changes support the concept of high instability and spatial variability of the lake habitats which are partly consequential to the extreme shallowness of the Lake Fertő.

**Acknowledgements** – The study was supported by the MTA OM-00371/2002 and NKFP-3B/0014/2002 projects. The authors would like to thank the anonymous reviewers for their valuable comments and suggestions improving the quality of the paper.

## REFERENCES

- ANDRIKOVICS, S., FORRÓ, L. & ZSUNICS, E. (1988): The zoogenic food composition of *Utricularia vulgaris* in the Lake Fertő. *Opuscula Zoologica Budapest*, 23: 65–70.
- DADAY, J. (1890): A magyarországi *Diaptomus*-fajok átnézete. (Conspectus Diaptomorum faunae Hungariae.) *Természetrajzi Füzetek*, 13: 114–180.
- DADAY, J. (1891): Adatok Magyarország édesvízi mikroszkópos faunájának ismeretéhez. *Természetrajzi Füzetek*, 14: 16–31.
- DADAY, J. (1897): A magyarországi tavak halainak természetes tápláléka. (A magyarországi tavak mikroszkópi állatvilága.) *Királyi Magyar Természet Tudományi Társulat*, Budapest, pp. 481.
- DADAY, J. (1900): A magyarországi kagylósrákok magánrajza. *Ostracoda Hungariae*. MTA, Budapest, pp. 320.
- DADAY, J. (1903): Mikroskopische Süßwassertiere der Umgebung des Balaton. *Zoologische Jahrbücher. Abteilung für Systematik, Ökologie und Geographie der Tiere*, 19: 37–98.
- DINKA, M., ÁGOSTON-SZABÓ, E., BERCZIK, Á. & KUTRUCZ, Gy. (2004): Influence of water level fluctuation on the spatial dynamic of the water chemistry at Lake Fertő/Neusiedler See. *Limnologia*, 34: 48–56.

- DUSSART, B. (1967): *Les Copépodes des eaux continentales. I. Calanoides et Harpacticoides*. N. Borbée & Cie, Paris, pp. 500.
- DUSSART, B. (1969): *Les Copépodes des eaux continentales. II. Cyclopoides et Biologie*. N. Borbée & Cie, Paris, pp. 292.
- FORRÓ, L. (1990): Littoral microfauna (Cladocera and Copepoda) in the reedbelt of Neusiedler See (Austria). *Biologisches Forschungsinstitut für Burgenland*, 74: 77–82.
- FORRÓ, L. (2002): *The Branchiopoda and Copepoda fauna of the Fertő-Hanság National Park*. In: MAHUNKA, S. (Ed.) *The fauna of the Fertő-Hanság National Park*. pp. 249–254. Hungarian Natural History Museum, Budapest, p. 249–254.
- FORRÓ, L. & GULYÁS, P. (1992): *Eurytemora velox* (Lilljeborg, 1853) (Copepoda, Calanoida) in the Szigetköz region of the Danube. *Miscellanea Zoologica Hungarica*, 7: 53–58.
- FORRÓ, L. & METZ, H. (1987): Observations on the zooplankton in the reedbelt area of the Neusiedlersee. *Hydrobiologia*, 145: 299–307.
- GULYÁS, P. & FORRÓ, L. (1999): Az ágascsapú rákok (Cladocera) kishatározója 2. (bővített) kiadás. *Vízi természet- és környezetvédelem*, 9: 1–237.
- GULYÁS, P. & FORRÓ, L. (2001): Az evezőlábú rákok (Calanoida és Cyclopoida) alrendjeinek kishatározója 2. Bővített kiadás. *Vízi természet- és környezetvédelem*, 14: 1–200.
- GYÖRE, K. (1985): Three ostracod species from Lake Velence new to the fauna of Hungary. *Miscellanea Zoologica Hungarica*, 3: 65–72.
- HAMMER, R., HARPER, D. A. T. & RYAN, P. D. (2001): PAST: Paleontological statistics software package for education and data analysis. *Paleontologia electronica*, 4(1): 1–9.
- HERZIG, A. (1979): *The zooplankton of the open lake*. In: LÖFFLER, H. (Ed.) *Neusiedlersee, the limnology of a shallow lake in Central Europe*. Dr Junk, The Hague, p. 281–335.
- HERZIG, A. & KOSTE, W. (1989): The development of *Hexathra* spp. in a shallow alkaline lake. *Hydrobiologia*, 186/187: 129–136.
- KISS, A. (2002a) *The Cladocera, Ostracoda and Copepoda fauna of the Fehér-tó (Fertő-Hanság National Park)*. In: MAHUNKA, S. (Ed.) *The fauna of the Fertő-Hanság National Park*, Hungarian Natural History Museum, Budapest, p. 245–247.
- KISS, A. (2002b): Distribution of microcrustacea in different habitats of a shallow lake in the Fertő-Hanság National Park, Hungary. *Opuscula Zoologica Budapest*, 34: 43–50.
- KISS, A. (2007a): Adatok a Fertő kistrák (Cladocera, Ostracoda, Copepoda) faunájához. *Hidrológiai Közlöny*, 87: 80–82.
- KISS, A. (2007b): Factors affecting spatial and temporal distribution of Ostracoda assemblages in different macrophyte habitats of a shallow lake (Lake Fehér, Hungary). *Hydrobiologia*, 585: 89–98.
- KISS, A. & SCHÖLL, K. (2009): Adatok a Duna gemenci árterének Rotatoria és Crustacea (Cladocera, Ostracoda, Copepoda) faunájához. *Hidrológiai Közlöny*, 89: 133–135.
- JUNGWIRTH, M. (1979): *Limnocythere inopinata* (Baird) (Cytheridae, Ostracoda): its distribution pattern and relation to the superficial sediments of Neusiedlersee. In: LÖFFLER, H. (Ed.) *Neusiedlersee, the limnology of a shallow lake in Central Europe*. Dr Junk, The Hague, p. 385–388.
- LÖFFLER, H. (1959): Zur Limnologie, Entomostraken- und Rotatorienfauna des Seewinkelgebietes (Burgenland, Österreich). *Sitzungsberichte der Österreichische Akademie der Wissenschaften*, 168: 315–362.
- LÖFFLER, H. (1979): *The crustacean fauna of the Phragmites belt (Neusiedlersee)*. In: LÖFFLER, H. (Ed.) *Neusiedlersee, the limnology of a shallow lake in Central Europe*. Dr Junk, The Hague, p. 281–335.
- LÖFFLER, H. (1990): Paleolimnology of Neusiedlersee, Austria. I. The succession of ostracods. *Hydrobiologia*, 214: 229–238.
- MEISCH, C. (2000): *Freshwater Ostracoda of Western and Central Europe*. In: SCHWOERBEL, P. ZWICK (Eds.) *Suesswasserfauna von Mitteleuropa* 8/3. Spektrum Akademischer Verlag, Heidelberg, Berlin, pp. 522.
- METZ, H. & FORRÓ, L. (1991): The chemistry and crustacean zooplankton of the Seewinkel pans: a review of recent conditions. *Hydrobiologia*, 210: 25–38.
- PESTA, O. (1954): Studien über die Entomostrakenfauna des Neusiedlersees. *Wissenschaftlichen Arbeiten aus dem Burgenland*, 2: 1–82.

- PONYI, J. & DÉVAI, I. (1977): A Fertő magyar területének rákjai (Crustacea). *Hidrológiai Közlöny*, 6–7: 262–269.
- PONYI, J. & DÉVAI, I. (1979): The Crustacea of the Hungarian area of Lake Fertő. *Opuscula Zoologica Budapest*, 16: 107–127.
- SCHIEMER, F., LÖFFLER, H. & DOLLFUSS, H. (1969): The benthic communities of Neusiedlersee (Austria). *Verhandlungen des Internationalen Vereins für Limnologie*, 17: 201–208.
- SCHIEMER, F. & PROSSER, M. (1976): Distribution and biomass of submerged macrophytes in Neusiedlersee. *Aquatic Botany*, 2: 289–307.
- SOMOGYI, B., FELFÖLDI, T., DINKA, M. & VÖRÖS, L. (2010): Periodic picophytoplankton predominance in a large, shallow alkaline lake (Lake Fertő, Neusiedlersee). *Annales de Limnologie*, 46: 9–19.
- ZAKOVSEK, G. (1961): Jahreszyklische Untersuchungen am Zooplankton des Neusiedlersees mit Berücksichtigung der meteorologischen und chemischen Verhältnisse. *Wissenschaftlichen Arbeiten aus dem Burgenland* 27: 1–85.



**Appendix 1.** Microcrustacean species frequencies in the different water bodies (O W – open water, I P – inner ponds, B C – Bozi canal, R B – reed-belt) and lists of species in the examined years. (WP = Wastewater Project: The species which only occurred in the inhomogeneous reed patch, after the introduction of pre-treated wastewater in 2004 (Kiss 2007a)).

	O W	I P	B C	R B	2002	2003	2004	2005	2006	2009	2010	2012
	N=33	N=41	N=22	N=25	N=9	N=4	N=36	N=10	N=14	N=14	N=14	N=20
<b>CLADOCERA</b>												
<i>Alona affinis</i> (Leydig, 1860)		<0.01								X		
<i>Alona costata</i> Sars, 1862			<0.01	<0.01						X		
<i>Alona intermedia</i> Sars, 1862							WP					
<i>Alona rectangula</i> Sars, 1862	<0.01	<0.01	<0.01	0.03	X		X	X	X		X	X
<i>Alonella excisa</i> Fischer, 1854							WP					
<i>Alona nana</i> Baird, 1843							WP					
<i>Bosmina longirostris</i> (O. F. M., 1785)	0.03	0.37	0.02	<0.01	X	X	X	X	X	X	X	X
<i>Bunops serricaudata</i> Daday, 1888							WP					
<i>Ceriodaphnia laticaudata</i> P. E. M., 1867	<0.01	<0.01	0.06	0.03					X	X	X	
<i>Ceriodaphnia quadrangula</i> (O. F. M., 1785)	0.01	0.08	0.04	0.13	X		X	X	X	X	X	X
<i>Ceriodaphnia reticulata</i> (Jurine, 1820)	<0.01	<0.01	0.04	0.14			X	X	X	X	X	X
<i>Chydorus sphaericus</i> (O. F. M., 1776)	<0.01	<0.01	0.02	0.05	X		X	X	X	X	X	X
<i>Daphnia curvirostris</i> Eylmann, 1878							WP					
<i>Daphnia pulex</i> Leydig, 1860			0.34	0.07	X		X	X	X	X		
<i>Daphnia longispina</i> O. F. M., 1785	<0.01	<0.01	0.01	<0.01			X	X		X	X	X
<i>Daphnia magna</i> Straus, 1820		<0.01		<0.01			X		X			
<i>Diaphanosoma mongolianum</i> Uéno, 1938	0.49	0.17	0.28	0.02	X	X	X	X	X	X	X	X
<i>Leydigia acanthocercoides</i> (Fischer, 1854)			<0.01	<0.01			X				X	
<i>Macrothrix hirsuticornis</i> N. & B. 1867			<0.01		X		X					
<i>Macrothrix rosea</i> (Liévin, 1848)				<0.01			X					
<i>Megafenestra aurita</i> (Fischer, 1849)			<0.01	<0.01			X		X	X	X	
<i>Moina brachiata</i> (Jurine, 1820)	<0.01	<0.01	<0.01			X	X					
<i>Oxyurella tenuicaudis</i> Sars, 1862							WP					
<i>Pleuroxus aduncus</i> (Jurine, 1820)	<0.01		<0.01	<0.01	X		X	X	X	X	X	X
<i>Pleuroxus truncatus</i> (O. F. M. 1785)	<0.01									X		
<i>Polyphemus pediculus</i> (Linné, 1761)		<0.01	<0.01	<0.01			X	X			X	X
<i>Scapholeberis mucronata</i> (O. F. M., 1785)				<0.01						X	X	
<i>Scapholeberis ramneri</i> D. & P., 1983		<0.01	<0.01	0.14	X	X	X	X	X		X	X
<i>Simocephalus exspinosus</i> (Koch, 1841)							WP					
<i>Simocephalus vetulus</i> (O. F. M., 1776)	<0.01	<0.01	0.02	0.02	X		X	X	X	X	X	X
<i>Tretocephala ambigua</i> (Lilljeborg, 1900)			<0.01	<0.01						X		

OSTRACODA												
<i>Candona neglecta</i> Sars, 1887							WP					
<i>Candona weltneri</i> Hartwig, 1899							WP					
<i>Candona</i> sp. juv.			<0.01			X	X	X				X
<i>Candonopsis kingslei</i> (B & R, 1870)							WP					
<i>Cypria ophtalmica</i> (Jurine, 1820)	<0.01		<0.01				X	X	X			
<i>Cypris pubera</i> O. F. M., 1776							WP					
<i>Cyprois marginata</i> (Straus, 1821)							WP					
<i>Cyclocypris laevis</i> (O. F. M., 1776)	<0.01		<0.01				X	X	X			
<i>Cyclocypris ovum</i> (Jurine, 1820)	<0.01	<0.01	<0.01	<0.01	X		X	X		X	X	
<i>Cypridopsis vidua</i> (O. F. M., 1776)				<0.01							X	
<i>Fabaeformiscandona fabaeformis</i> (Fischer, 1851)							WP					
<i>F. fragilis</i> (Hartwig, 1898)							WP					
<i>F. holzkapmfi</i> (Hartwig, 1900)							WP					
<i>Limnocythere inopinata</i> (Baird, 1843)		<0.01		<0.01					X			X
<i>Notodromas monacha</i> (O. F. M., 1776)			<0.01	<0.01			X	X	X	X	X	
<i>Potamocypris unicaudata</i> Schäfer, 1943		<0.01		<0.01					X			X
<i>Pseudocandona compressa</i> (Koch, 1838)							WP					
<i>Pseudocandona pratensis</i> (Hartwig, 1901)	<0.01			<0.01			X			X	X	
COPEPODA												
<i>Acanthocyclops vernalis</i> (Fischer, 1853)	0.09	0.05	0.03	0.01	X	X	X	X	X	X	X	X
<i>Arctodiaptomus bacillifer</i> (Koelbel, 1885)	<0.01	<0.01		<0.01			X					X
<i>Arctodiaptomus spinosus</i> (Daday, 1891)	0.32	0.11	0.06	0.09	X	X	X	X	X	X		X
<i>Cyclops strenuus</i> Fischer, 1851	<0.01	<0.01	<0.01	0.01	X		X	X				
<i>Cyclops vicinus</i> Uljanin, 1857	<0.01	<0.01	<0.01	<0.01			X	X			X	X
<i>Diacyclops bicuspidatus</i> (Claus, 1857)	<0.01	<0.01			X		X					
<i>Ectocyclops phaleratus</i> (Koch, 1838)			<0.01						X			
<i>Eucyclops macrurus</i> (Sars, 1863)			<0.01		X		X	X				
<i>Eucyclops macruroides</i> (Lilljeborg, 1901)			<0.01						X			
<i>Eucyclops serrulatus</i> (Fischer, 1851)	<0.01	<0.01	0.01	0.04	X		X	X	X	X	X	X
<i>Eurytemora velox</i> (Lilljeborg, 1853)	<0.01	0.02		0.04						X	X	X
<i>Macrocyclus albidus</i> (Jurine, 1820)		<0.01	<0.01				X	X				
<i>Macrocyclus distinctus</i> (Richard, 1887)	<0.01		<0.01	<0.01	X						X	
<i>Macrocyclus fuscus</i> (Jurine, 1820)		<0.01	<0.01				X	X				
<i>Megacyclus viridis</i> (Jurine, 1820)	<0.01		<0.01	0.07			X	X	X	X	X	
<i>Mesocyclops leuckarti</i> (Claus, 1857)	<0.01	<0.01	0.01	0.02	X		X		X	X	X	X
<i>Microcyclus varicans</i> (Sars, 1863)			<0.01						X	X		
<i>Paracyclus affinis</i> (Sars, 1863)							WP					
<i>Paracyclus fimbriatus</i> (Fischer, 1853)	<0.01									X		
<i>Thermocyclops crassus</i> (Fischer, 1853)	<0.01	0.15	<0.01	<0.01		X	X		X	X		X
<i>Thermocyclops dybowskii</i> (Lande, 1890)							WP					
<i>Harpacticoida</i> sp.	<0.01			<0.01							X	
<b>Number of taxa</b>	<b>30</b>	<b>29</b>	<b>38</b>	<b>39</b>	<b>19</b>	<b>8</b>	<b>37</b>	<b>31</b>	<b>23</b>	<b>27</b>	<b>27</b>	<b>22</b>

## New Mesostigmata records and species from the Korean Peninsula\*

J. KONTSCHÁN<sup>1</sup>, S. J. PARK<sup>2</sup>, J. W. LIM<sup>2</sup>, J. M. HWANG<sup>3</sup> and H. Y. SEO<sup>2</sup>

<sup>1</sup>Dr. Jenő Kontschán, Plant Protection Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, H-1525 Budapest, P.O. Box 102, Hungary and Department of Zoology and Animal Ecology, Szent István University, Gödöllő, Péter Károly str. 1, H-2100, Hungary.

E-mail: kontschan.jeno@agrar.mta.hu

<sup>2</sup>Dr. Sun Jae Park, Dr. Jae Won Lim and Dr. Hong Yul Seo, Animal Research Division, National Institute of Biological Resources, Gyeongseo-dong, Seo-gu, Incheon 404-708, Republic of Korea.

<sup>3</sup>Dr. Jeong Mi Hwang, Korean Entomological Institute, Korea University, Anam-dong, Seongbuk-gu, Seoul 136-701, Republic of Korea.

**Abstract.** A total of 20 Mesostigmata species are recorded from the Korean Peninsula, of which 15 (*Asca nubes* Ishikawa, 1969, *Lasioseius tomokoae* Ishikawa, 1969, *Evimirus uropodinus* (Berlese, 1903), *Macrocheles glaber* (Müller, 1860), *Macrocheles punctatus* Ishikawa, 1967, *Pachylaelaps ishizuchiensis* Ishikawa, 1977, *Gamasiphis pulchellus* (Berlese, 1887), *Ololaelaps ussurinensis* Bregetova & Koroleva, 1964, *Gamasellus humosus* Ishikawa, 1969, *Gamasholaspis variabilis* Petrova, 1967, *Parholaspulus hiasmaticus* Petrova, 1967, *Podocinum tsushimanum* Ishikawa, 1970, *Neoparasitus scleoides* Ishikawa, 1969, *Veigaia ochracea* Bregetova, 1961, *Uropoda similiamulifera* Hiramatsu, 1979) are presented as first occurrences from this peninsula. *Asca aphidioides* (Linnaeus, 1758) is already reported from the southern part of the peninsula, but we present the first occurrence in the Democratic People's Republic of Korea. One species (*Trachytes koreana* Kontschán & Lim, sp. nov.) is described and illustrated in this paper. Seventeen of the recovered species were collected in the Democratic People's Republic of Korea; the others were collected in the area of Republic of Korea.

**Keywords.** Acari, Mesostigmata, new species, new records, Korean Peninsula

### INTRODUCTION

The Soil Zoology Collection of the Hungarian Natural History Museum is rich in unsorted soil samples collected in both countries of the Korean Peninsula. More than 200 soil samples comprise this collection, but up to now only a few papers have been presented on their contents. Sándor Mahunka, the noted Hungarian mite researcher studied the collected soil samples and published four papers on mites from these materials. Mahunka (1971) presented new results on tarsonemid mites collected in the Democratic People's Republic of Korea, and two years later (1973) he described two new oribatid mites from the same location. Subsequently, Mahunka (1980) described a new tarsonemid species from the North Korean soil samples and afterwards described numerous new ptychoid oribatid species from the same material (Mahunka 1982). The Polish zerconid specialist, Czesław Błaszak, elab-

orated the zerconid fauna from the Korean collection of the Hungarian Natural History Museum and published two papers based on his results (Błaszak 1976a, 1976b). More than 30 years later, Jenő Kontschán started his work on the mites of these previously collected materials, and he and his co-authors summarized their results in two consecutive papers (Kontschán *et al.* 2012, 2013).

The present work contains new results on Korean Mesostigmata mites selected from the above mentioned unsorted soil samples of the Hungarian Natural History Museum.

### MATERIAL AND METHODS

Newly sorted specimens were taken from the Soil Zoology collection of the Hungarian Natural History Museum (Budapest, Hungary) (HNHM). They were cleared in lactic acid and observed in

deep, half covered slides under a microscope, or prepared on slides with Kaiser Fluid or lactic acid and gelatin mixture. Other specimens were stored in alcohol. Illustrations were made with a drawing tube. Measurements are given in micrometers ( $\mu\text{m}$ ), and the width of the idiosoma was measured at the level of coxae IV.

The specimens examined are deposited in the Soil Zoology Collection of Hungarian Natural History Museum (Budapest, Hungary) (HNHM) and in the National Institute of Biological Resources, Incheon, Republic of Korea (NIBR).

## RESULTS

### Order Mesostigmata

#### Family Ascidae

##### *Asca aphidioides* (Linnaeus, 1758)

*Material examined.* One female (NIBR). As4215, One female (NIBR). Democratic People's Republic of Korea, Gangwon-do, Geumgangsán, Guriong Pokpo, riverside, northern slope, mosses from soil surface and cliff-side, 01.VI.1970, leg. Mahunka, S. & Steinmann, H.

*Distribution.* Palearctis.

*Remarks.* This species has already been recorded from the Republic of Korea, but new for Democratic People's Republic of Korea (Lee 1994).

##### *Asca nubes* Ishikawa, 1969

*Material examined.* One female (NIBR). As4215, One female (NIBR). Democratic People's Republic of Korea, Gangwon-do, Geumgangsán, Guriong Pokpo, riverside northern slope, mosses from soil surface and cliff-side, 01.VI.1970, leg. Mahunka, S. & Steinmann, H.

*Distribution.* Japan and Korean Peninsula.

*Remark.* This is the first record of *Asca nubes* from the Korean Peninsula.

##### *Lasioseius tomokoae* Ishikawa, 1969

*Material examined.* One female (NIBR). As454, Democratic People's Republic of Korea, North Pyeonganbuk-do, Mt. Myohyang-san sifted litter taken under Ryongyon waterfall to be extracted in Moczarsky-Winkler apparatus, 15.VII.1982, leg. Forró, L. & Ronkay, L.

*Distribution.* Japan and Korean Peninsula.

*Remark.* This is the first record of *L. tomokoae* from the Korean Peninsula.

#### Eviphididae

##### *Evimirus uropodinus* (Berlese, 1903)

*Material examined.* One female (NIBR). As229, Democratic People's Republic of Korea, North Hwanghaebuk-do, Bagyon san, San-chon tong, about 10 km from Gyeseong, sweet chestnut woods, sod of grass (turf) beyond margin of woods, 08.VI.1970, Mahunka, S. & Steinmann, H. (NIBR).

*Distribution.* Europe, Japan and Korean Peninsula. This species may have a Palearctic distribution.

*Remark.* This is the first record of this species from the Korean Peninsula.

#### Macrochelidae

##### *Macrocheles punctatus* Ishikawa, 1967

*Material examined.* Two females (NIBR). As462 Democratic People's Republic of Korea, North Pyeonganbuk-do, Mt. Myohyang-san soil sample from mixed forest under Hwajangam extracted in Berlese-funnel, 19.VII.1980, leg. Forró, L. & Ronkay, L.

*Distribution.* Japan and Korean Peninsula.

*Remark.* This is the first record of this species from the Korean Peninsula.

***Macrocheles glaber* (Müller, 1860)**

*Material examined.* One female (NIBR). As443, Democratic People's Republic of Korea, Gangwon-do, Mt. Kumgang-san, near Hotel Geumgang, five soil traps in them, in coniferous forest with rich undergrowth, 29.IX.1979, leg. Steinmann, H. & Vászrhelyi, T.

*Distribution.* Europe, Asia, North-America, and Australia. This species occurs presumably in temperate climatic zones.

*Remark.* This is the first record of this species from the Korean Peninsula.

**Pachylaelapidae**

***Pachylaelaps ishizuchiensis* Ishikawa, 1977**

*Material examined.* One female (NIBR). As571, Democratic People's Republic of Korea, Yanggang-do, NW of Samjiyeon, 31 km on Baekdusen road, *Larix vologensis*-forest (not mixed with *Betula pendula*) with rather poor underwood, not far from the tree borderline, sifting decayed trunks of *Larix olgensis*, 28. VI.1988, leg. Merkl, O. & Szél, Gy.

*Distribution.* Japan and Korean Peninsula.

*Remark.* This is the first record of this species from the Korean Peninsula.

**Ologamasidae**

***Gamasellus humosus* Ishikawa, 1969**

*Material examined.* One female (NIBR). As214, Democratic People's Republic of Korea, Gangwon-do, Geumgangsán, Guriong Pokpo, cliffs near waterfall basin, moss wetted by seeping water in the same site, 01.VI.1970, leg. Mahunka, S. & Steinmann, H.

*Distribution.* Japan and Korean Peninsula.

*Remark.* This species is the first recorded from the Korean Peninsula.

***Gamasiphis pulchellus* (Berlese, 1887)**

*Material examined.* Three females and one male (NIBR). As197, Democratic People's Republic of Korea, South Pyeongannam-do, Pyongyang, steep lakeside cliff, 27.V.1970, leg. Mahunka, S. & Steinmann, H.

*Distribution.* Europe and Asia.

*Remark.* This species is the first recorded from the Korean Peninsula.

**Laelapidae**

***Ololaelaps ussuriensis* Bregetova & Koroleva, 1964**

*Material examined.* One female (NIBR). As197, Democratic People's Republic of Korea, South Pyeongannam-do, Pyongyang, steep lakeside cliff, 27.V.1970, leg. Mahunka, S. & Steinmann, H.

*Distribution.* Russia and Korean Peninsula.

*Remark.* This species is the first recorded from the Korean Peninsula.

**Parholaspididae**

***Gamasholaspis communis* Petrova, 1967**

*Material examined.* One female (NIBR). As964, Republic of Korea, Gangwon-do, Inje-gun, Seoraksan, Misiryeongogae, beneath the rest area, forest brook, deciduous rocky forest, open grassland and rocks, from leaf litter, 745m, N38°12.963' E128°26.189', 10.X.2010, leg. Murányi, D.

*Distribution.* Russia and Korean Peninsula.

*Remark.* This species was recorded from the Korean Peninsula by Lee & Lee (2000).

***Gamasholaspis variabilis* Petrova, 1967**

*Material examined.* One female (NIBR). As454, Democratic People's Republic of Korea,

North Pyonganbuk-do, Myohyangsan, sifted litter taken under Ryongyon waterfall to be extracted in Moczarsky-Winkler apparatus, 15.VII.1982, leg. Forró, L. & Ronkay, L. (NIBR).

*Distribution.* Russia and Korean Peninsula.

*Remark.* This is the first record of this species from the Korean Peninsula.

***Parholaspulus hiasmaticus* Petrova, 1967**

*Material examined.* One female (NIBR). As558, Democratic People's Republic of Korea, North Pyonganbuk-do, Myohyangsan, pathway Sangwon-am, sifted material from the litter of a rocky forest, to be extracted by Moczarsky-Winkler-funnel, 09.X.1987, leg. Korsós, Z. & Ronkay, L.

*Distribution.* East-Russia and Korean Peninsula.

*Remark.* This is the first record of this species from the Korean Peninsula.

***Holaspina alstoni* (Evans, 1956)**

*Material examined.* One female (NIBR). As956, Republic of Korea, Gyeongsangnam-do, Sancheong-gun, Jirisan, Ogeok valley, 3km NW of Daewon temple, N branch of Yup-yeong, mixed forest, forest stream, open spring and its outlet, forest edge, 675m, N35°22.926' E127°47.112', 16.09.2010, leg. Hye Woo Byeon, László Forró, Tae Woo Kim, Makranczy, Gy. & Murányi D.

*Distribution.* Palearctis.

*Remark.* This species was recorded from the Korean Peninsula by Lee & Lee (2000).

***Gamasholaspis browningi* (Bregetova & Koroleva, 1960)**

*Material examined.* One female (NIBR). As665, Democratic People's Republic of Korea, Cheju-do, Halla-san National Park, moss and soil

samples (four different items) were taken from mosses, detritus, litter and upper layers of soil, 30.X.1993, leg. Peregovits, L. & Ronkay, L.

*Distribution.* Russia and Korean Peninsula.

*Remark.* This species was recorded from the Korean Peninsula by Lee & Lee (2000).

**Podocinidae**

***Podocinum tsushmanum* Ishikawa, 1970**

*Material examined.* Four females (two in HNHM, two in NIBR) As452, Democratic People's Republic of Korea, North Pyonganbuk-do, Myohyangsan, sifted litter taken from a mixed forest under Unsam waterfall to be extracted in Moczarsky-Winkler apparatus, 17.VII.1982, leg. Forró, L. & Ronkay, L.

*Distribution.* Japan and Korean Peninsula.

*Remark.* This is the first record of this species from the Korean Peninsula.

***Neoparasitus scleoides* Ishikawa, 1969**

*Material examined.* One female (NIBR). As450, Democratic People's Republic of Korea, Pyeongyang-si: Yongaksan, soil sample taken from a mixed forest to be extracted in Berlese-funnel, 12.VII.1982, leg. Forró, L. & Ronkay, L.

*Distribution.* Japan and Korean Peninsula.

*Remark.* This is the first record of this species from the Korean Peninsula.

**Veigaiidae**

***Veigaia ochracea* Bregetova, 1961**

*Material examined.* Two females (NIBR). As446, Democratic People's Republic of Korea, Pyeongyang-si: Daesongsan, 10 km NW of Pyongyang, soil sample taken from Pinus forest near Ingo-mot pond to be extracted in Berlese-

funnel, 08.VII.1982, leg. Forró, L. & Ronkay, L. Two females (NIBR). As454, Democratic People's Republic of Korea, North Pyeonganbuk-do, Myohyangsan sifted litter taken under Ryongyon waterfall to be extracted in Moczarsky-Winkler apparatus, 15.VII.1982, leg. Forró, L. & Ronkay, L. Four females (two in NIBR, two in HNHM). As455, Democratic People's Republic of Korea, North Pyeonganbuk-do, Myohyangsan sifted material collected in the mixed forest behind Hotel Myohyang-san to be extracted in Moczarsky-Winkler apparatus, 17.VII.1982, leg. Forró, L. & Ronkay, L.

*Distribution.* East-Russia and Korean Peninsula.

*Remark.* This is the first record of this species from the Korean Peninsula.

### Uropodidae

#### *Uropoda similiamulifera* Hiramatsu, 1979

*Material examined.* Two females (NIBR). As224 Democratic People's Republic of Korea, Hwanghaebuk-do, Bagyeonsan, San-chon tong, about 20 km SE from Gyeseong, margin of stream bed, ant nest under stone, 08.VI.1970, leg. Mahunka, S. & Steinmann, H.

*Distribution.* Japan and Korean Peninsula.

*Remark.* This is the first record of this species from the Korean Peninsula.

### Trachytidae

#### *Trachytes koreana* Kontschán & Lim sp. nov.

(Figures 1–7)

*Material examined.* *Holotype.* female (NIBR). As212, Democratic People's Republic of Korea, Gangwon-do, Geumgangsán, Man-mul san, from ant nest, 30.V.1970, leg. Mahunka, S. & Steinmann, H. *Paratypes.* Females, 4 ex. in NIBR and 3 ex. in HNHM, locality and date same as in holotype.

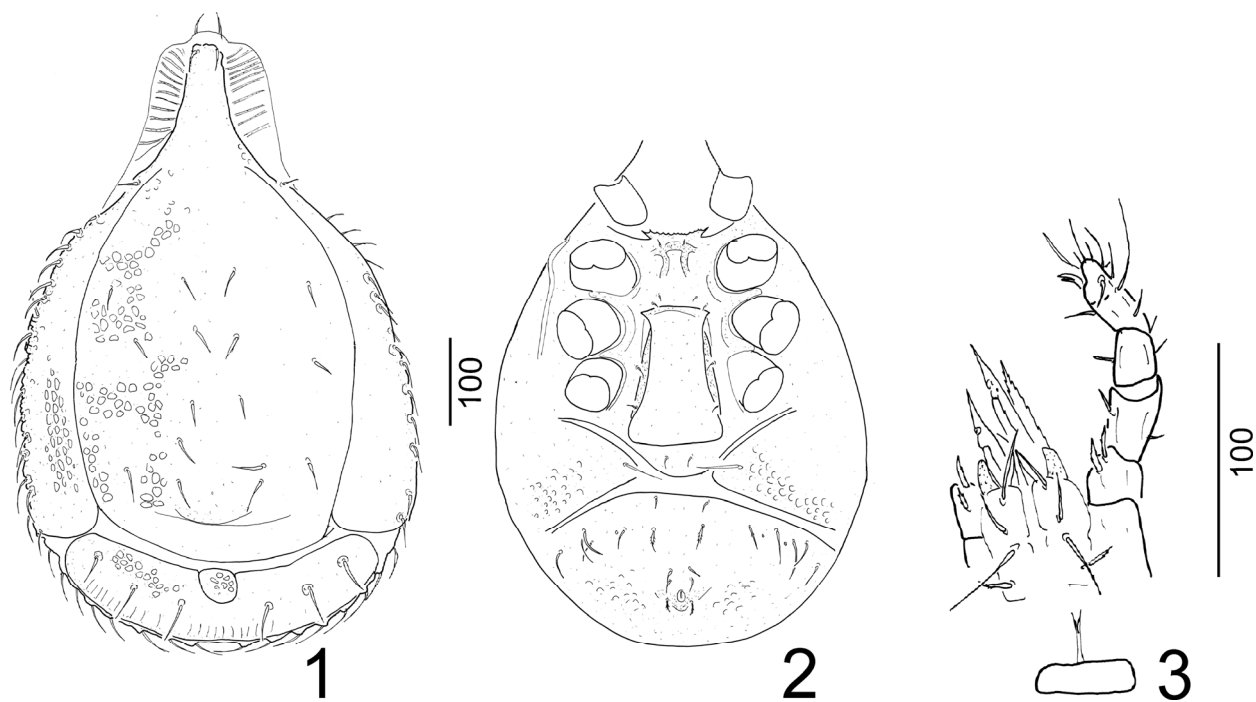
*Description.* Female. Length of idiosoma 650–660  $\mu\text{m}$ , width 400–410  $\mu\text{m}$  ( $n=8$ ). Shape of idiosoma pear-like.

*Dorsal idiosoma* (Fig. 1). Wide and ribbed lateral sections on vertex present. Marginal and dorsal shields fused anteriorly. Pygidial shield small and rounded, placed between the posterior margin of dorsal shield and the anterior margin of postdorsal shield. All setae on dorsal and postdorsal shields smooth, needle-like and *ca.* 25–35  $\mu\text{m}$  long, setae on central area of dorsal shield placed on small, strongly sclerotized platelets. Setae on marginal shield needle-like and *ca.* 30–33  $\mu\text{m}$  long. Surface of dorsum covered by deep, irregular pits.

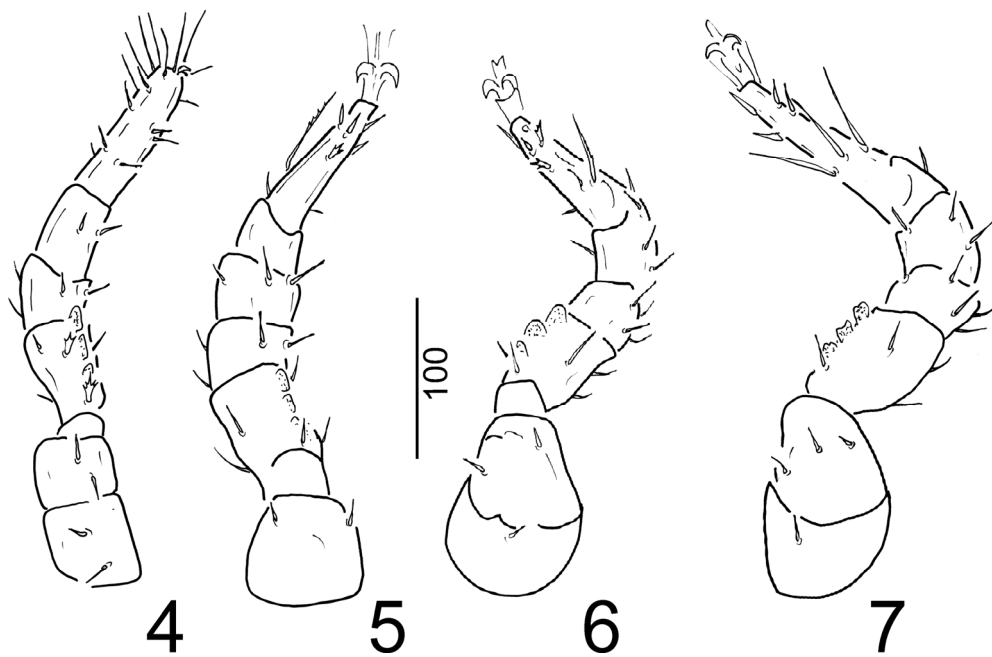
*Ventral idiosoma* (Fig. 2). First three pairs of sternal setae (St1–St3) short (*ca.* 7–8  $\mu\text{m}$ ), other three pairs longer (*ca.* 13–15  $\mu\text{m}$ ), all sternal setae smooth and needle-like. St1 situated near the anterior margin of sternal shield, St2 and St3 near anterior margin of genital shield. St4 placed at level of anterior margin of coxae IV, St5 on basal part of adgenital platelets, St6 placed near basal margin of genital shield. Surface of sternal shield smooth, but a II-shaped strongly sclerotized line situated near anterior margin of sternal shield. Sternal, ventral, and inguinal shields not fused. Inguinal shield with one pair long (*ca.* 49–51  $\mu\text{m}$ ) and needle-like setae and covered by oval pits. Surface of ventral shield ornamented by oval pits. Eight pairs of setae situated on ventral shield, two of them marginally pilose, others with smooth margins. First pairs of these setae short (*ca.* 12–13  $\mu\text{m}$ ), other setae on ventral shield long (*ca.* 27–45  $\mu\text{m}$ ) Membranous cuticle without setae. First pair of adanal setae smooth, and needle-like, second pair marginally pilose, short (*ca.* 20–22  $\mu\text{m}$ ) and situated near anal opening.

*Genital shield* ax-like anterolateral angles of genital shield pointed, points directed laterally. Surface of genital shield smooth. Genital shield situated between coxae III and IV. Peritremes long and straight, stigmata situated between coxae II and III. Tritosternum (Fig. 3) with wide base, tritosternal laciniae divided into two branches.

*Gnathosoma* (Fig. 3). Corniculi horn-like, internal malae longer than corniculi and smooth. Hypostomal setae h1 long (*ca.* 35  $\mu\text{m}$ ) and



**Figures 1–3.** *Trachytes koreana* sp. nov., female. 1 = dorsal view of body, 2 = ventral view of body, 3 = tritosternum, ventral view of gnathosoma and palp.



**Figures 4–7.** *Trachytes koreana* sp. nov., female. 4 = leg I, 5 = leg II, 6 = leg III, 7 = leg IV.



smooth, h2 short (ca. 18 µm) and smooth, h3 similar to h1 in shape, ca. 75 µm long, h4 marginally serrate and ca. 15 µm long. Chelicerae with long and sharpened apical process on fixed digit, movable digit shorter than fixed digit. Epistome marginally serrate. Palps with two serrate ventral setae, other setae on palp smooth.

**Legs.** Leg I with small ambulacral claws (Fig. 4), than on other legs (Figs 4–7), all legs bearing smooth and needle-like and robust and serrate setae.

Male, nymphs and larvae unknown.

**Etymology.** The new species is named after the peninsula (Korean Peninsula) where it was collected.

**Remarks.** The new species is similar to *Trachytes aegrota* (C. L. Koch, 1841) on the basis of the presence of the wide and ribbed lateral sections of vertex. However, the new species do not have setae on the membranous cuticle between the ventrianal and sternal shields as in *T. aegrota*. The new species has a Π-shaped strongly sclerotized line on the anterior part of the sternal shield, which character is missing in *T. aegrota*.

## ZOOGEOGRAPHICAL NOTES

Our new contribution contains new records of 20 Mesostigmata species from the Korean Peninsula, 17 of which are recorded from the Democratic People's Republic of Korea and 3 from the Republic of Korea. One species can be endemic, the herein described *Trachytes koreana* sp. nov., which was collected in the Democratic People's Republic of Korea. Eight species (*U. similihumulifera*, *N. scleoides*, *P. tsushmanum*, *G. humosus*, *P. ishizuchiensis*, *M. punctatus*, *L. tomokoae* and *A. nubes*) from the found 20 occur in Japan as well. The species *V. ochracea*, *O. ussuriensis*, *G. browni*, *P. hiasmaticus*, *G. variabilis* and *G. communis* are described from Russia, but these species are distributed mostly in eastern Asia. The other species have wider distributions and can be found on other continents (e.g. Europe) as well. According to these new records, the Mesostig-

mata fauna of the Korean Peninsula shows a mixed character with Japanese, east Asian, and Palearctic elements found in it.

**Acknowledgements** – This work was supported by a grant from the National Institute of Biological Resources (NIBR), funded by the Ministry of Environment (MOE) of the Republic of Korea (NIBR No. 2013-02-054). We are grateful to our colleagues, who collected the mite samples.

## REFERENCES

- BLASZAK, C. (1976a): *Xenozercon glaber* gen. nov., sp. nov. (Acari, Zerconidae) from Democratic People's Republic of Korea. *Bulletin of the Polish Academy of Sciences*, 24(1): 33–36.
- BLASZAK, C. (1976b): Systematic studies on family Zerconidae II. Democratic People's Republic of Korea. Zerconidae (Acari, Mesostigmata). *Acta Zoologica Cracoviensia*, 21(16): 527–552.
- KONTSCHÁN, J., PARK, S. J., YOON, T. J. & CHOI, W. Y. (2012): New Uropodina records and species from the Korean Peninsula (Acari: Mesostigmata). *Opuscula Zoologica Budapest*, 43(2): 169–177.
- KONTSCHÁN, J., PARK, S. J., YOON, T. J. & CHOI, W. Y. (2013): *Uropodina mites from Korean Peninsula* (Acari: Mesostigmata). AdLibrum Kiadó, Budapest, 70 p.
- LEE, S.-Y. (1994): *A taxonomic studies on genus Asca* (Ascidae: Mesostigmata) in Korea. Master's Thesis, 71 p.
- LEE, W.-K., & LEE, S. Y. (2000): Taxonomic Study of Parholaspid Mites (Acari: Mesostigmata) in Korea. *The Korean Journal of Systematic Zoology*, 16(1): 105–112.
- MAHUNKA, S. (1971): Tarsonemina (Acari) species from Korea. Zoological Collectings of the Hungarian Natural History Museum in Korea (Nr.3.). *Acta Zoologica Academiae Scientiarum Hungaricae*, 17(3–4): 271–294.
- MAHUNKA, S. (1973): Zwei neue Lohmanniiden-Arten aus Korea (Acari, Oribatida). *Folia Entomologica Hungarica*, 26(1): 49–56.
- MAHUNKA, S. (1980): *Paraptygmephorus delyorum* sp. n., eine neue Art aus Korea (Acari: Tarsonemina). *Parasitologica Hungarica*, 13: 95–98.
- MAHUNKA, S. (1982): Ptychoide Oribatiden aus der Koreanischen Volksdemokratischen Republik (Acari). *Acta Zoologica Academiae Scientiarum Hungaricae*, 28 (1–2): 83–103.



## Phytoseiid mites (Acari, Mesostigmata) from the rest areas of Hungarian highways

J. KONTSCHÁN<sup>1</sup>, A. KARAP<sup>2</sup> and B. KISS<sup>2</sup>

<sup>1</sup>Dr. Jenő Kontschán, Plant Protection Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, H-1525 Budapest, P.O. Box 102, Hungary and Department of Zoology and Animal Ecology, Szent István University, Gödöllő, Páter Károly str. 1, H-2100, Hungary  
E-mail: kontschan.jeno@agrar.mta.hu

<sup>2</sup>Anita Karap & Dr. Balázs Kiss, Plant Protection Institute, Centre for Agricultural Research, Hungarian Academy of Sciences, H-1525 Budapest, P.O. Box 102, Hungary

**Abstract.** The mesostigmatid mite family Phytoseiidae was surveyed in rest areas of Hungarian highways by examination of leaves collected from arboreal plants. All together 15 species, ca. 20 % of the Hungarian Phytoseiid fauna were recorded. Seven species were collected from the ring highway around Budapest (M0), ten species were found alongside the north-western highway (M1), six-six species were recorded from the north-eastern and south-eastern highways (M3 and M5), and five species from the area of south-western highway (M7), finally two species were found on the newly built southern highway (M6). *Euseius finlandicus* (Oudemans, 1915) was present in most of the sampling sites, while other common species were *Phytoseius macropilis* (Banks, 1909); *Kampimodromus aberrans* (Oudemans, 1930); *Neoseiulella aceri* (Collyer, 1957) and *Typhlodromus* (*Typhlodromus*) *tiliae* Oudemans, 1929. *Typhloseiulus peculiaris* (Kolodochka, 1980) was shown at the first time from Hungary in the framework of our study, thus a short description and new illustrations are given to this species.

**Keywords.** Acari, Phytoseiidae, highways, first record, Hungary.

### INTRODUCTION

The fast moving species of the family Phytoseiidae are well known as natural enemies of mite and insect pests from the agricultural and natural areas (McMurtry & Croft 1997, Tsolakis *et al.* 2012). Due to their economical importance, they are among the most intensively studied groups of the mites; more than 2280 species being discovered and described so far (Chant & McMurtry 2007, Tixier *et al.* 2012).

Highway margins are specific habitats, which can be situated in agricultural zones or in forested areas, in plains or in mountainous areas as well. Therefore, the fauna of the planted rest stations may reflect natural, agricultural or urban influences, while they can be colonized by mountainous or lowland elements as well. Due to the intensive transport activity, highways have important role in the dispersion of numerous animal

groups. Therefore, the fauna of rest stations of highways consists of several invasive species as well, which mainly arrived from the neighbouring countries.

Investigations on the role of the Hungarian highway margins in altering the autochthonous fauna and migration of the animals, as well as in conservation of biodiversity in certain animal taxa were started in 2001 (Kozár 2009, Kozár *et al.* 2012). The present work is a part of a multitaxa survey of Hungarian highway margins.

### MATERIAL AND METHODS

Leaves of arboreal plants were collected in 2012 and 2013, two times in a year in 28 rest areas along six Hungarian highways (Fig. 1). The collected leaves were stored in plastic bags for 1–3 days before microscopic examination. Mites were removed with a small brush from the leaves under stereomicroscope and they were examined

on slides in a gelatine-lactic acid mixture. Specimens were then mounted on slide in Hoyer medium and deposited in the Soil Zoology collection of the Hungarian Natural History Museum. For the identification, Karg's (1993) book was used accompanied with several other important papers (e.g. Cargnus *et al.* 2012, Faraji

*et al.* 2007); the distributions and systematic status are given after Moraes *et al.* (2004) catalogue. Setal nomenclature used follows that of Lindquist & Evans (1965), as adapted by Rowell *et al.* (1978). We use the following sequence in designating the origin of the samples: highway code (M0–M7), name of rest station, host plant.



Figure 1. Phytoseiid collection sites along the Hungarian highways.

## RESULTS

### Family Phytoseiidae Berlese, 1916

#### Subfamily Amblyseinae Muma, 1961

#### *Amblyseius andersoni* (Chant, 1957)

*Material examined.* M0, Dunakeszi, maple

*Remark.* Holarctic species (Moraes *et al.* 2004).

#### *Euseius finlandicus* (Oudemans, 1915)

*Material examined.* M0, Annahegy, unknown plant; M0, Csepel, ash; M0, Csepel, hackberry; M0, Dunakeszi, maple; M0, 0km, SOS, oak; M0, 0km, SOS, maple; M1, Arrabona, linden; M1, Bábólna, hornbeam; M1, Bábólna, cornel; M1 Zsámbék, linden; M3, Kisbág, hornbeam; M3, Nyíregyháza, oak; M3, Polgár, maple; M3, Polgár, mulberry; M3, Rekettyés, linden; M3, M3, Rekettyés, oak; Rekettyés, unknown plant; M3, Szilas, ash; M5, Kecskemét, linden; M5, Kecskemét, birch;

M5, Kecskemét, elm; M5, Örkény, unknown plant; M5, Örkény, hornbeam; M5, Petőfiszállás, bird cherry; M6, Fácános, hornbeam; M7, Budaörs, bird cherry; M7, Szegerdő, hornbeam; M7, Törek, maple; M7, Velence, mulberry; M7, Velence, linden.

*Remarks.* This is a very common species. *E. finlandicus* possesses a Holarctic distribution, but it can be found in Nicaragua, Mexico and Indonesia as well (Moraes *et al.* 2004).

***Kampimodromus aberrans* (Oudemans, 1930)**

*Material examined.* M0, 0km, SOS, maple; M0, Annahegy, maple; M1, Zsámbék, apple; M3, Kisbag, linden; M5, Lajosmizse, linden; M5, Röske, linden; M7, Táská, maple.

*Remarks.* This is a common species in Europe but it has sporadic reports from North-Africa and North-America as well (Moraes *et al.* 2004).

***Kampimodromus corylosus* Kolodochka, 2003**

*Material examined.* M0, SOS, 0km, hazelnut; M5, Kecskemét, hazelnut; M5, Örkény, hazelnut; M7, Sormás, hazelnut.

*Remarks.* Quite rare species perhaps with Mediterranean distributional pattern (Cargnus *et al.* 2012). It was reported first time from Hungary just recently (Ripka & Szabó 2010).

**Subfamily Phytoseiinae Berlese, 1916**

***Phytoseius juvenis* Wainstein & Arutunjan, 1970**

*Material examined.* M1, Arrabona, willow.

*Remarks.* This species occurs from France to Armenia and Kazakhstan (Moraes *et al.* 2004).

***Phytoseius macropilis* (Banks, 1909)**

*Material examined.* M1, Moson, ash; M1, Zsámbék, maple; M3, Gelej, hazelnut; M3, Kisbag, hornbeam; M3, Reketyés, linden; M5, Röske, linden.

*Remarks.* Cosmopolitan species, it is common and widely distributed all over in Europe (Moraes *et al.* 2004).

**Subfamily Typhlodrominae**

***Neoseiulella aceri* (Collyer, 1957)**

*Material examined.* M0, Alacska, linden; M0, Annahegy, unknown plant; M1, Arrabona, linden; M1, Arrabona, maple; M3, Kisbag, maple; M3, Reketyés, dewberry.

*Remark.* This species is listed from Europe and North-America (Moraes *et al.* 2004).

***Neoseiulella formosa* (Wainstein, 1958)**

*Material examined.* M1, Bábolna, hazelnut; M3, Kisbag, linden.

*Remarks.* *N. formosa* is distributed mainly in Eastern Europe (Armenia, Georgia, Moldova, Ukraine and Hungary (Moraes *et al.* 2004).

***Paraseiulus triporus* (Chant & Yoshida-Shaul, 1982)**

*Material examined.* M0, Annahegy, unknown plant.

*Remarks.* *P. triporus* was recorded from North-America and Europe (Moraes *et al.* 2004).

***Typhlodromus (Anthoseius) intercalaris* Livshitz & Kuznetsov, 1972**

*Material examined.* M1, Óbarok, elm.

*Remarks.* This species is known from France, Greece, Italy, Hungary and Iran (Moraes *et al.* 2004, Ripka 2006, Faraji *et al.* 2007).

***Typhlodromus (Anthoseius) recki* Wainstein, 1958**

*Material examined.* M1, Óbarok, elm; M3, Kisbag, hornbeam; M6, Fácános, maple; M6, Sárköz, hazelnut.

*Remarks.* *T. (A.) recki* was recorded from Europe and the Middle-East (Moraes *et al.* 2004).

***Typhlodromus (Typhlodromus) corticis* Herbert, 1958**

*Material examined.* M5, Petőfiszállás, maple.

*Remarks.* This is a very rare but widely distributed species, which is reported from Canada, China, Italy, Russia (Moraes *et al.* 2004) and Hungary (Ripka 2006).

***Typhlodromus (Typhlodromus) pyri* Scheuten, 1857**

*Material examined.* M7, Táská, linden.

*Remarks.* This species occurs in Europe, Middle-East, North-America, Australia, and New Zealand (Moraes *et al.* 2004).

***Typhlodromus (Typhlodromus) tiliae* Oudemans, 1929**

*Material examined.* M0, Alacska, linden; M1, Óbarok, hornbeam; M5, Örkény, hornbeam; M7, Budaörs, unknown plant.

*Remarks.* Widely distributed species; reported from Europe, Asia, and North-America (Moraes *et al.* 2004).

***Typhloseiulus peculiaris* (Kolodochka, 1980)**

*Material examined.* M1, Óbarok, oak.

*Remarks.* *T. peculiaris* was found so far only in Moldova, Iran (Faraji *et al.* 2007) and Greece (Papadoulis & Emmanouel 1993; Papadoulis *et al.* 2009). This is the first Hungarian record.

**Description of *Typhloseiulus peculiaris* (Kolodochka, 1980) from Hungary**

***Typhloseiulus peculiaris* (Kolodochka, 1980)**

*Seiulus peculiaris* Kolodochka, 1980: 41

*Typhlodromus peculiaris* (Kolodochka, 1980): Chant & Yoshida-Shaul 1983: 1150.

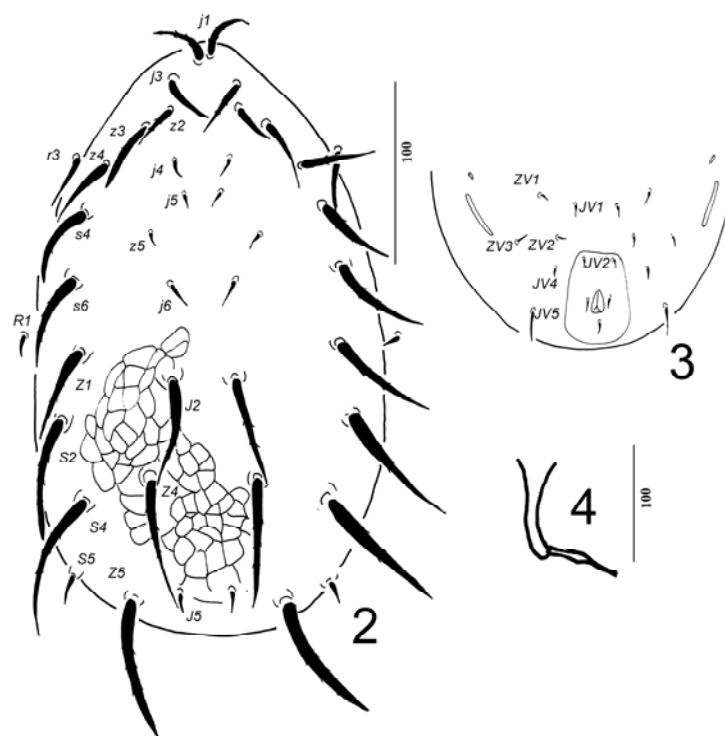
*Typhloseiulus peculiaris* (Kolodochka, 1980): Chant & McMurtry 1994: 246. Faraji *et al.* 2007: 231–233.

*Material examined.* Two females, Hungary, Óbarok rest station in highway M1, from leaves of oak, 08.V.2013. leg. B. Kiss. Three females, Hungary, Óbarok rest station in highway M1, from leaves of oak, 20.IX.2013. leg. A. Karap & B. Kiss.

*Short description.* Dorsal shield covered by reticulate sculptural pattern. Dorsal setae j4 (14–15), j5 (8–10), z5 (8–10), j6 (18–20), S5 (19–20), J5 (8–10) and R1 (13–15) short, smooth and needle-like. Other setae on dorsal body long, robust and finely pilose, except setae r3 (39–40), which smooth and shorter (Fig. 2). Length of other dorsal setae as follows: j1 and j3 38–40, z2 33–35, z3 50–52, z4 50–52, s4 58–60, s6 65–67, Z1 68–70, S2 83–85, S4 102–105, Z5 101–103. Apical part of peritremes reaching to setae j1. Ventrianal shield oblong, bearing setae JV2 and one pair of adanal setae and one postanal seta. JV5 setae longer than other ventral setae (Fig. 3). Spermatheca with long and narrow calyx (Fig. 4).

*Notes to the Hungarian specimens.* The specimens found are similar to the Iranian one in the shape of the spermatheca (Faraji *et al.* 2007), but the mentioned light ornamentation on sternal and ventrianal shields are missing in the Hungarian specimens.

*Remarks.* *Typhloseiulus simplex* (Chant, 1956) is the only *Typhloseiulus* Chant & McMurtry, 1994 species reported from Hungary before our study (Ripka 2006, Ripka *et al.* 2013). The two species differ from each other in the following characters: setae J2 are more than four times longer than setae j6, and setae J2 reach to the basis of setae Z4 in the species *T. peculiaris*, in contrast, the setae J2 are only twice longer than setae j6 and setae J2 do not reach to the basis of setae Z4 in *T. simplex*.



Figures 2–4. *Typhloseiulus peculiaris* (Kolodochka, 1980). 2 = dorsal shield, 3 = ventrianal region, 4 = spermatheca.

## DISCUSSION

15 phytoseiid species were recorded from the rest stations of the Hungarian highways, which represent *ca.* 20% of the phytoseiid species so far reported from Hungary (Ripka 2006). Seven species were collected from the area of the ring highway around Budapest (M0), ten species from north-western highway (M1), 6–6 species from the north-eastern and the south-eastern highway (M3 and M5), five species from the south-western highway (M7) and two species from the newly constructed central southern highway (M6). The highway M1 and the sections of M3 and M7 close to Budapest are the oldest highways in Hungary, the plantations of their rest stations started several decades ago. In contrary, the highways M0 and M6 are newly built and several parts of the highways M3, M5 and M7 (primarily the parts far from Budapest) are established in the last decade, therefore higher and older trees can only be found in rest stations close to Budapest. On the contrary, we found small and young trees along the newly

built sections. In consequence, the lowest number (2 species) of phytoseiids was observed along the M6 highway which is the most recently built.

The most common species in the area of the Hungarian highways is *E. finlandicus*; it was collected on several different host plants. This species is very frequent in Hungary both in natural and agricultural environments as well.

The species *K. aberrans*, *N. aceri*, *Ph. macropilis*, *T. (A.) recki* and *T. (T.) tiliae* were found in several rest stations of the highways. The other species were found only one-two rest stations. The species *K. corylosus* was found only on leaves of hazelnut trees or bushes in four different places. It seems this species has a preference for the hazelnut trees. *K. corylosus* has only recently been reported from Hungary (Ripka & Szabó 2010), but probably occurs everywhere together with its host plant. Due to the difficulty in identification of *K. corylosus*, numerous earlier Hungarian data of *K. aberrans* can be misidentification of *K. corylosus*.

The newly recorded species *T. peculiaris* and the rare *T. (A.) intercalaris* were collected near Óbarok (highway M1) where the rest station is surrounded by forested area. Kozár (2009) mentioned that the same sampling place was among the most species reach localities of Hungarian highways for scale insects also. *T. peculiaris* was observed on leaves of oak, similarly to the Iranian specimen, which was found on the same tree species (Faraji *et al.* 2007).

Most of the species found possess Holarctic, Palearctic or European distribution patterns. Only four species *K. corylosus*, *T. peculiaris*, *T. (A.) intercalaris* and *T. (A.) recki*, are perhaps of Mediterranean distribution, colonized the Carpathian Basin from the nearby glacial refuges (Italy and Balkan Peninsula) or using an alternative colonization way from the Northern part of the Black Sea.

**Acknowledgements.** – We are grateful to the late Dr. Ferenc Kozár for the initiation of the faunistic survey of Hungarian highway margins, as well as to the colleagues, who helped us in collecting the samples. The research was supported by the Hungarian Scientific Research Fund (OTKA 72744, 75889, 83829, 108663).

## REFERENCES

- CARGNUS, E., GIROLAMI, G. & ZANDIGIACOMO, P. (2012): Re-examination of specimens of three species of *Kampimodromus* Nesbitt (Acari: Phytoseiidae) from north-eastern Italy, with first report on *Kampimodromus corylosus* Kolodochka in Italy. *International Journal of Acarology*, 38(7): 583–594.
- CHANT, D. A. & MCMURTRY, A. J. (1994): A review of the subfamilies Phytoseiidae and Typhlodrominae (Acari: Phytoseiidae). *International Journal of Acarology*, 20(4): 223–310.
- CHANT, D. A. & MCMURTRY, J. A. (2007): *Illustrated keys and diagnoses and subgenera of the Phytoseiidae of the world (Acari: Mesostigmata)*. Indira Publishing House, West Bloomfield, 220 pp.
- CHANT, D. A. & YOSHIDA-SHAUL, E. (1983): A world review of the simplex species group in the genus *Typhlodromus* Scheuten (Acarina: Phytoseiidae). *Canadian Journal of Zoology*, 61: 1142–1151.
- FARAJI, F., HAJIZADEH, J., UECKERMAN, E. A., KAMALI, K. & MCMURTRY, J. A. (2007): Two new records for Iranian Phytoseiid mites with synonymy and keys to the species of *Thyphloseiulus* Chant and McMurtry and Phytoseiidae in Iran (Acari: Mesostigmata). *International Journal of Acarology*, 33(3): 231–239.
- KARG, W. (1993): *Acari (Acarina), Milben. Parasitiformes (Anachitinochaeta). Cohors Gamasina Leach. Raubmilben*. Die Tierwelt Deutschlands und der angrenzenden Meeresteile nach ihren Merkmalen und nach ihrer Lebensweise. Gustav Fisher Verlag, Jena-Stuttgart-New York, 523 pp.
- KOLODOCHKA, L. A. (1980): New phytoseiid mites (Parasitiformes, Phytoseiidae) from the Moldova SSR, U.S.S.R. *Vestnik Zoologii*, 4: 39–45.
- KOZÁR, F. (2009): Pajzstetű (Hemiptera: Coccoidea) fajok és a klímaváltozás: Vizsgálatok magyarországi autópályákon. (Scale species (Hemiptera, Coccoidea) and climate change studies on Hungarian Highways. *Növényvédelem*, 45(11): 577–588.
- KOZÁR, F., FETKÓ, K., SZITA, É. & KONCZNE BENDICTY ZS. (2012): A fehér fenyő-pajzstetvek újabb jelentős felszaporodása a hazai autópályákon (Hemiptera: Coccoidea, Diaspidiidae, *Leucaspis* sp.). (A new significant outbreak of white pine scales on Hungarian highways (Hemiptera: Coccoidea, Diaspidiidae, *Leucaspis* sp.). *Növényvédelem*, 48(8): 349–354.
- LINDQUIST, E. E. & EVANS, G. O. (1965): Taxonomic concepts in the Ascidae, with a modified setal nomenclature for the idiosoma of the Gamasina (Acarina: Mesostigmata). *Memoirs of the Entomological Society of Canada*, 47: 1–64.
- MCMURTRY, J. A., & CROFT, B. A. (1997): Life-styles of phytoseiid mites and their roles in biological control. *Annual Review of Entomology*, 42: 291–321.
- MORAES, G. J. DE, MCMURTRY, J. A., DENMARK, H. A. & CAMPOS, C. B. (2004): A revised catalogue of the mite family Phytoseiidae. *Zootaxa*, 434: 1–494.
- PAPADOULIS, G. T. & EMMANOUEL, N.G. (1993): New records of phytoseiid mites from Greece with a description of the larva of *Typhlodromus erymanthii* Papadoulis & Emmanouel (Acarina: Phytoseiidae). *International Journal of Acarology*, 19(1), 51–56.



- PAPADOULIS, G. T., EMMANOUEL, N. G. & KAPAXIDI E. V. (2009): *Phytoseiidae of Greece and Cyprus: (Acari: Mesostigmata)*. Indira Publishing House, West Bloomfield, 200 pp.
- RIPKA, G. (2006): Checklist of the Phytoseiidae of Hungary (Acari: Mesostigmata). *Folia Entomologica Hungarica*, 67: 229–260.
- RIPKA, G. & SZABÓ, Á. (2010): Additional data to the knowledge of the mite fauna of Hungary (Acari: Mesostigmata, Prostigmata and Astigmata). *Acta Phytopathologica et Entomologica Hungarica*, 45(2): 373–381.
- RIPKA, G., SZABÓ, Á., TEMPFLI, B. & VARGA, M. (2013): New Plant-inhabiting Mite Records from Hungary (Acari: Mesostigmata, Prostigmata and Astigmata) II. *Acta Phytopatologica et Entomologica Hungarica*, 48(2): 237–244.
- ROWELL, H. J., CHANT, D. A. & HANSELL, R. I. C. (1978): The determination of setal homologies and setal patterns on the dorsal shield in the family Phytoseiidae (Acarina: Mesostigmata). *Canadian Journal of Entomology*, 110: 859–876.
- TIXIER, M.S., KREITER S., DOUIN, M. & MORAES, G. J. DE. (2012): Rates of description of Phytoseiidae mite species (Acari: Mesostigmata): space, time and body size variations. *Biodiversity and Conservation*, 21: 993–1013.
- TSOLAKIS, H., TIXIER, M. S., KREITER, S. & RAGUSA, S. (2012): The concept of genus within the family Phytoseiidae (Acari: Parasitiformes): historical review and phylogenetic analyses of the genus *Neoseiulus* Hughes. *Zoological Journal of the Linnean Society*, 165: 253–273.

# The genus *Allogamus* Schmid, 1955 (Trichoptera, Limnephilidae): revised by sexual selection-driven adaptive, non-neutral traits of the phallic organ

J. OLÁH<sup>1</sup>, P. CHVOJKA<sup>2</sup>, G. COPPA<sup>3</sup>, W. GRAF<sup>4</sup>, H. IBRAHIMI<sup>5</sup>, O. LODOVICI<sup>6</sup>, A. RUIZ GARCIA<sup>7</sup>,  
M. SÁINZ-BARIÁIN<sup>8</sup>, M. VALLE<sup>9</sup> and C. ZAMORA-MUÑOZ<sup>10</sup>

<sup>1</sup>János Oláh, Residence postal address: Tarján u. 28, H-4032 Debrecen, Hungary. E-mail: profolah@gmail.com

<sup>2</sup>Pavel Chvojka, Department of Entomology National Museum, Kunratic 1, CZ-148 00 Praha 4, Czech Republic.  
E-mail: pavel\_chvojka@nm.cz

<sup>3</sup>Gennaro Coppa, 1, rue du Courlis, F-08350 Villers-sur-Bar, France. E-mail: gennaro.coppa@wanadoo.fr

<sup>4</sup>Wolfram Graf, Institute of Hydrobiology and Aquatic Ecology Management, University of Natural Resources  
and Applied Life Sciences, Vienna, Austria. E-mail: wolfram.graf@boku.ac.at

<sup>5</sup>Halil Ibrahim, University of Prishtina, Faculty of Mathematics and Natural Sciences, Department of Biology,  
Mother Teresa p.n., 10000 Prishtina, Kosovo. E-mail: halilibrahimi@yahoo.com

<sup>6</sup>Omar Lodovici, Museo Scienze Naturali “E. Caffi”, Piazza Cittadella 10, I-24129 Bergamo, Italy.  
E-mail: olodovici@comune.bg.it

<sup>7</sup>Antonio Ruiz Garcia, Departamento de Sistemas Físicos, Químicos y Naturales (Zoología), Universidad Pablo  
de Olavide, A-376, Km 1, 41013 Sevilla, Spain. E-mail: aruigar@upo.es

<sup>8</sup>Marta Sáinz-Bariáin, Departamento de Zoología, Universidad de Granada, 18071 Granada, Spain.  
E-mail: msainzb@ugr.es

<sup>9</sup>Marco Valle, Museo Scienze Naturali “E. Caffi”, Piazza Cittadella 10, I-24129 Bergamo, Italy.  
E-mail: mvalle@comune.bg.it

<sup>10</sup>Carmen Zamora-Muñoz, Departamento de Zoología, Universidad de Granada, 18071 Granada, Spain.  
E-mail: czamora@ugr.es

**Abstract.** Based upon our previous reviews on the phylogenetic species concept, initial split criteria and fine structure analysis here we summarize population and model thinking as support to our diverged structure matrix procedure to test simply visually or, if required, by geometric morphometrics the stability of sexual selection-driven adaptive, non-neutral traits of the phallic organ. Complexity review helped us to establish plesiomorphic and apomorphic states of parameres of the phallic organ. Fine structure diversity of the adaptive traits of paramere and the apical portion of aedeagus has been applied to revise the *Allogamus* genus. All the known 22 taxa, 19 species and 3 subspecies, have been revised. Apomorphic fusion of parameres and complexity evolution of aedeagus directed us to erect 2 rediagnosed species groups, 1 new species group, 4 new species subgroups, 1 new species complex, 10 new species and 4 new or revised species status as follows: *Allogamus auricollis* species group, rediagnosed. *Allogamus antennatus* new subgroup: *A. antennatus* (McLachlan, 1876), *A. ausoniae* Moretti, 1991, stat. rev., *A. morettii* DePietro & Cianficconi, 2001, stat. rev., *A. silanus* Moretti 1991, stat. nov. *Allogamus auricollis* new subgroup: *A. alpinensis* Oláh, Lodovici & Valle sp. nov., *A. auricollis* (Pictet, 1834), *A. despaxi* Decamps, 1967, *A. zomok* Oláh & Coppa sp. nov. *Allogamus hilaris* new subgroup: *A. hilaris* (McLachlan, 1876). *Allogamus ligonifer* new subgroup: *A. gibraltarius* Gonzalez & Ruiz, 2001, *A. kefes* Coppa & Oláh sp. nov., *A. laureatus* (Navas, 1918), *A. ligonifer* (McLachlan, 1876), *A. pertuli* Malicky, 1974, *A. pupos* Coppa & Oláh sp. nov. *Allogamus mortoni* new species complex: *A. kampos* Oláh & Ruiz sp. nov., *A. kettos* Oláh & Ruiz sp. nov., *A. kurtas* Oláh & Zamora-Muñoz sp. nov., *A. mortoni* (Navas, 1907), *A. pohos* Oláh & Zamora-Muñoz sp. nov., *A. tuskes* Oláh & Sáinz-Bariáin sp. nov. *Allogamus corsicus* new species group: *A. corsicus* (Ris, 1897). *A. illiesorum* Botosaneanu, 1980 stat. rev. *Allogamus uncatus* species group, rediagnosed: *A. botosaneanui* Moretti, 1991, *A. dacicus* (Schmid, 1951), *A. fuesunae* Malicky, 2004, *A. mendax* (McLachlan, 1876), *A. pantinii* Oláh, Lodovici & Valle sp. nov., *A. periphetes* Malicky, 2004, *A. stadleri* (Schmid, 1951), *A. starmachi* Szczesny, 1967, *A. tomor* Oláh, 2012, *A. uncatus* (Brauer 1857).

**Keywords.** *Allogamus*, Trichoptera, shape analysis, complexity evolution, non-neutral structural traits, new species.

## INTRODUCTION

The species of the autumn flying genus *Allogamus* Schmid, 1955 populate the European triangle of England-Pyrénées-Greece and inhabit mountain streams and springs. Nine species of the genus *Allogamus* have previously been listed in the *uncatus* group of the genus *Halesus* (Schmid 1951a): *Halesus mendax* McLachlan, *H. uncatus* Brauer, *H. ligonifer* McLachlan, *H. hilaris* McLachlan, *H. mortonii* Navas, *H. laureatus* Navas, *H. auricollis* Pictet, *H. antennatus* McLachlan, and *H. corsicus* Ris. Two new *Halesus* species were described by Schmid (1951b): *H. stadleri* from France and Germany and *H. dacicus* from Romania. The genus *Allogamus* has been erected for these eleven *Halesus* species (Schmid 1955).

Eleven new *Allogamus* taxa have been described in the last half century: *Allogamus starmachi*, *A. lazarei* and *A. tatricus* from the High Tatras (Szczeny 1967), but *A. lazarei* and *A. tatricus* were synonymised with *A. starmachi* by Botosaneanu & Malicky (1978). *A. despaxi* was described from the French Pyrénées by Décamps (1967), *A. pertuli* from Greece by Malicky (1974), *A. illiesorum* from Sardinia by Botosaneanu (1980), however this latter was reduced to subspecies status by Malicky (2005) as *A. corsicus illiesorum*. *A. ausoniae* was described from Italy by Moretti (1991), but reduced to subspecies status by Malicky (2005) as *A. antennatus ausoniae*. *A. botosaneanui* was described from Italy by Moretti (1991). *A. hilaris silanus* described also from Italy by Moretti (1991) was later transferred by Malicky (2005) to *A. antennatus* as subspecies *silanus*. *A. morettii* was described from Sicily by De Pietro & Cianficconi (2001), but synonymized with *Allogamus antennatus silanus* Moretti, 1991 by Malicky (2005). *A. gibraltarius* was described from Spain by González & Ruiz (2001), *A. periphetes* from Italy and Switzerland as well as *A. fuesunae* from Spain, Pyrénées by Malicky (2004). *A. tomor* was described from Albania by Oláh in Oláh & Kovács (2012). In the present state of knowledge the genus *Allogamus* contains 22 taxa: 19 species and 3 subspecies.

Based on the phylogenetic species concept (Oláh et al. 2012), on the initial split criteria and on the fine structure analysis (Oláh et al. 2013a) here we revise the taxonomy of the genus *Allogamus* applying the sexual selection-driven, non-neutral adaptive traits of the phallic organ: the parameres and the head of the aedeagus. In order to visualize the stability of these adaptive traits we have applied here the diverged structural trait matrix, by reviewing population and model thinking, shape analysis and complexity alternatives of adaptive parameres.

## THEORETICAL PART

Working on closely related species complexes exhibiting morphological signs of recent speciation processes it may be necessary to enrich our routine alpha taxonomy with more population and model thinking and to apply the growing arsenal of shape analysis. Here we introduce a simple practice of producing graphical matrices of recently diverged fine structures. In the everyday practice of species determination and description such a visual presentation is sufficient. The drawings of diverged structural matrices indicate clearly the stability or variability of the diverged structural traits without need of statistics and morphometrics. If later is required, the published population matrices of diverged fine structures offer future possibility to analyse and compare them by various procedures of geometric morphometrics. The interpretation of the discovered stable fine structure of the diverged incipient species requires to understand and to evaluate its complexity, whether plesiomorphic or apomorphic. Here we review briefly the population and model thinking and the application of our diverged structure matrix as well as the principles of shape analysis and the complexity interpretation of the investigated shape.

### Diverged structure matrix and population thinking

Darwin's innovation, the population thinking opposes the Platonic doctrine of "essentialism" or "typological thinking" (Ariew 2008). Type (eidos)

is real and variation is an illusion or type (average) is an abstraction and the variation is real (Mayr 1959). Aristotle's natural-state model with interfering forces unites the type and expressing variations (Sorber 1994). The reality is dual: particles and interacting forces. This is why every particle differs from each others. Natural states and interfering forces illustrate best also the theory of heredity. This is why the population thinking developed into the growing universe of population genetics.

Our goal in alpha taxonomy is to distinguish the incipient species with initial split criteria. In practice we examine structural diversifications nearby the structural diverging point. We search the first morphological product of speciation with unknown ranges of ubiquitous variation. Searching such fine structures we need to study many specimens from many populations to discover the first, although delicate structural trait already diverged. Its mere existence indicates that it is probably stable enough to provide early barriers to gene flow. If discovered we start a detailed research on its stability by preparing the graphical diverged structure matrix for each population.

### Visual empiricism and model thinking

In alpha taxonomy we are studying the phenotypes, the morphological expression of genomic processes. We rely upon mostly on the visual empiricism, while molecular genetics applies almost exclusively models. Model thinking gives us a powerful tool to understand the realistic processes. This is further fortified by progress in statistical methodology for detecting molecular adaptation and positive selection (Nei *et al.* 2010). However statistics are measuring something and the reality could be far more complex than our interpretations. Moreover several distinct causal mechanisms can yield the same statistical pattern (Pigliucci 2006). We have to acknowledge if visual empiricism is available and applicable to separate incipient species without molecular genetical models. Visualized structure matrix is a graphical copy of the reality. Model is our idea, a human created limited thinking about reality.

However it could be far from the real environmental situation. For instance in contrast to the Wright-Fisher population model widely applied in molecular genetics: (1) most of the population has two sexes; (2) mating is non-random due assortative mating and sexual selection; (3) reproductive success is non-random; (4) population size vary in time; (5) population is subdivided into demes of local populations; and deterministic forces of (6) selection and stochastic forces of (7) recombination, (8) genetic drift and (9) gene flow are all variously present (Charlesworth 2009).

### Shape analysis

Comparing shapes of anatomical structures forms our work in the classification of organisms and helps us to understand and to quantify the diversity of life. At the same time we do not realize that shapes are fundamental genetic traits as well competing with molecular traits. It is tempting to believe that genomic complexity is mirrored in phenotypic morphological and functional complexity and vice versa with obvious difficulty of matching genes with structure or function (Adami *et al.* 2000). New genes are the sources of functional and phenotypic diversity and recent progress has been made in understanding the evolution and phenotypic effects of genomes acquiring novel genetic elements (Chen *et al.* 2013). Combining fine structures of shape with principles of molecular traits yields synthetic insights into understanding of biological diversity at refined resolution.

Morphometrics is the study of shape variation and covariation. Analysis of shape developed to multivariate morphometrics. Quantitative variables of length, width, height, sometimes counts, ratios, and angles are compared among populations and species applying several statistic procedures: statistical analyses of principal component analysis, factor analysis, canonical variates analysis, and discriminant function analysis.

Difficulties while working in traditional morphometrics appear in size correction, linear homology, shape-independent distance as well as the

lack of graphical representation. These limits forced scientists to explore alternative methods to capture the geometry of shape. The newly developed approach has revolutionized our shape research with the geometric morphometrics (Rohlf & Marcus 1993). Outline methods were the first method developed by digitized points along outline and fitting the points with mathematical function, usually by Fourier analysis. Landmarks methods are based on the collection of two- or three-dimensional coordinates of biologically definable landmarks on shapes. Superimposition methods eliminated non-shape variation in landmark configuration and produced reliable shape information from primary landmark data.

The future of geometric morphometrics was discussed by Adams *et al.* (2004). There are potential for (1) the use of three-dimensional data, (2) combining landmarks and surfaces using sliding semilandmarks, (3) use imputation methods for missing data and absent structures, (4) estimating landmark covariance structure, (5) solving difficulties to combine morphometrics and phylogenetics.

### Evolution of paramere complexity

Genome complexity is correlated with morphological complexity and driven primarily by non-adaptive stochastic forces, rather than by adaptive evolution (Lynch 2006, Yi 2006). There is a need to answer the simple question still unresolved in the evolution of paramere complexity: do parameres evolve from simple to complex or the opposite? This question emerged important for paramere structures, especially nowadays, when their non-neutral, adaptive sexual selection driven evolution become more documented (Oláh *et al.* 2012, Oláh & Ito 2013, Oláh *et al.* 2013a; Oláh *et al.* 2013b). Titillating and/or harming parameres of the phallic organ directly involved in sexual selection processes diverge into variously complex structural patterns fitting to perform their multiple and complex functions in the initial stage of divergence (Oláh *et al.* 2013b). In order to understand what is simple and complex or which character state is ancestral plesiomorphic or de-

rived apomorphic we need to outline some basic relations in complexity theory. This condensed survey oversimplifies the ever-changing and complicated understandings and speculations about entities and interactions inside the self-organising complexity, intending simply to help some orientation in alpha taxonomy.

According to the Williston's law the structures tend toward reduction: in vertebrate evolution the numbers of skull bones are reduced by loss and fusion (Williston 1914). A general evolution pattern of reduction in structural parts was demonstrated by Gregory (1935). An ancestor must be constituted by the integration of the largest possible number of characters (Schmid 1979). Based upon these findings we have selected the structurally most complex parameres for the ancestral plesiomorphic state in the *Potamophylax nigricornis* species group (Oláh *et al.* 2013a), but considered that the terms simple, complex, primitive, generalized, specialized, are all strictly comparative (Ross 1956; Schmid 1958). This experienced simplification trend in evolution is associated to a decrease in complexity or whether or not complexity increases through evolution has become a contentious issue.

The second law of statistical thermodynamics, the stochastic average energy behaviours of large groups of individual particles (Boltzmann 1886), viewed nature as decaying toward a death of random disorder by equilibrium seeking. This pessimistic view opposed Darwin's paradigm that is based on increasing complexity, specialization and organisation of biological systems through time. This dilemma was solved by Schrödinger (1944). He observed that the gene generates order from order (negentropy from negentropy) during reproduction that is the progeny inherits the traits of the parents. To sustain this process the living systems defy of the second law of thermodynamics and move away from disorder into highly organised structures far from equilibrium, and create order from disorder. Life exists and builds complexity in energy and material fluxes, as constrained gradient dissipator, while importing energy (negentropy) from outside at the ex-

pense of producing entropy in the environment (Schneider & Kay 1995). However, how this permanent increase in complexity during evaluation supports Williston's finding of the experienced reduction or simplification?

A mechanism for reduction, simplification, or specialization during evolution of complexity was speculated in debate with the concept of irreducible complexity (McShea & Hordijk 2013). Unfortunately their oversimplified complexity concept was unreasonably reduced to the number of parts (skull bones). Their complexity by subtraction suggests that complexity could arise, not by incremental addition but by incremental subtraction. Early complexity is followed by later reduction, but this is a kind of Williston's law.

To account for this early complexity liable to subtract, McShea & Brandon (2010) have developed and introduced the zero-force evolutionary law, as an analog of the law of inertia in Newtonian mechanics. This is the evolution of complexity without natural selection. They say that in any evolutionary system in which there is variation and heredity, there is a tendency for diversity and complexity increase. This may be opposed by natural selection, other forces, or constraints acting on diversity or complexity. Organisms are expected to accumulate random variations spontaneously. Their internal parts become differentiated along an internal-variance-vector. Selection could reinforce, act neutrally or oppose it (McShea 2005). Evolutionary zero-force law states what will happen if no forces impinge on the system. However complexity is negentropy governed through macrostate probabilities and adjusted stochastically by the greater number of microstates, by the combined, often opposite effects of the entropy increasing "constraint-entropy" and the entropy decreasing "temperature-entropy". Complexity is the result of exergy, the capacity of an energy system to perform useful work processing to equilibrium with the environment. The zero-force evolutionary law seems to move into an opposite direction with decomposing variation. A recent criticism says that di-

versity and complexity do not change when there are no evolutionary causes (Barett *et al.* 2012).

Williston's Law has been revisited recently by network theory (Esteve-Altava *et al.* 2013). It was found that reduction in the number of structural parts could be associated with increasing complexity. Complexity increased with complementary qualities associated to the decrease of structural units. Reduction of elements was compensated (1) by anisomerism, that is by specialization of the structures (measured by dissimilarity of connectivity heterogeneity); (2) by the number of unpaired structures as a side-measure of anisomerism (fusion of two or more pre-existing structures, representing the most modified, specialized ones); (3) by density of connections (more connected is more complex); (4) by characteristic path length (speed of information flow), (5) by cluster development (loops of connections, integration, modularity). As a result the reduction in skull bones correlates with an increase in complexity. Specialization by simplification could be an inherent complexity increase. Parts tend toward reduction in number, with the fewer parts greatly specialized in function. In already complex systems, sometimes more complex than they need to be, selection (natural or sexual) may favour a reduction in the structural pattern of complexity. Ancestral more complex structures were less fit than the less-complex derived ones. Early excessive complexity followed by adaptive reduction is a possible route to adaptation. More advanced structures can have fewer parts.

We need more rigorously defined and measurable traits to study the evolution of complexity in biological evolution. Genomic complexity expressed in morphological and functional diversity can be measured directly by the number of base pairs in a sequence (Adami *et al.* 2000). Equating genomic complexity with genome length in base pairs produced several conundrums. G-value paradox refers to the lack of correspondence between gene number and organismal complexity. C-value paradox disconnect between genome size and morphological complexity (Gregory 2004).

## MORPHOLOGICAL PART

### Pointed accessory process on paraproctal complex

Here we briefly review what is the accessory pointed process on the paraproctal complex? Why is it so diverse? In limnephilids the *paraproct complex* is a paired structure with variously developed branches named in four different directional nomenclature: (1) apparent dorsal and ventral branches of Vshivkova (2007), (2) internal (plus plesiomorphic external) and inferior branches of Schmid (1955), (3) apical and basal branches or (4) horizontal and vertical branches. Dorsal branches are produced caudad and more or less horizontal, ventral branches oriented more or less dorsoventrad. Combining the four nomenclatures of the paraproctal branches we may summarize that the dorsal branch is bilobed in plesiomorphy (internal and external), apical and horizontal; the ventral branch is inferior, basal and vertical. Branches are partially or completely fused in various shape and forming a completely or partially sclerotized ring around anus.

This paraproct complex is variously fused with dorsum IX, segment X and with cerci forming together the *superanal genitalic complex* of Vshivkova (2007). Structures of the superanal genital complex are separated from each other by membranes or by sutures. According to Schmid (1968, 1970) the body of segment X is frequently reduced and even the paraproct as well as the cerci are somite and podite remains of the vestigial segment XI. A plesiomorphic condition in insect generally is the separation of segment IX from segment X by discernible sutures. At many insects the limits of segment X often difficult to determine due to the frequent union between the segments X and XI. Probably the superanal genital complex of Limnephilidae represents the amalgamated segments X and XI. We may conclude that in limnephilids an apomorphic condition developed by the variously fused dorsum of segments IX, X and XI.

According to Kumanski (1968, 1969, 1987) at the *Chaetopteroides* genus the ventral (inferior,

basal, vertical) branch of paraproct forming a complete heavily sclerotized ring around anus and the entire paraproct complex, except the dorsal (internal, apical, horizontal) branches, represents the vestigial segment X.

The paraproctal complex is strongly sclerotized, mostly devoid of setae, muscled and movable. The ventral branches, representing probably the reduced somite of segment X and XI (Kumanski 1968, 1969, 1987), form a pair of triangulum with various sclerotization. The pair of triangulums encircles the anal opening with mesal edges less sclerotized or completely membranous. These triangles enlarge the total surface of the ventral branches embedded into the soft tissue around the anal region and below the genital cavities. The triangles are formed (1) by the lateral angle, housing the accessory process; (2) by the dorsal angle connecting into the dorsal branches; and (3) by the mesal angle. The mesal angles of the two ventral branches are frequently fused to complete the sclerotized ring around the anal opening. The mesal edge of the triangle is less sclerotized, frequently obscure or even indiscernible. The lateral angle or corner is the lateral sclerite of segment X (Schmid 1998). The ventral edges of the triangulums are called sometimes as the ventral sclerites.

### Why the pointed accessory process is so diverse?

The enlarged triangulums of the ventral (inferior, basal, vertical) branch of the paraproctal complex serves as a supporting, pivoting fulcrum for the muscled movable dorsal branch of the paraproct. The dorsal branches function as grabbing tool and/or as stimulating courtship or harm device delivering internal signals to the females. It seems that the *Allogamus mortoni* species group has an effective additional apomorphic tool evolved to produce stimulating and titillating signals to the females during copulation. This is the pair of the extremely enlarged accessory processes developed, diversified, and stabilized on the lateral corner of the basal triangles of the paraproctal complex. Diversification was driven pro-

bably by intense sexual selection processes. Post-copulatory sexual selection can lead to rapid divergence in reproductive traits related to the very complex mating and copulating processes. These genital structures may have courtship, harm, cleaner and anchor device functions, depending on the dominating actual processes of the sexual selection: cryptic female choice, sperm competition or sexually antagonistic coevolution. Finding stable fine structures in order to establish initial split criterion nearby the structural diverging point, where early barriers to gene flow develops is a promising tool for alpha taxonomy. These childhood stable traits of the incipient phylogenetic species are the targets of selection and the first morphological product of speciation. In incipient species the genetic mosaic of speciation involves only few stable characters of the diverging loci leaving the genom largely homogenised with polymorphisms by ongoing gene flow (Oláh et al. 2013a). In caddisflies we have already discovered stable structures to detect incipient phylogenetic species by fine structure analysis on the intro-mittent organ: parameres and various processes on the aedeagus (Oláh et al. 2012, Oláh & Ito 2013, Oláh et al. 2013a, Oláh et al. 2013b). The accessory processes on the paraproctal complex discovered in the *Allogamus mortoni* species complex and in the *A. ligonifer* species is diversified in sexual selection processes.

### Understanding and visualization of the vaginal sclerite complex

Earlier we have distinguished six substructures in the vaginal sclerite complex (Oláh et al. 2013a). As we are examining more limnephilid genera and species we understand more details on this diversified sclerite complex. Here we separate three more substructures for practical taxonomic purposes and listing them together with the previously distinguished six substructures. (1) *Vaginal sclerite plate* itself on the dorsum of the membranous vagina and ventrum of the membranous accessory gland duct; this basal plate integrates all the substructural components of the vaginal sclerite complex. (2) *Dorsal articulation sclerites*, a variously sclerotized internal continu-

ation of the supragenital plate (upper vulvar lip). The internal dorsal articulation sclerites and external supragenital plate together participate to receive the stimulating or harm effect of the male parameres in the processes of sexual selection. Much developed if accessory duct enlarged laterad or elongated anterad and gives additional support to help the function of the junction sclerite. Heavily sclerotized if male parameres function as harm device in the sexually antagonistic coevolution. (3) *Ventral articulation sclerites* attach the sclerite complex to the internal continuation of the lateral processes of the vulvar scales (lower vulvar lip), that is to the paired gonopods of segment IX. (4) *Lateral joints* of the upper and lower lips. Usually not, or less sclerotized, but sometimes enlarged and bloated by proliferation of hard tissue. (5) *Wing sclerites* with stretch function for vagina and with apodemic function anterad to receive vaginal muscles, variously combined with ventral articulation sclerites. (6) Hood-shaped *junction sclerite* holding and stretching the junction where the ducts of accessory gland and ovarium meet as well as separating accessory duct from spermathecal duct. (7) *Spermathecal process* receiving ductus spermathecae and forming frequently a longitudinal keel on the ventrum of the vaginal sclerite. (8) *Bursal sclerite* receiving ductus bursae that opens between the spermathecal process and the common oviduct at the anteriomesal margin of the vaginal sclerite. These substructures and functions constitute the vaginal sclerite complex, but their development and sclerotization are highly varying in the different groups. (9) *Anterior apodemes* appear as the anteriomost lateral extension of the vaginal plate separated by the mesal bursal sclerite. Receive muscles and frames the space for the bursal sclerite ensuring to receive ductus bursae.

### Modified duct of the accessory gland

A paired accessory reproductive gland is present in most male and female insects. Its main function in females is to secrete sticky substance that forms either the egg cases or the cement that binds the eggs to a surface. Other name is colleterial gland or glue-secreting organ from Greek



*kolla* glue. The common unpaired duct of the accessory glands opens on the posteriodorsal wall of the genital chamber. In some species of the *Allogamus* genus this unpaired section of accessory gland is elongated and enforced by strong musculature or hardened tissue. This elongated sheath frequently with various lateral wings is connected to the dorsum of the vaginal or spermathecal sclerite was first mentioned by Schmid (1951a) as a *vestibular apparatus* with equilibrating function. Later Schmid (1955) mentioned as *bursa copulatrix*. However the ductus bursae of bursa copulatrix opens between the processus spermathecae and the common oviduct and not posterad. Posterad opening common duct drains the accessory gland to the vaginal chamber through the brace of vaginal sclerite complex. It seems the modified accessory duct participate in sexual selection and coevolves with male parameres. We have collected *Allogamus tomor* in copula and have found the long tube-like structure of the modified duct of the accessory glands in function as to receive the long fused paramere during copulation.

## MATERIAL AND METHODS

It was a great challenge and required sustained effort to bring together all the necessary specimens to revise this genus. We have to emphasize again that collected, sorted and determined materials already incorporate significant scientific work and has high primary value for such surveys. Therefore we invited colleagues who had interest and specimens and agree with our final findings to become a coauthor of the paper and/or of the species automatically.

*Clearing, cleaning, and drawing procedures.* This study is based on animals preserved in 70–80% alcohol. In order to observe morphological details in the genitalia, the entire or only the terminal segments of abdomen were removed and placed in a small glass beaker of 25 cm<sup>3</sup> with 10% KOH solution and boiled during 5–15 minutes for digestion above a spirit burner. The duration of the treatment is adjusted individually to the effectiveness of clearing process which depends on the

species or even on the nutritive state of tissues or on the physiological condition of the specimens. The process of digestion can easily be followed by transparency. The dissolution rate of the soft tissues, the clearing transparency is visible to naked eye. The clearing process and time are so much taxon, size, age, sex, and nutrition state specific that automatic hot plate or bath clearing is not practical. The digested abdomen was subsequently transferred to distilled water and the macerated tissue was removed mechanically in patient cleaning process by fine tipped forceps and needles. The internal vaginal sclerite complex was exposed to clear view by cutting windows into the dorsum and left pleuron with fine scissor. The cleared and cleaned abdomen was transferred to 80% ethylalcohol, and to glycerine for examination under microscope. Different sized pins modified to supporting ring bottom was introduced into the abdomen and used to hold and stabilise the genitalia in lateral, dorsal, and ventral position for drawing. However, the plane of view is never perfect and we made no special procedures of grid, matrix, or reflection to produce absolute mirror symmetry of the drawings. Instead, the genital structures were drawn exactly as seen in the microscope. However, setae are represented only by their alveoli and moreover their density is only symbolic. If essential, the setal length or setal shape are presented by drawing a single or a few setae only. The genital structure was traced by pencil on white paper using a drawing tube mounted on a WILD M3Z microscope at between 260x and 416x magnification. Final illustrations were prepared by enlarging the original pencil drawings and re-drawn on transparent paper by Black India Ink.

*Terminology.* We used our functional appendicular terminology and not the conventional anatomical directional terminology to describe the genital structures in species description (Oláh & Johanson, 2008). Species descriptions were standardized to ensure consistently formatted and comparable description in general accord with Evenhuis's template principle (Evenhuis 2007). We have standardized also the terminology to describe space extensions of variously formed

structural elements. The following terms were used to qualify the dimensions and extensions of genital structural elements: (1) *short* or *long* for length dimension on the longitudinal direction of coronal plane along the anteroposterior axis; (2) *low* or *high* (traditionally *shallow* or *deep* especially for excisions) for height dimension on the vertical direction of the sagittal plane along the dorsoventral axis and (3) *narrow* or *wide* (broad) on the lateral direction of the transversal plane along the mediolateral or left-right axis. The three dimensional Cartesian coordinate system provides theoretical possibility to quantify by measurements the three physical dimensions of length, width, and height of each structural element. However this quantification is used very seldom in species description. Here we quantify only the length of forewing.

### Depositories

Natural History Museum, London (NHML)  
Civic Natural Science Museum “E. Caffi”, Bergamo, Italy (CNSMB)  
Cianficconi Collection, Italy (CC), deposited at the Civic Natural Science Museum “E. Caffi” of Bergamo, Italy  
Civic Natural History Museum, Verona, Italy (CNH MV)  
Coppa Private Collection, France (CPC)  
Departamento de Zoología Facultad de Ciencias. Universidad de Granada, Spain (DZFCUG).  
Friuli Museum of Natural History, Udine, Italy (FM NHU)  
Moretti Collection, Department of Chemistry, Biology, and Biotechnology, University of Perugia, Italy (MC)  
National Museum, Prague, Czech Republic (NMPC)  
Oláh Private Collection, under national protection by the Hungarian Natural History Museum (OPC).  
The Manchester Museum, University of Manchester, England (MMUE)

### TAXONOMY

#### *Allogamus* Schmid, 1955

*Type species.* *Halesus uncatus* Brauer, 1857 by original designation.

*Allogamus* genus belongs to the *Stenophylacini* tribe. This tribe has wing and spur characters very homogenous and less diverse. All the new stenophylacini genera erected by Schmid (1955) are based on male genital divergences. Genus *Allo-*

*gamus* has short segment IX, deep genital cavity (anal cavity of Schmid), small paraproct, as well as long and vertical gonopods. This character combination, especially the presence of genital cavity brings *Allogamus* close to *Hydatophylax* and *Pycnopsyche* genera. *Allogamus* differs from these two related genera by the gonopod apex that is turned to transversal plane and appears like a harpago. However, this is an apparent harpago not a true one. There is no suture discernible between coxopodite and apparent harpago.

In the genus *Allogamus* the periphallic organs, the cerci, the paraprocts and the gonopods, are very homogenous. Cerci form a lateral located, variously compact, heavily setose plate and supplied with variously developed mesal digitiform process. Only *A. hilaris* has lateral digitate process on the lateral plate of the cerci. Paraproct is small; in some lineages the basal triangle produced a pointed accessory setaless process, possibly in the sexual selection processes. This unique titillating or harming structure much developed in the recently diverging *A. ligonifer* species and in the already diverged *A. mortoni* new species complex. Gonopods directed in sagittal plane are characterised by an apparent harpago turned almost right-angle to the transversal plane. This apparent harpago could be very variable both among and inside populations. The apparent harpago exhibits rather high intraspecific variation in the widely distributed *A. uncatus* species well discernible in caudal view. Cerci, paraproct, and gonopods, all are characterized by low structural diversity and high infraspecific variability. These structures have no real diagnostic value to distinguish among species. At the same time the intermittent component of the genitalia, that is the phallic organ, directly involved in the copulatory and postcopulatory processes, is very diverse, species specific and stable.

*Non-neutral adaptive traits.* In the *Allogamus* genus the aedeagus and/or the parameres of the phallic organ are adaptive traits under rapid evolution driven by sexual selection. Their divergences provide diverse fine structures in alpha taxonomy to recognise early stages of recent speci-

ation and can be used as initial split criteria to establish incipient phylogenetic species. The mostly neutral non-adaptive traits of periphallallic genital structures of cerci, paraproct, and gonopods evolved slowly, during millions of years, as estimated by neutral molecular markers. At the same time the non-neutral adaptive traits of the phallic organ undergo more rapid evolution with some historical accumulation of branching structure of lineages.

**Species grouping.** The ancestral plesiomorphic state of the parameres is represented by a pair of rod-shaped shaft nested separately in the membranous endotheca and armed with variously developed spine-like setae. Paramere fusion is an apomorphic state of the phallic organ accompanied by a pair of apicoventral sclerites of varying complexity on the aedeagus. This paramere evolution together with complexity evolution of aedeagus helps us to establish species groups inside the genus *Allogamus*.

The plesiomorphic state of the separated parameres characterizes the ancestral *Allogamus auricollis* species group. Further lineages inside this group have been distinguished by the location of setae on the paramere shaft and by the presence and development of the ventroapical sclerites on the aedeagus. In *auricollis* group we have distinguished four species subgroups based on setal distribution on the parameres: *Allogamus ligonifer* subgroup with subequal apical spines, *A. antennatus*, and *A. auricollis* subgroups with a heavily enforced single primary spinelike seta accompanied by smaller secondary spine-like setae dorso-apical at *A. antennatus* and ventromesad at *A. auricollis* subgroups. *A. hilaris* subgroup has been separated by paramere with ventral row of setae. *Allogamus mortoni* new species complex has been distinguished in the *ligonifer* subgroup based upon the diversified apomorphic neoformation of the paraproctal accessory process.

In the small *Allogamus corsicus* new species group the paired parameres fused basally and diverted apically.

The *Allogamus uncatus* rediagnosed species group has diverged basally fused and apically adhering parameres and evolved the highest complexity of aedeagus with a pair of heavily sclerotized dorsal rod-shaped processes.

The female genitalia are more plesiomorphic in *A. auricollis* group compared to *A. corsicus* and *A. uncatus* species groups. External structure of female genitalia has anal tube less fused having various lobes of the amalgamated segment IX and X in *auricollis* and more fused without such lobes in *corsicus* and *uncatus* groups. The vaginal sclerite complex of the internal structure has plesiomorphic state with simple accessory duct and apomorphic state with enlarged, elongated, and enforced duct of the accessory glands. The apomorphic state of the duct is present and variously developed in *A. antennatus* and *A. hilaris* subgroups as well as in the *A. uncatus* group.

Applying these principles we have grouped all the known and the new species into the following three species groups, four species subgroups and one species complex.

#### ***Allogamus auricollis* species group, rediagnosed**

Schmid (1955) listed three species in his *auricollis* group: *A. auricollis*, *A. antennatus*, and *A. corsicus*. According to the paramere evolution these species belong either to different species groups or to different species subgroups. *Allogamus auricollis* species group is characterized and rediagnosed here by the plesiomorphic state of paramere that is having paramere shafts well separated and embedded individually into the membranous endotheca. Female anal tube complex supplied with various lobes. Modified accessory duct present in *A. antennatus* and *A. hilaris* subgroups, but absent in *A. auricollis* and *A. ligonifer* subgroups.

The *A. auricollis* group developed four lineages according to the position of the paramere setae: *Allogamus ligonifer* subgroup with sub-

equal apical spines, *A. antennatus* subgroup with a strong single primary seta accompanied by smaller secondary setae in dorsoapical position, *A. auricollis* subgroup with a strong single primary seta accompanied by smaller secondary setae in ventromesad position, *A. hilaris* subgroup with ventral row of setae.

***Allogamus antennatus* new species subgroup**

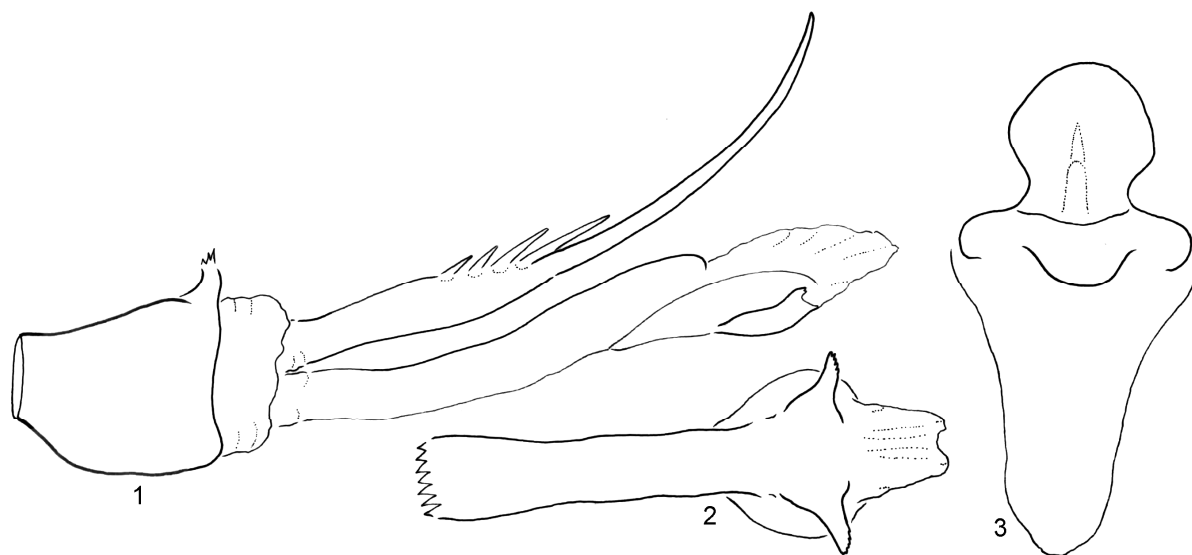
Light species with a strong single primary seta on paramere accompanied by smaller secondary setae in dorsoapical position. Modified accessory duct of female variously modified into an anterad elongated structure.

***Allogamus antennatus* (McLachlan, 1876)**

(Figures 1–3, 11)

*Material examined. Italy.* Liguria-Savona, Garesio, affluente fiume Tanaro c/o Trappa, N 44.235° E8.1267°, 650 m, 10.X.2001, leg. Museo Caffi BG, (1 male, 1 female; OPC). Liguria-Genova, Montoggio, Acquafredda Superiore, N 44.4878° E9.0162°, 500 m, 12.X.1996, leg. Museo Caffi BG, (10 males, 10 females; OPC). Liguria-Imperia, Triora, rio di Barbone, 1000 m, light trap, N44,0370° E7,7197°, 9.X.2001, leg. Museo Caffi BG (2 males, 4 females; CNSMB). Lombardia - Bergamo, Nembro, Salmezza, 1000

m, light trap, N45,7811° E9,7275°, 30.IX.1989, leg. M. Magoni (1 male; CNSMB). Lombardia-Bergamo, Nembro, Salmezza, 1000 m, light trap, N45,7811° E9,7275°, 4.X.1989, leg. M. Magoni (2 males; CNSMB). Emilia-Romagna-Parma, Bedonia, 600 m, N44,5032° E9,6292°, 25.X.1992, leg. R. Cerbino, M. Valle (2 males; CNSMB). Toscana-Firenze, Marradi, Ponte Valle, N 44.0481° E11.6746°, 500 m, 9.X.2002, leg. A. Usvelli, (12 males, 5 females; OPC). Toscana-Firenze, Marradi, Badia Valle, N44.0481° E 11.6746°, 430 m, 28.X.1999, leg. A. Usvelli, (1 male; FMNHU). Toscana-Arezzo, Pieve Santo Stefano, F. Tevere, Valsavignone, N43.738° E12.029°, 550 m, 25.XI.1992, (1 male; n°251 CC). Toscana-Arezzo, aff. di destra dell'Arno, 27.X.1991, leg. Melai (4 females, n°120 CC). Marche-Ancona, Fabriano, alto corso torr. Giano, N43.28° E12.80°, about 600–700m, 11.XI.1994, leg. S. Capocchia (1 male; n°1064 CC). Piemonte-Torino, Robassomero, Canale Druento, N 45.2095° E7.5519°, 385 m, 30.XI.2005, leg. F. Vaccarino, (3 males, 2 females; OPC). Piemonte-Torino, Robassomero, Canale Druento, N 45.2095° E7.5519°, 385 m, 22.X.2006, leg. F. Vaccarino, (1 male; CNSMB). Piemonte-Cuneo, Revello, La Rocchietta, fiume Po, N44.6340° E7.3714°, 390 m, 1.X.1997, leg. O. Lodovici, (6 males, 11 females; OPC).



**Figures 1–3.** *Allogamus antennatus* (McLachlan, 1876). 1 = male phallic organ in left lateral view, 2 = aedeagus in ventral view, 3 = female vaginal sclerite complex with the tip of accessory duct, dorsal profile.

**Remarks.** It is distinguished as an incipient species by the shape of the ventral sclerites on the head of the aedeagus modified into a laterally serrated large tooth, by the pattern of the secondary spines on the parameres and by both the dorsal and lateral pattern of the modified accessory duct of the female vaginal sclerite complex. The dorsolateral pair of semisclerotized plates less produced laterad, subtriangular. Anterior ending of the enlarged modified accessory duct broad, not tapering slender and not capitate.

***Allogamus ausoniae* Moretti, 1991 stat. nov.**

(Figures 4–6, 12)

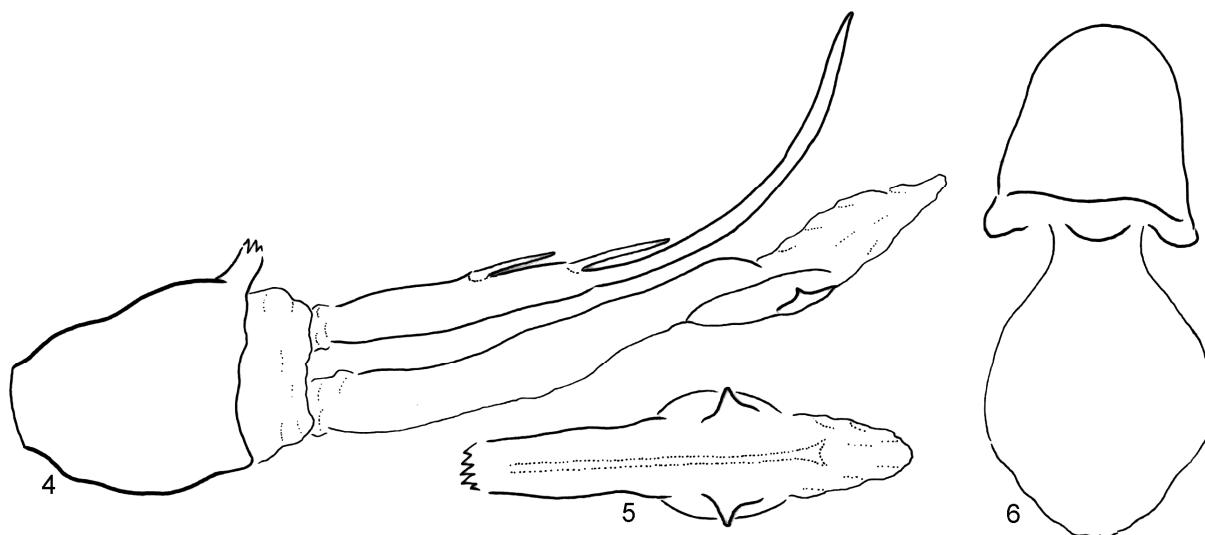
*Allogamus ausoniae* Moretti, 1991:393,399.

*Allogamus antennatus ausoniae* Moretti, 1991 reduced to subspecies level by Malicky (2005:574–575).

**Material examined.** *Italy.* Marche-Macerata, Visso, torrente Nera, 9.X.1997, leg. F. Cianficconi, (1 male, 4 females; OPC). Marche-Macerata, Visso, fiume Nera c/o stab. Cherubini, 24.X.1977 leg. Santicchia, (8 males, n°243 CC; 4 males, OPC). Abruzzo, Monti della Laga, 18. IX.1996, leg. B. Osella (5 males, 1 female; n°201 CC). Abruzzo-Aquila, Ortona de'Marsi, Cesoli, fiume Giovenco, N42.011° E13.709°, 870 m, 21. X.2000, leg. B. Osella (3 males, 6 females;

n°1594 CC). Molise-Campobasso, Bojano, sorgenti del Biferno, N41.4798° E14.4779°, 480 m, 31.VIII.2000, leg. E. Bertuetti et al. (1 male, 1 female, CNSMB). Molise-Campobasso, Bojano, torr. Calderone aff. Biferno, N41.482° E14.659°, 24.X.1995, leg. M. Baccaro (18 males, n°1010 CC; 10 males, OPC). Molise-Campobasso, Bojano, Fiume Biferno, sorg. Majella, N41.483° E 14.461°, 500 m, 30.X.1995, leg. M. Baccaro (14 females, n°1005 CC). Molise-Campobasso, Bojano, Fiume Biferno, Sorg. Pietre Cadute, N41.479° E14.478°, 488 m, 24.X.1995, leg. M. Baccaro (3 males; n°1013 CC). Lazio-Rieti, Cittareale, Fiume Velino 1 km a valle del paese, loc. Vezzano, N 42.615° E13.156°, 940 m, 17.X.1991, leg. P. Capoccia (1 male; n°926 CC). Lazio-Rieti, Rieti, Sorgenti del Cantaro, N42.409° E12.889°, 418 m, 25.X.1999, leg. S. Ceccarelli (1 male; n°772 CC).

**Remarks.** It is distinguished as an incipient species by the shape of the ventral sclerites on the head of the aedeagus with protruding sharp lateral tooth, by the pattern of the secondary spines on the parameres and by both the dorsal and lateral pattern of the modified accessory duct of the female vaginal sclerite complex. The dorsolateral pair of semisclerotized plates less produced laterad, rounded. Anterior ending of the enlarged modified accessory duct is capitate or clavate.



**Figures 4–6.** *Allogamus ausoniae* Moretti, 1991 stat. nov. 4 = male phallic organ in left lateral view, 5 = aedeagus in ventral view, 6 = female vaginal sclerite complex with the tip of accessory duct, dorsal profile.

***Allogamus morettii* De Pietro & Cianficconi,  
2001 stat. nov.**

(Figures 7–8, 13)

*Allogamus morettii* De Pietro & Cianficconi, 2001:61–66.

*Allogamus antennatus silanus* Moretti, 1991 synonymized by Malicky (2005:574–575).

**Material examined.** *Italy.* Sicilia-Messina, San Teodoro Aff. T. dei 3 Valloni, c. da Lineri, 1220 m, 10.XI.2001, leg. R. DePietro (1 male; OPC). Sicilia-Catania, Randazzo, affluente sorgente Alcantara, N37,8924° E14,9453°, 850 m, 28.XI.1995, light trap, Leg. P. Pantini, M. Valle (1 male; CNSMB). Sicilia-Catania, Maniace, Nebrodi Mountains, torrente Saracena, 1350 m, 23.X.1992, R. DePietro (1 female; OPC). Calabria-Reggio Calabria, Reggio Calabria, Serro Longo, torr. Listi, 1360 m, light trap, N38,145° E15,836°, 10.XI.2013, leg. E. Castiglione, F. Manti, P. Pantini (2 males, 5 females CNSMB; 1 male 3 females, OPC). Calabria-Reggio Calabria, Scilla, P.te S. Antonio, torr. Favazzina, 1260 m, light trap, N38,187° E15,846°, 10.XI.2013, leg. E. Castiglione, F. Manti, P. Pantini (1 male; CNSMB). Calabria-Reggio Calabria, Cardeto, Cendri, rivolo sorgentizio, 1340 m, light trap, N38,105° E 15,845°, 10.XI.2013, leg. E. Castiglione, F. Manti, P. Pantini (1 male; CNSMB). Calabria-Reggio

Calabria, San Lorenzo, Sega di Cufolo, fiume Melito, 1300 m, light trap, N38,097° E15,854°, 10.XI.2013, leg. E. Castiglione, F. Manti, P. Pantini (10 females; CNSMB).

**Remarks.** Distinguished as an incipient species by the blunt triangular shape of the ventral sclerites on the head of the aedeagus without protruding sharp lateral tooth and by both the dorsal and lateral pattern of the modified accessory duct of the female vaginal sclerite complex. The dorsolateral pair of semisclerotized plates much produced laterad, rounded. Anterior ending of the enlarged accessory duct is tapering, not broad, clavate or capitate; in lateral view S-shaped sigmoid.

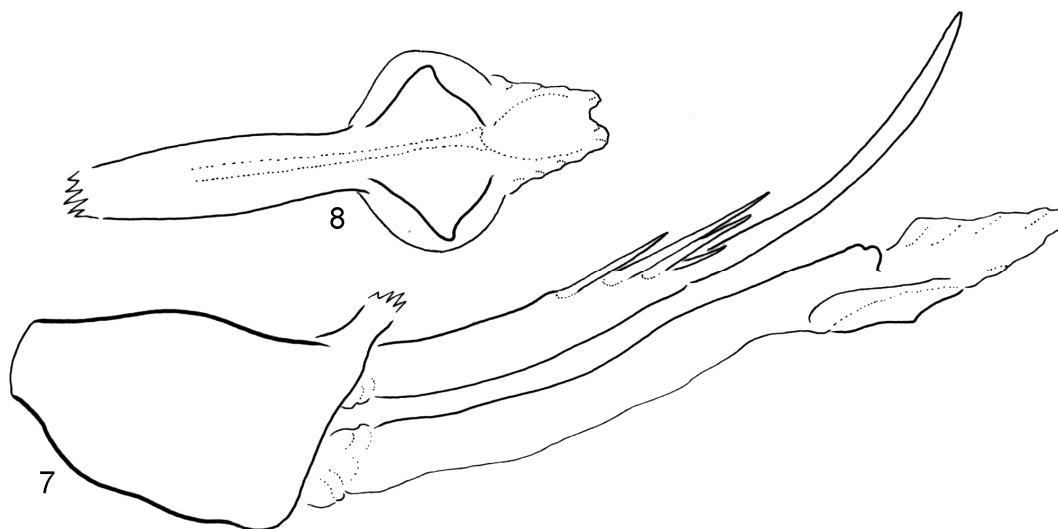
***Allogamus silanus* Moretti, 1991, stat. nov.**

(Figures 9–10)

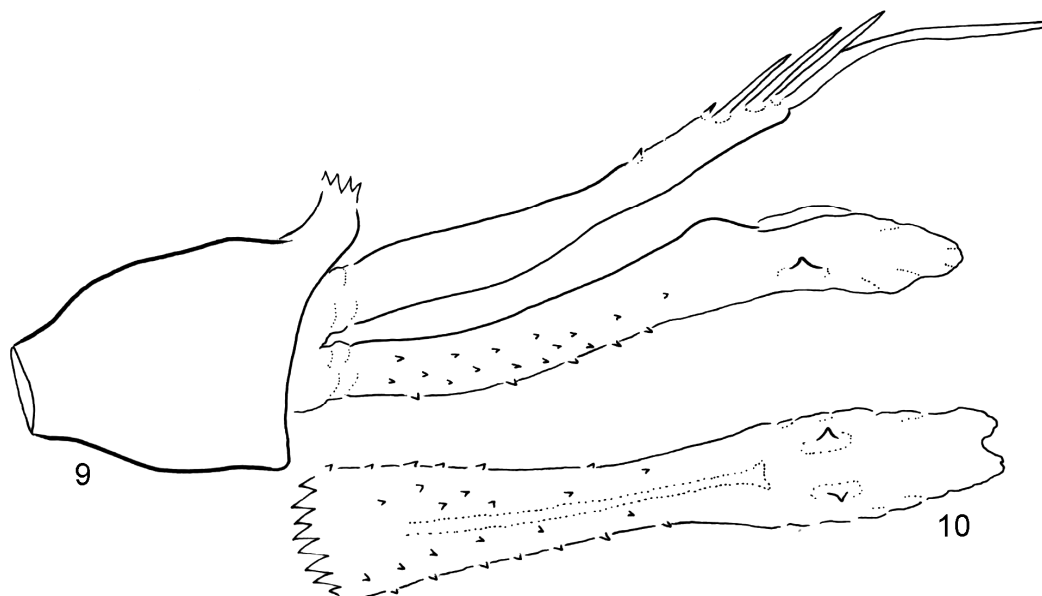
*Allogamus hilaris silanus* Moretti, 1991:400.

*Allogamus antennatus silanus* Moretti, 1991. Transferred by Malicky 2005:574–575.

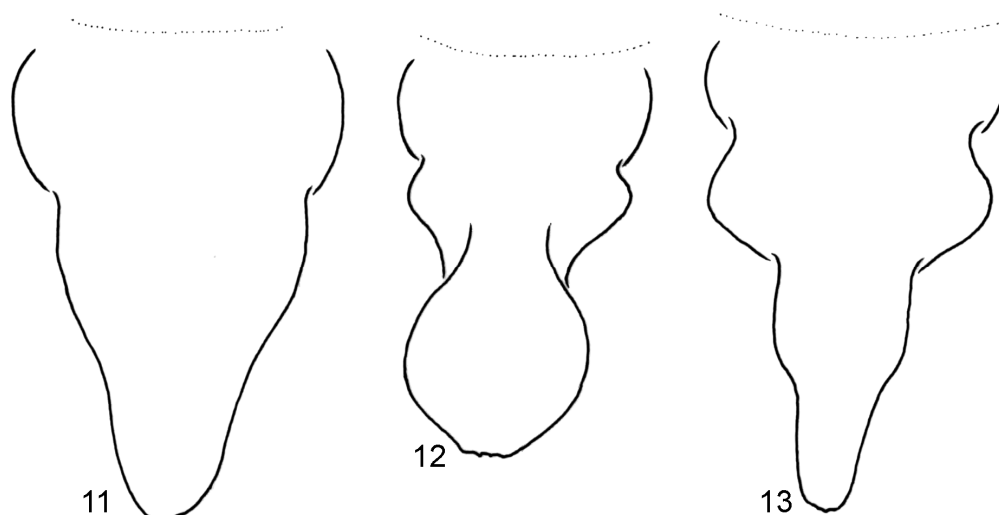
**Material examined.** Holotype. The collection data have been corrected on the label of the holotype: Calabria, Sorgente, Materazzelli, Aspromonte, 1780 m, 18.IX.1972, leg. A. Michelizzi (1 male, MC).



**Figures 7–8.** *Allogamus morettii* De Pietro & Cianficconi, 2001 stat. nov. 7 = male phallic organ in left lateral view, 8 = aedeagus in ventral view.



**Figures 9–10.** *Allogamus silanus* Moretti 1991, stat. nov. 9 = male phallic organ in left lateral view, 10 = aedeagus in ventral view.



**Figures 11–13.** Dorsal profile of the tip of female accessory duct. 11 = *Allogamus antennatus* (McLachlan, 1876), 12 = *Allogamus ausoniae* Moretti 1991, 13 = *Allogamus morettii* De Pietro & Cianficconi, 2001.

*Remarks.* The description of this taxon has been based on a single male specimen and no more material was discovered. The re-examination of the carefully cleared genitalia of the holotype confirms its well differentiated divergent state. The ventral pair of sclerotized plates reduced its triangular tooth miniaturized, almost indiscernible. The dorsolateral pair of semisclerotized plates are very narrow, not produced laterad;

aedeagal stem densely covered with small triangular teeth, a unique apomorphic trait. Terminal spine pattern of parameres specific.

#### *Allogamus auricollis* new species subgroup

Dark species characterized with a strong single primary seta on paramere accompanied by smaller secondary setae in ventromesal position. Modified accessory duct of female lacking.

***Allogamus alpinensis* Oláh, Lodovici & Valle sp. nov.**

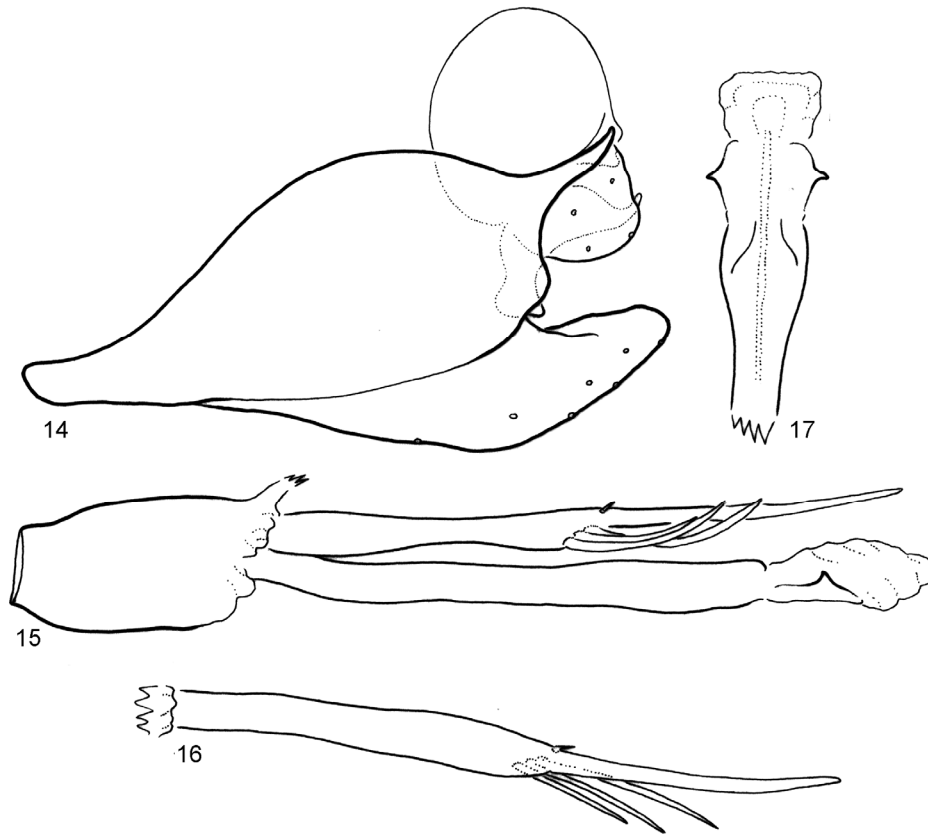
(Figures 14–17, 18–21, 22–46, 47–66)

**Diagnosis.** All specimens revised here from the Central Alps have been determined earlier as *Allogamus auricollis*. Here we split *Allogamus alpinensis* sp. nov. from *Allogamus auricollis* as an incipient species inhabiting the Central Alps. This new species is characterized by having very stable non-neutral, selection-driven adaptive diverged traits on the phallic organ evolved in sexual selection processes. The periphallid organs are similar and vary in wide range of the neutral traits. Especially the lateral profile of cerci varies both among and inside populations. In contrary the recently diverged non-neutral fine structures of the parameres and aedeagus are very stable. *Allogamus alpinensis* sp. nov. has 3 (2–4) secondary setae on parameres in ventral position, lacking at *A. auricollis*. The pair of ventroapical sclerite on the aedeagus head is characterized by distinct lateral dentate and pointed tip. The ventroapical sclerite on the aedeagus head has oblique apical pointed tip at *A. auricollis*. There are stable divergences also in the structures of the vaginal sclerite complex both in lateral and dorsal profiles. However the fine structure diversifications on vaginal sclerite complex are frequently difficult to recognise clearly because of masking effect of the undigested residues of membranous vaginal chamber and its draining ducts even after careful clearing and cleaning processes. We have examined the diverged structure matrices of the new species from Austria, Italy, Liechtenstein and Switzerland populations (Figures 22–46, 47–66). The comparison of matrices of the new species to diverged structure matrices of *A. auricollis* populations collected from the entire distributional area demonstrates significant and stable divergences in the diverged non-neutral traits of paramere setae and aedeagus sclerites.

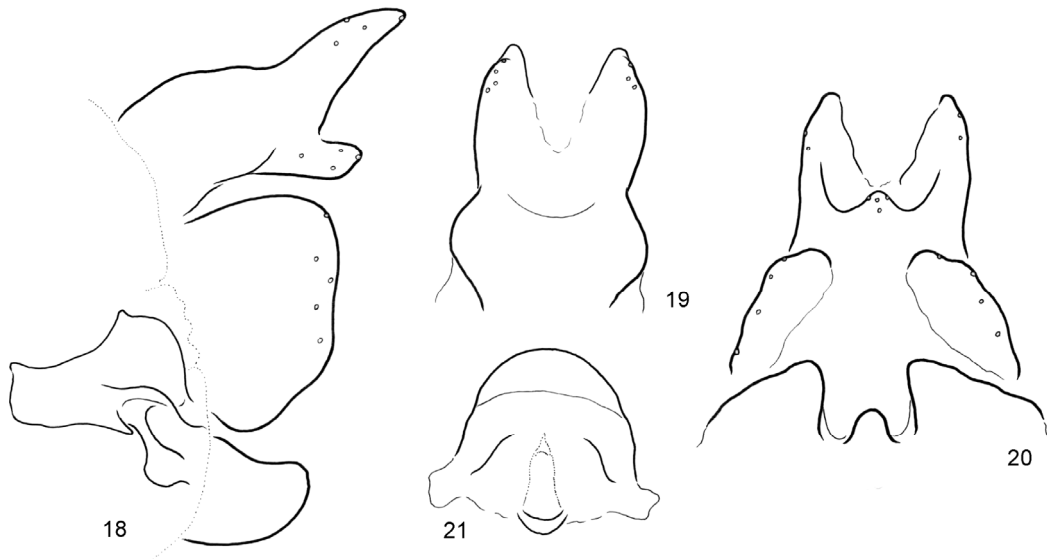
**Material examined.** *Holotype.* Italy, Lombardia Bergamo, Valgoglio, Valsanguigno, torrente, N 45.9669° E 9.8853°, 1300 m, 10.X.2009, light trap, leg. S. CERA (1 male, CNSMB). *Allotype*

same as holotype (1 female, CNSMB). *Paratypes* same as holotype (1 male, OPC). Lombardia-Bergamo, Valcanale 1000 m, 30.X.2007, leg. W. Zucchelli (1 male, CNSMB). Lombardia-Bergamo, Ardesio, Valcanale, prato stabile, Light trap, N45.949° E 9.855°, 1000 m, 15.X.2008, leg. W. Zucchelli (2 males, CNSMB). Lombardia-Bergamo, Carona, N46.0196° E 9.7802°, 1100 m, 11.X.2006, leg. M. Valle (1 male, 2 females; CNSMB). Lombardia-Bergamo, Casnigo, 45.8175 9.8695, 520 m, 12.IX.2002, leg. R. Calandrina (2 males, 1 female; CNSMB). Lombardia-Bergamo, Mezzoldo, fiume Brembo, 1100 m, light trap, N46.0236° E 9.6611°, 3.X.1995, leg. F. Albrici, M. Valle (1 male; CNSMB). Lombardia-Bergamo, Gazzaniga, valle Platz, 850 m, light trap, 2.X.1993, leg. Gusmini (38 males, 3 females; CNSMB). Lombardia-Brescia, Vione, Val Canè Rifugio Cortebona, 1800 m, light trap, N46.2765° N10.4521°, 20.IX.1982, leg. Bonacina, M. Valle (21 males; CNSMB). Trentino-Alto Adige-Trento, Rabbi, affluenti torrente Rabbits, N 46.4085° E10.7913°, 1250 m, 8.IX.2004, light trap leg. O. Lodovici & M. Massaro (1 male, CNSMB; 4 males, OPC). Trentino-Alto Adige-Bolzano, Taufers im Münstertal (Tubre), Südtirol, 1300 m, 6.X.2007, leg. F. Pühringer, (9 males, present from MPC, OPC). Trentino-Alto Adige-Bolzano, Bolzano, IX.1978, leg. Osella (1 male; CNHNV). Trentino-Alto Adige-Bolzano, Glorenza, IX.1978, leg. Osella (4 males, 2 females; CNHNV). Trentino-Alto Adige-Bolzano, Bressanone, 28.IX.1986, leg. Campadelli (5 males, 1 female; CNSMB); Piemonte-Cuneo, Crissolo, Pian del Re, fiume Po, N44.7005° E7.0934°, 2020 m, 1.X.1997, light trap leg. O. Lodovici (11 males, 5 females; OPC). Piemonte-Cuneo, Briga Alta, rivolo sorgentizio dopo Viozene, N44.1443° E7.7751°, 1250 m, 10.X.2001, light trap leg. Museo Caffi BG (19 males, 1 female; OPC). Piemonte - Cuneo, Crissolo, Piano della Regina, Monviso sorgenti del Po, 20.IX.1990, leg. Chiappafreddo, Pulcinelli (1 female, n°1254 CC). Piemonte - Cuneo, Sampeyre, Becetto, Meire Ruà, 1550 m, N44.596° E7.201° 6.X.2007, leg. G. Gardini (1 male; CNSMB). Piemonte - Cuneo, Crissolo, Piano della Regina, fiume Po, light trap, N44.7000° E7.1163°, 2.IX.1997 (51 males, 1 fe-

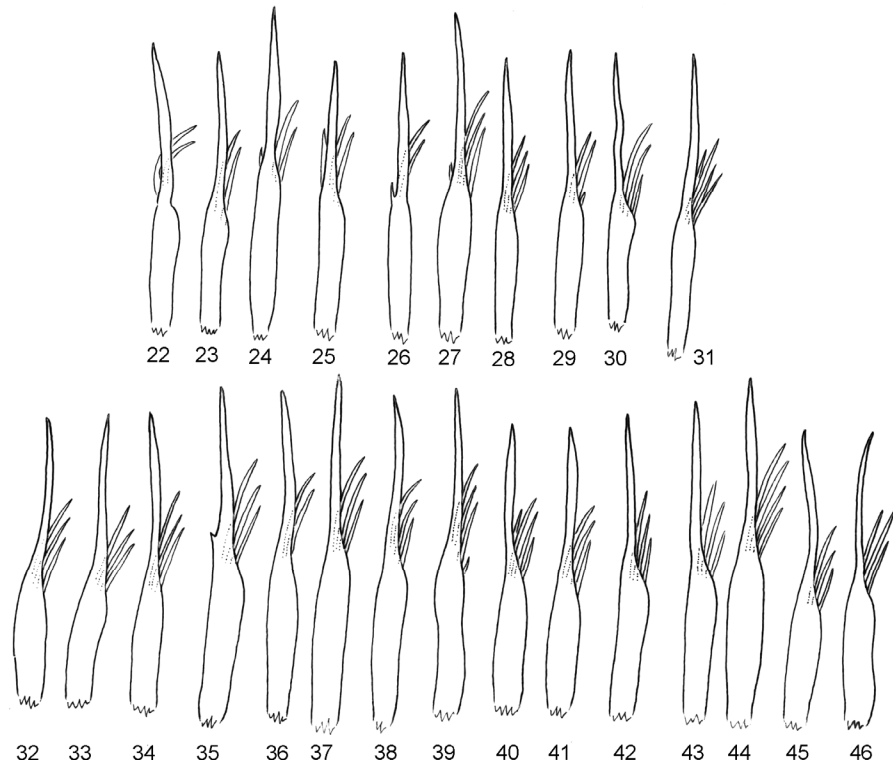




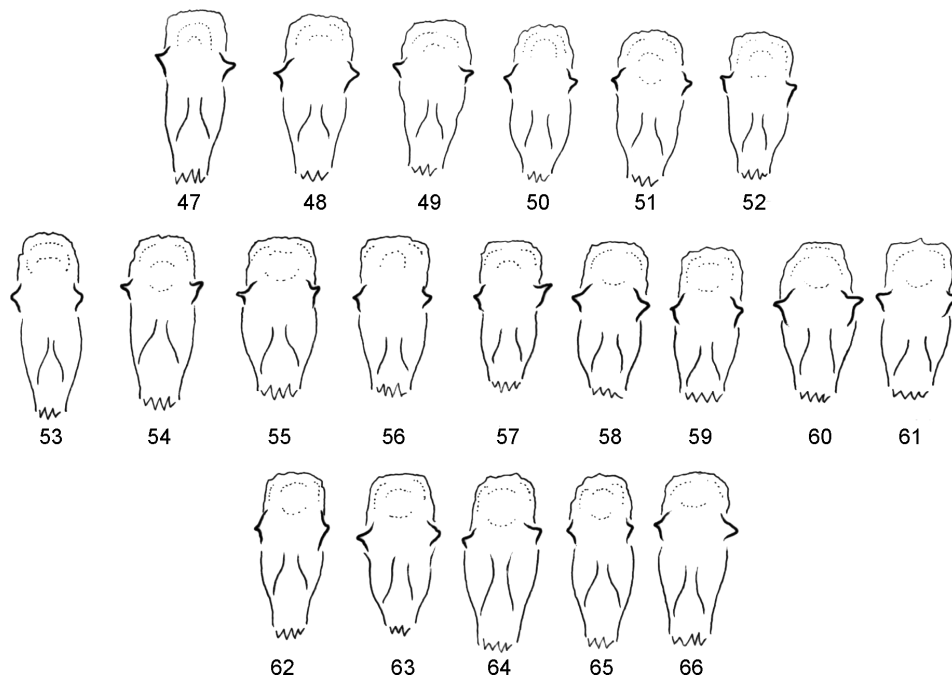
**Figures 14–17.** *Allogamus alpenis* Oláh, Lodovici & Valle sp. nov. 14 = male genitalia in left lateral view, 15 = phallic organ in left lateral view, 16 = left paramere in dorsal view, 17 = aedeagus head in ventral view.



**Figures 18–21.** *Allogamus alpenis* Oláh, Lodovici & Valle sp. nov. 18 = female genitalia in left lateral view with vaginal sclerite complex, 19 = female anal tube in dorsal view, 20 = female genitalia in ventral view, 21 = dorsal profile of vaginal sclerite complex.



**Figures 22–46.** *Allogamus alpinus* Oláh, Lodovici & Valle sp. nov. Diverged structure matrix of left paramere in dorsal view.  
22–31 = Italian populations, 32–41 = Switzerland population, 42 = Liechtenstein population, 43–46 = Austrian population.



**Figures 47–66.** *Allogamus alpinus* Oláh, Lodovici & Valle sp. nov. Diverged structure matrix of aedeagus head in ventral view.  
47–52 = Italian population, 53–61 = Switzerland population, 62 = Liechtenstein population, 63–66 = Austrian population.

male; CSNMB). Valle d'Aosta - Aosta, Aosta, 500 m, 26.IX.1980, leg. F. Faraci (1 male, CNHNV). Valle d'Aosta - Aosta, Prè Saint Didier, 1200 m, 27.IX.1980, leg. F. Faraci (2 males; CNHNV). Veneto-Belluno, Cesiomaggiore, Val Canzoi, torrente Caorame, N46.1167° E 11.9376°, 590 m, 14.X.2002, light trap leg. O. Lodovici, P. Pantini (2 males, 29 females; CNSMB). Veneto-Belluno, Cesiomaggiore, Val Canzoi, rivolo sorgentizio, N46.1167° E 11.9376°, 590 m, 14.X.2002, light trap leg. O. Lodovici, P. Pantini (3 males, 3 females; CNSMB). Veneto-Belluno, Cesiomaggiore, Val Canzoi pozza c/o rivolo sorgentizio, 590 m, light trap, N46.111673° E 11.937602°, 14.X.2002, leg. O. Lodovici, P. Pantini (2 males, 3 females; CNSMB). Friuli Venezia Giulia-Udine, Paularo, torr. Chiarsò, 670 m, light trap, N45.5776° E 13.1139°, 18.IX.1996, leg. Pantini, Valle (1 male; CNSMB). Friuli Venezia Giulia-Udine, Tarvisio, torr. Slizza, 630 m, light trap, N46.5136° E 13.6137°, 19.IX.1996, leg. P. Pantini, M. Valle (1 male; CNSMB). Austria. superior, Reichraming, 9.X.1983, leg. H. Malicky (10 males, 6 females; present from MPC, OPC). Voralberg, Ferwall, Zeinisjoch, 1850m, 4. IX.1975, leg. Aistleitner (7 males, present from MPC, OPC). Styria, Ardning, 29.IX.1992, leg. H. Malicky, (9 males, 7 females; present from MPC, OPC). Tirol, Innsbruck, Alpenzoo, 1977, leg. G. Tarmann, (11 males, 8 females; present from MPC, OPC), (PS vary 3-1). Carinthia, Gitschtal, 1984-1990, leg. C. Wieser (25 males, 10 females; present from MPC, OPC). Carinthia, Lendorf, 14.IX.1987, leg. C. Wieser (73 males, 13 females, OPC; 9 males, 3 females MMUE; 9 males, 1 female; NHML). France. Isère Department, Saint Christophe en Oisans, D 530 les Pièces du Clot la Berande, 13. IX. 2007 leg. G. Coppa (1 male, CPC). Liechtenstein. Schellenberg, 26. IX. 1988, leg. Aistleitner (9 males, 7 females; present from MPC, OPC). Switzerland. Wallis, 2.5 km nò Salgesch, N46°19'34" E7° 35'24", 1390 m, 12.X.2001, leg. A. Bischof & G. Bischof, (6 males, present from MPC, OPC). Ticino, Gudo, Mitte X. 1982, leg. L. Rézbányai (7 males, 2 females; present from MPC, NMPC). Uri, Hospental, 1500 m, Ende IX. 1982, leg. L. Rézbányai (6 males, 4 females; present from MPC, OPC).

*Description.* Male and female (in alcohol). Dark and medium-sized animals. Forewing length 12 mm.

*Male genitalia.* Genital cavity is very large and deep. Cerci rounded in lateral and harpagones rounded in caudal view. Parameres with 3 secondary setae in ventral position. Sclerites on aedeagus head with lateral tooth.

*Female genitalia.* External genital structure is similar to the subgroup. Anterior apodemes on the vaginal sclerite complex laterad directed. Accessory duct on the vaginal sclerite simple not enlarged and modified.

*Etymology.* Named for the region of Central Alps, where this new species is distributed.

### *Allogamus* sp.

*Material examined.* Molise - Campobasso, Guardiaregia, Piana Perrone, Matese, 1200 m, 27. IX.2000, leg. Marinelli (1 female, CNSMB).

*Remarks.* A single female lacking modified accessory duct belongs to the *Allogamus auricollis* species subgroup. More specimens including males are requested to identify properly. It could be either *A. alpenensis* or *A. auricollis*.

### *Allogamus auricollis* (Pictet, 1834)

(Figures 67–73, 74–117, 118–142)

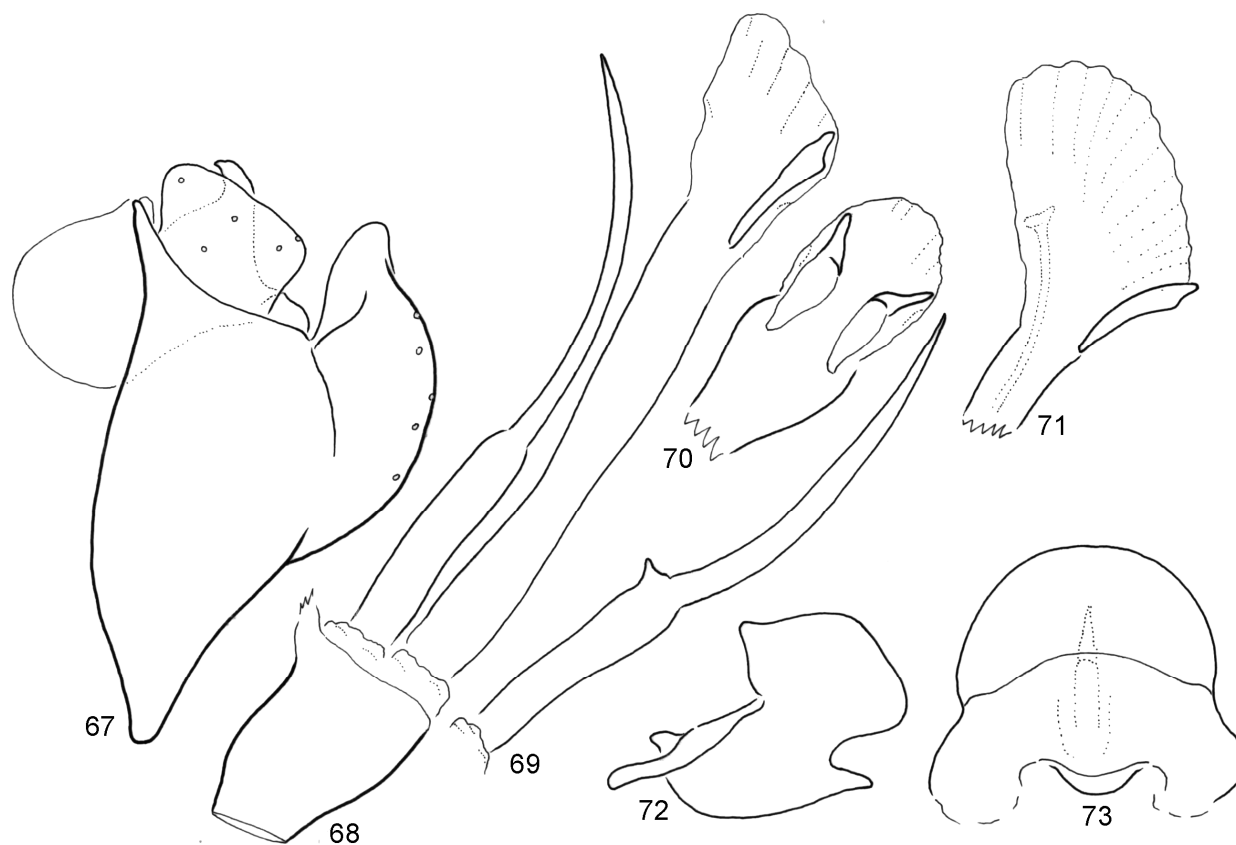
*Material examined.* Albania. Dibër district, Korab Mts, brook beneath Fushë Korabit, N41°49.209' E20°30.745', 1770 m, 07.X.2012, leg. P. Juhász, T. Kovács, D. Murányi, G. Puskás (1 male, OPC). Dibër district, Korab Mts, Radomirë, stream E (above) of the village, N41°49.043' E20°30.013', 1440 m, 7.X.2012, leg. P. Juhász, T. Kovács, D. Murányi, G. Puskás (2 males, 4 females; OPC). Dibër district, Korab Mts, open stream above Fushë Korabit, N41°49.215' E20°32.738', 1945 m, 07.X.2012, leg. P. Juhász, T. Kovács, D. Murányi, G. Puskás (2 females, OPC). Dibër district, Korab Mts, Radomirë, brook E (above) of the village, N41°49.152' E20°30.111', 1495 m, 07.X.2012, leg. P. Juhász, T. Kovács, D. Murányi, G. Puskás

- (3 males, 3 females; OPC). *Austria*. Inferior, Lunz, Ybbs bei Weissenbach, 20. VIII. 1969 leg. H. Malicky, (12 males, 7 females; present from MPC, OPC). Inferior, Purgstall, N 48.255 E15.81, 305m, 7.X.2012, leg. E. & J. Hüttinger (19 males, 25 females; present from MPC, OPC). *Czech Republic*. Southern Bohemia, Šumava Mts, Modrava, Weitfallerské slatě, N49°01' E13°25', 3.VIII.2011, leg. A. Pavlicko (4 males, 4 females; present from MPC, OPC). Southern Bohemia, Šumava Mts, Teplá Vltava river above Kvilda, 1050 m, N49°00'38" E13°34'23", 26. VII.1991, leg. P. Chvojka (7 males, 3 females, NMPC). Northern Bohemia, Jizerské hory Mts, Jizerka, 850 m, N50°49'12" E15°20'43", 05.-08.VIII.1997, at light, leg. F. Krampl (15 males, NMPC). Northern Bohemia, Jizerské hory Mts, Příčná voda (tributary of Jizerka stream), 880 m, N50°50'14" E15°18'55", 27.VIII.1991, leg. P. Chvojka (7 females, NMPC). Eastern Bohemia, Broumovské hills, Metuje river below Adršpach, 500 m, N50°36'54" E16°07'22", 08.X.1997, leg. P. Chvojka (1 male, 3 females, NMPC). *England*. River Dove, Derbysire, 4. X. 1913, leg. M. E. Mosely, Mosely Bequest. B.M. 1948-589, Ex. NHM-London (6 males, 4 females; OPC). R. Wharfe, Grass Wood, Grassington, North Yorks, 17. IX. 1925, leg. A. Brindle (6 males, 6 females; present from MMUE; OPC). *France*. Massif-central, Lozère Department, Meyrueis, La Breze, 27. X. 2010 leg. G. Coppa (1 male, 3 females; CPC). Massif-central, Lozère Department, Bassurels, Le Tarnon Pont D19, 28. X. 2010 leg. G. Coppa (6 females; CPC). Massif-central, Lozère Department, Bassurels, Le Trepalou, 26. X. 2010 leg. G. Coppa (4 females; CPC). Massif-central, Puy-de-Dôme Department, La Tour d'Auvergne, La Burande Pont, 28. X. 2011 leg. G. Coppa (1 male; OPC). Massif-central, Puy-de-Dôme Department, Saint Victor la Riviere, Ru en Dessus de Courbanges Ru Malvoissiere/Gr, 24. X. 2013 leg. G. Coppa (1 male; 3 females; OPC). Vosges Department, Le Valtin, La Meurthe en Amont de l'Etang, 4. X. 2012 leg. G. Coppa (1 male, OPC). Pyrénées, Pyrénées-Orientales Department, Porte Puymorens, Ru de l'Orris, 21. VIII. 2011, leg. G. Coppa (6 males, 6 females; OPC). Pyrénées, Pyrénées-Orientales Department, Err, Ru d'Err Aiguanein, 24. VIII. 2011, leg. G. Coppa (2 males, 1 female; CPC). Pyrénées, Aude Department, Saint Martin Lys, Pont Village sur l'Aude, 29. X. 2008, leg. G. Coppa (1 male, 1 female; CPC). Pyrénées, Ariège Department, Belesta, Source Fontes Tarbes, 29. X. 2008, leg. G. Coppa (1 male, CPC). Pyrénées-Atlantiques, Vallée Ossau, 1984, leg. G. Vincon (1 male, OPC). *Kosovo*. Brod River, 6. X. 2013, leg. H. Ibrahim (7 males, 4 females; OPC). *Macedonia*. Polog region, Šar Planina, Vešala (Veshallë), open, rocky stream at the village, N42°03.865' E20°50.866', 1290m, 1.X.2013, leg. T. Kovács, D.Murányi, (2 males, 5 females; OPC). Polog region, Šar Planina, Bozovce, seeps and woody pasture W (above) of the village, N42°03.125' E20°49.377', 1350m, 1.X.2013, leg. T. Kovács, D.Murányi, (2 males, OPC). *Montenegro*. Berane municipality, Bjelasica Mts, Kurikuće, Suvoda Stream, 1170 m, N42°52.781', E19°44.467', 11.X.2008, L. Dányi, Z. Fehér, J. Kontschán & D. Murányi (11 females). Plav municipality, Gusinje, Alipašini Springs, 935 m, N42°33.014', E19°49.486', 4.X.2005, leg. T. Deli, Z. Erőss, Z. Fehér & D. Murányi (2 males, 1 female). Plav municipality, Prokletije Mts, Vusanje, Oko Spring and Grlja Stream, 1035 m, N42°30.704', E19°50.088', 12.X.2008, leg. L. Dányi, Z. Fehér, J. Kontschán & D. Murányi (1 female). Šavnik municipality, Sinjajevina Mts, Boan, Bukavica Stream W of the village, 1005 m, N42°57.042', E19°10.410', 10.X.2008, leg. L. Dányi, Z. Fehér, J. Kontschán & D. Murányi (1 female). Šavnik municipality, Vojnik Mts, Mokro, forest spring and its outlet brook at the village, 1060 m, N42°56.858', E19°05.463', 9.X.2008, leg. L. Dányi, Z. Fehér, J. Kontschán & D. Murányi (3 males, 1 female). Prokletije Mts, Gusinje, Alipašini Izvori, 42°33'01.2", 19°49'30.5", 930 m, 08. XI.2011, leg. Kovács, T., Magos, G. (1 male, 7 females; OPC). *Poland*. High Tatras, Chochołowska valley 22.VIII.1986, leg. J. Oláh, (6 males, 2 females, OPC). High Tatras, Chochołowska valley, potok na Polianie Huciska, 21.VIII.2009 leg. J. Oláh, (1 male, OPC). High Tatras, Bela River, 6.X.1976, ligh trap leg. Nagy (7males, 1 female; OPC). Gorce Mts. 21.IX.1989, leg. H. Malicky (3 males, 3 females; present from MPC,

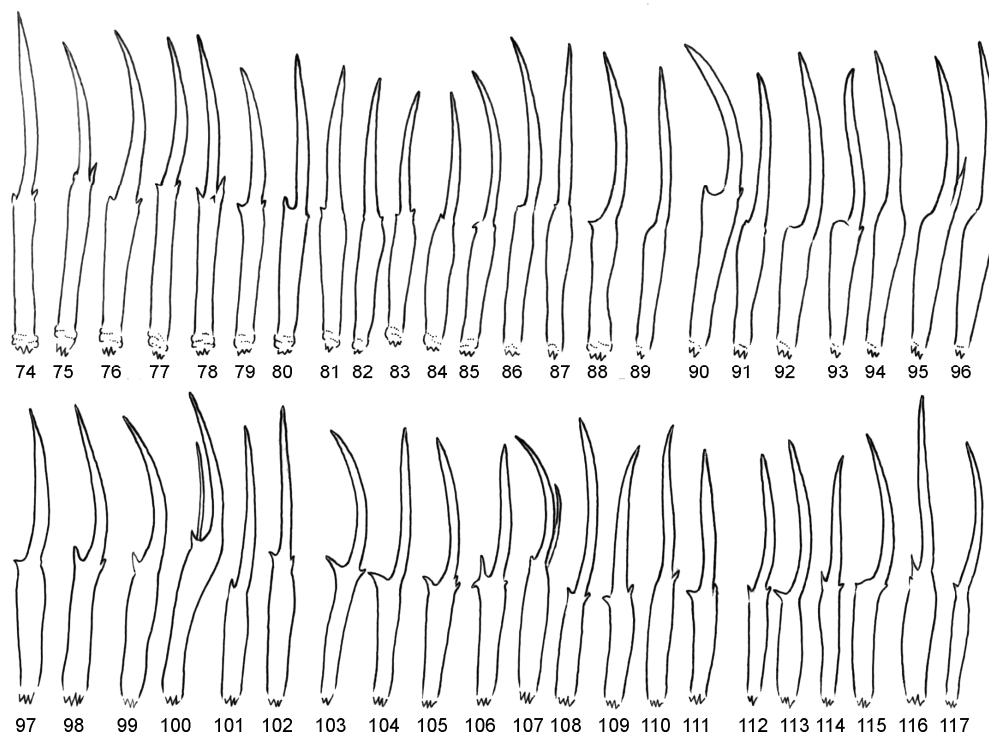
OPC). *Romania*. Arges County, Fagaras Mts. Capatanenii Ungureni, small springlake by the Capra stream along road No. 7C, N45°34.605' E45°34.605', 1405 m, 29.VIII.2012, leg. T. Kovács, D. Murányi & J. Oláh (4 males, 1 female, 13 pupae; OPC). *Slovakia*. Low Tatras, Východná, 17.IX.1999, leg. J. Ortner (4 males, 4 females; present from MPC, OPC). River Ľupčianka Partizánska Ľupča, Low Tatras National Park, 570 m, 5. X. 2008, leg. Richabun team (1 female, OPC). River Ľubochňanka, Ľubochňa, Veľká Fatra Natonal Park, 570 m, 5.X.2008, leg. Richabun team (3 females, OPC). Podtatranská kotlina basin, Belá river, Pribylina, 760 m, N49°06'06" E19°48'35", 11.X.1991, leg. P. Chvojka (2 males, 4 females, NMPC). Podtatranská kotlina basin, Studený potok stream, Stará Lesná, 780 m, N49°08'37" E20°17'25", 28.IX.1989, leg. P.

Chvojka (6 males, 6 females, NMPC). High Tatras, Javorinka stream, 1030 m, N49°15'37" E20°08'31", 17.IX.1988, leg. M. Černý (5 males, 6 females, NMPC). Belianske Tatras, Biela river, Ždiar, 880 m, N49°16'09" E20°15'58", 29.IX. + 06.X.1989, leg. P. Chvojka (6 males, 4 females, NMPC). *Ukraine*. Bieszczady Mts (Besszádok), Ung National Park, above Lubnya (Kiesvölgy), N: 49°02' 13,90" E: 22°42' 59,75", 579 m, singled, 20. IX. 2013, leg. J. Oláh, Cs. Balogh, Cs. Deák & I. Meszesán (1 male, OPC).

**Remarks.** The fine structures of the aedeagus and parameres summarized in the diverged structure matrices are rather stable both inside and among the different populations from the entire distributional area, from England to the Pyrénées and to Albania.



**Figures 67–73.** *Allogamus auricollis* (Pictet, 1834). 67 = male genitalia in left lateral view, 68 = phallic organ in left lateral view, 69 = left paramere in dorsal view, 70 = aedeagus head in ventral view, 71 = aedeagus head in lateral view; endophallus almost fully erected indicating the ejaculatory duct with gonopore as well as the ventral sclerite in anchore position. 72 = female vaginal sclerite complex profile in lateral view, 73 = vaginal complex profile in dorsal view.



**Figures 74–117.** *Allogamus auricollis* (Pictet, 1834). Diverged structure matrix of left paramere in dorsal view. 74–79 = England population, 80–87 = France (Pyrénées) population, 88–89 = Czech population, 90–96 = Poland population, 97–101 = Austrian population, 102 = Ukrainian population, 103–106 = Romanian population, 107–111 = Montenegro population, 112–115 = Macedonian population, 116–117 = Albanian population.

### *Allogamus despaxi* Décamps, 1967

(Figures 143–144)

**Material examined.** The species was described from a single specimen. This holotype was preserved in alcohol and deposited in the author's collection at the Laboratory of Hydrobiology, Paul-Sabatier University, Toulouse. Dr. Décamps retired, a colleague who took care of his collection also retired. The Laboratory of Hydrobiology moved to a new place and the collection was possibly transferred to the Museum of Natural History in Toulouse. By intensive correspondence we have tried to find the holotype at the museum without any success. Finally Dr. Décamps informed us that they are unable to send us any specimen because the collection is probably pending somewhere and nobody is directly in charge of it at present. We have redrawn the phallic organ from the original drawings.

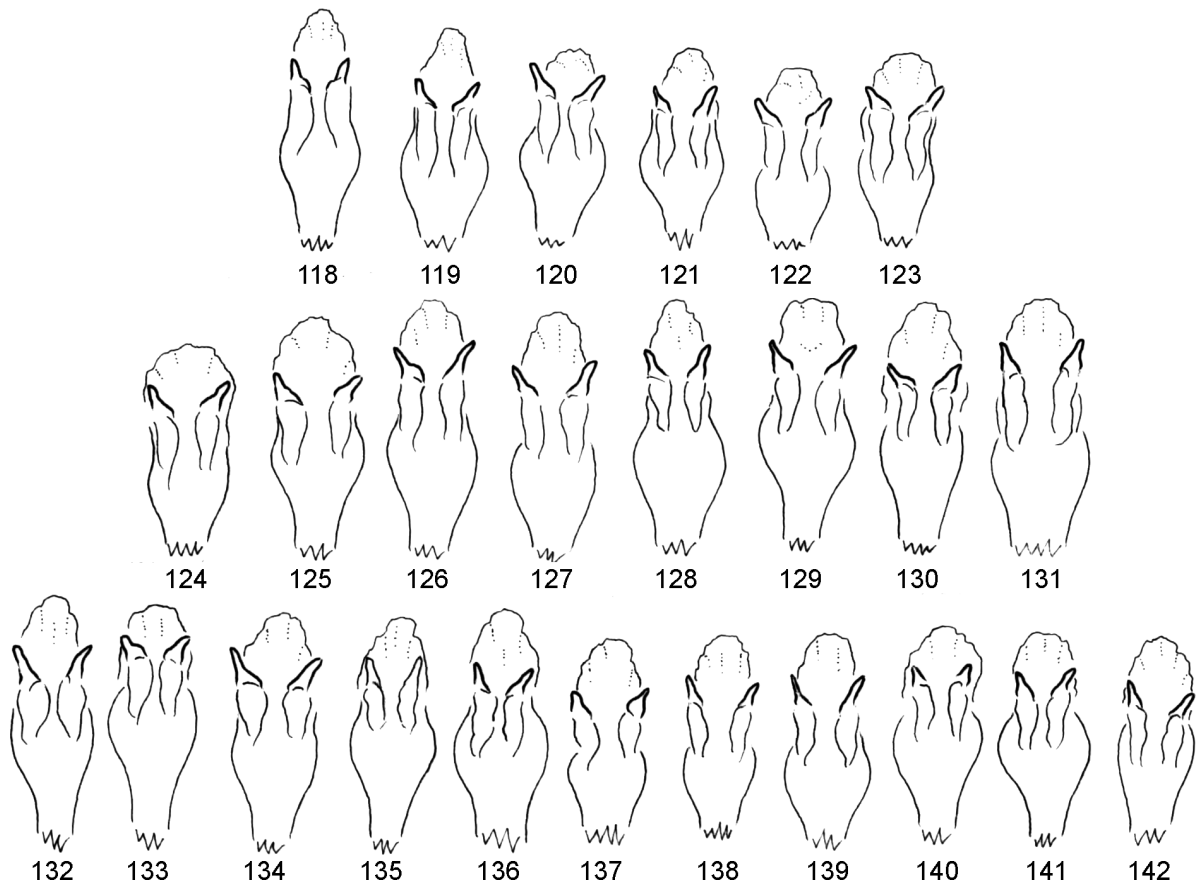
**Remarks.** This species was collected from Avajan, Neste d'Aure, 900 m, Hautes-Pyrénées.

Its taxonomic status was confirmed by M. D. E. Kimmins (Décamps 1967). Based upon the detailed original description and drawing and the characters of the closely related species from the nearby Valley Ossau *A. zomok* sp. nov. we have placed this species into the *Allogamus auricollis* subgroup.

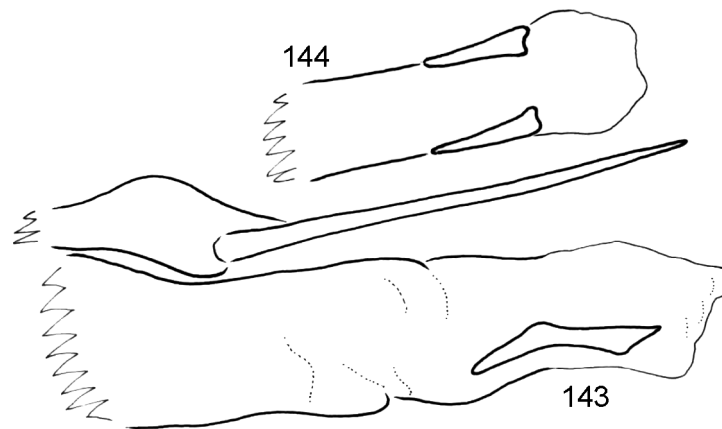
### *Allogamus zomok* Oláh & Coppa sp. nov.

(Figures 145–150)

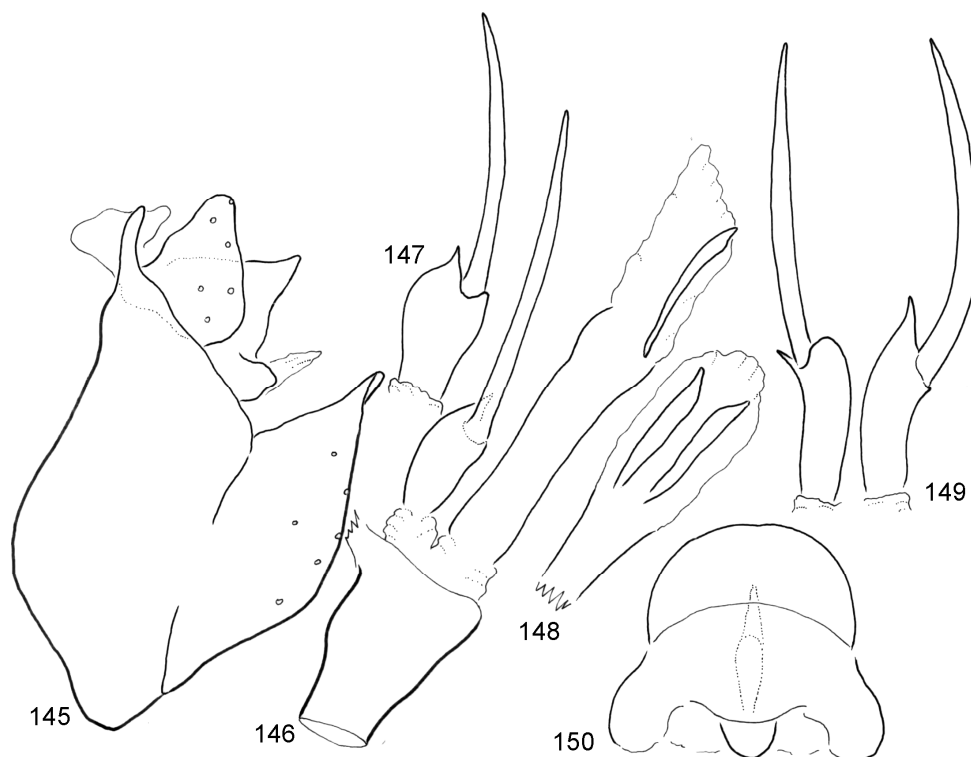
**Diagnosis.** Similar to *A. despaxi*, but differs by having genital cavity shrunken, almost vestigial, not large and deep; the third segment of the maxillary palp simple, not with unique tridentate distal end; apparent harpago of the gonopods broad rounded, not tapering, accessory process on the paraproctal basal triangle blunt, not slender in lateral view; apicoventral sclerite of the aedeagus differently formed and positioned.



**Figures 118–142.** *Allogamus auricollis* (Pictet, 1834). Diverged structure matrix of aedeagus head in ventral view. 118–123 = England population, 124–129 = Austrian population, 130 = Czech population, 131 = Ukrainian population, 132–136 = Montenegro population, 137–140 = Macedonian population, 141–142 = Albanian population.



**Figures 143–144.** *Allogamus despaxi* Décamps, 1967. 143 = male, phallic organ in left lateral view, 144 = aedeagus head in ventral view.



**Figures 145–150.** *Allogamus zomok* Oláh & Coppa sp. nov. 145 = male genitalia in left lateral view, 146 = phallic organ in left lateral view, 147 = left paramere in dorsal view, 148 = aedeagus head in ventral view, 149 = left and right parameres of paratype in dorsal view. 150 = female vaginal sclerite complex profile in dorsal view.

**Material examined.** *Holotype.* France, Pyrénées-Atlantiques, Vallée Ossau, 1984, leg. G. Vincon (1 male, OPC). *Allotype.* Same as holotype (1 female, OPC). *Paratypes.* Same as holotype (1 male, 2 females; OPC).

**Description.** In alcohol both male and female have forewing membrane dark. Forewing length 11 mm. Head, thorax and appendages dark brown.

**Male genitalia.** Genital cavity abbreviated, shrunken. Cerci subquadrangular. Paraproct triangular in lateral view. Accessory process on the basal triangulum of the paraproct present and blunt. Paramere shaft very short, stocky. Apico-ventral sclerite of the aedeagus narrow elongated.

**Female genitalia.** External genital structure similar to the species subgroup. Anterior apodemes of the vaginal sclerite complex simple rounded laterad.

**Etymology.** *zomok* from “zömök” stocky in Hungarian, refers to the reduced, abbreviated, al-

most vestigial genital cavity and the short and dumpy paramere shaft.

#### *Allogamus hilaris* new species subgroup

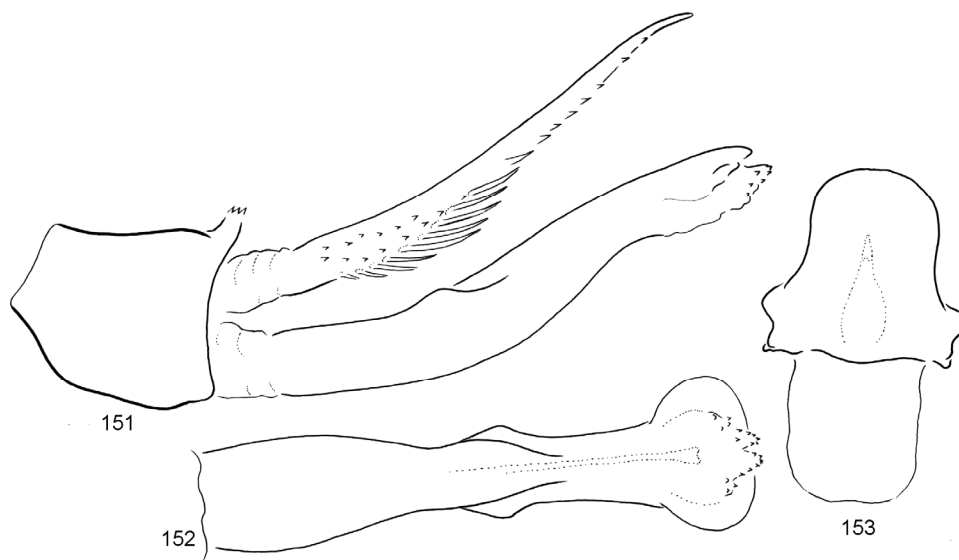
Light species characterized with a strong paramere shaft without primary seta. Longer secondary setae present midway, shorter setae present basolaterad and ventrad from middle to subapical. Modified accessory duct of female present.

#### *Allogamus hilaris* (McLachlan, 1876)

(Figures 151–153)

**Material examined.** France. Alpes-Maritimes, La Brigue, Torrent de Malaberhe, Lieu dit Vacherie, 24.IX.2008, leg. G. Coppa, (1 female; OPC). Italy. Piemonte-Cuneo, Ormea, rio Armella, N44.1639° E7.8821°, 1000 m, 10.X.2001, light trap, leg. Museo Caffi, Bergamo (2 males, 1 female; OPC). Piemonte-Torino, Ceresole Reale,





**Figures 151–153.** *Allogamus hilaris* (McLachlan, 1876). 151 = male phallic organ in lateral view, 152 = aedeagus in ventral view. 153 = female vaginal sclerite complex with the anterior tip of the modified accessory duct profile in dorsal view.

Colle di Nivolet, Parco Nazionale del Gran Paradiso, 2700 m, 21.X.1990, leg. Chiappafreddo (1 male; N°1256 CC). Lombardia-Bergamo, Averara, Alpe Cul versante sud, N46.0440° E9.6201°, 1800 m, 23.IX.2004, leg. E. Bertuetti (9 males, 3 females; OPC). Lombardia-Bergamo, Mezzoldo, Alpe Ancogno, 1800 m, light trap, N46.0381° E9.6359°, 3.X.1995, leg. F. Albrici, M. Valle (5 males, 13 females; CNSMB). Liguria-Imperia, Mendatica, torrente Tanarello, 1280 m, light trap, N44.0772° E7.7486°, 10.X.2001, leg. Museo Caffi BG (1 male; CNSMB). Liguria-Imperia, Triora, rio Lazzarin c/o Verdeggia, 1075 m, light trap, N44.0406° E7.7229°, 9.X.2001, leg. Museo Caffi BG (2 males, 1 female; CNSMB). Liguria-Savona, Calizzano, torrente Frassino, N44.2351° E8.1958°, 920 m, 11.X.2001, leg. Museo Caffi, Bergamo (5 males, 8 females; OPC). Liguria-Savona, Sassello, rio del Nido, 1000 m, N 44.4449° E8.5769°, 12.X.2001, leg. Museo Caffi BG (3 males; CNSMB).

**Remarks.** *Allogamus hilaris* new species subgroup is comprised of the single nominate species. This subgroup is a specialized lineage inside the *Allogamus auricollis* species group. The longer secondary setae and the short tertiary setae together are distributed along the entire ventrum

of the paramere. The pair of the ventral sclerite of the aedeagus is modified into a fused bilobed dentate structure. The semisclerotized dorsal sclerite on the head of the aedeagus has taken over the flexing function forming laterally extended rounded semicircular lobes. Female vaginal sclerite complex has accessory duct modified into an enlarged sac of subquadratic dorsal profile.

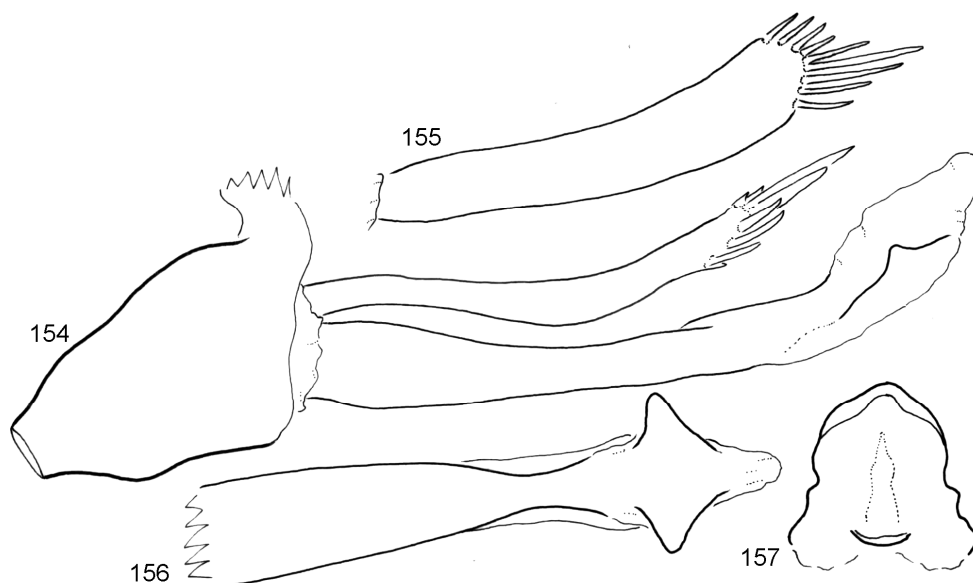
#### *Allogamus ligonifer* new species subgroup

Light species characterized with subequal secondary apical setae on the parameres. Modified accessory duct of female lacking.

#### *Allogamus gibraltarius* González & Ruiz, 2001

(Figures 154–157)

**Material examined.** Spain. Cádiz Province, Rio Majaceite, Canuto del Aljibe, N 36° 31' 50" W 5° 35' 07", 320 m, 2. XI. 2007, leg. A. RUIZ, (1 female, OPC). Cádiz Province, Rio Majaceite, Canuto del Aljibe, Guadalete Basin, N36° 32' 21" W 5° 38' 10", 320 m, 27. X. 2013, leg. A. RUIZ (8 males, 5 females DZFCUG; 8 males, 6 females, OPC).



**Figures 154–157.** *Allogamus gibraltarius* González & Ruiz, 2001. 154 = male, phallic organ in left lateral view, 155 = left paramere in dorsal view, 156 = aedeagus in ventral view, 157 = female vaginal sclerite complex profile in dorsal view.

***Allogamus kefes* Coppa & Oláh sp. nov.**

(Figures 158–160, 161–164)

**Diagnosis.** Similar to *A. pupos* sp. nov. but differs by having shorter leading seta in the apical seta brush; fused ventral sclerite on the aedeagus differently formed; stem of aedeagus without dorsal hump midway.

**Material examined.** *Holotype.* France, Drôme Department, Auelon, Le Deves, 19. IX. 2006, leg. G. Coppa (1 male, CPC). *Allotype.* Drôme Department, Montbrun les Bains, Torrent d'Anary Pont D542, 29. X. 2010, leg. G. Coppa (1 female, CPC). *Paratypes.* Same as allotype (1 male, 1 female; OPC).

**Description.** In alcohol both male and female have forewing membrane light brown with scarcely scattered lighter spots. Forewing length 18 mm. Head, thorax and appendages brown.

**Male genitalia.** Genital cavity well developed. Cerci rounded subquadrangular. Paraproct triangular in lateral view with small apical hook. Paramere shaft with apical brush of setae, leading seta slightly longer than the others. The pair of apico-ventral sclerites of the aedeagus fused into a

ventral quadrangular plate, lateral tooth moved more anterad.

**Female genitalia.** External genital structure similar to the species subgroup. Anterior apodemes of the vaginal sclerite complex simple rounded laterad.

**Etymology.** Epithet *kefes* from “*kefés*” brushy in Hungarian refers to the pattern of the apical setae on the parameres.

***Allogamus laureatus* (Navas, 1918)**

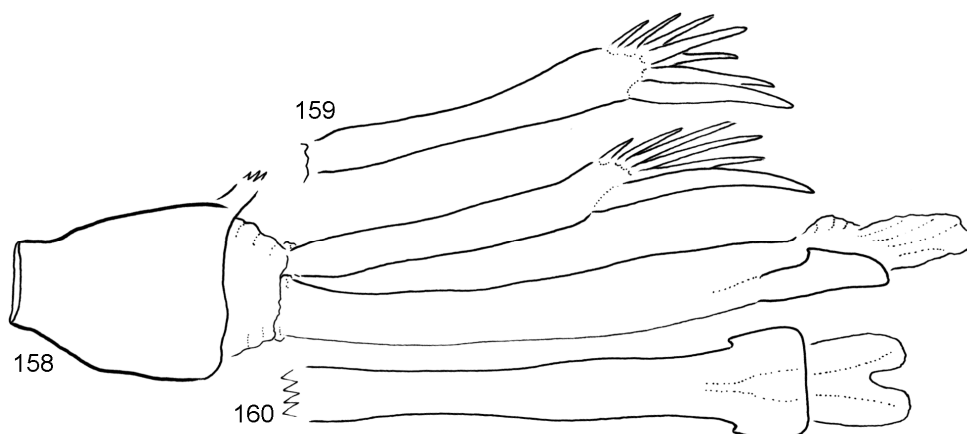
(Figures 165–167)

**Material examined.** Spain. Orense Province, Serra do Invernadeiro, Seixo Blanco, 998 m, 42°7'1.98" N 7°20'43.60" W, 6.X.2010, leg. M. González & J. Martínez (3 males, 2 females, OPC).

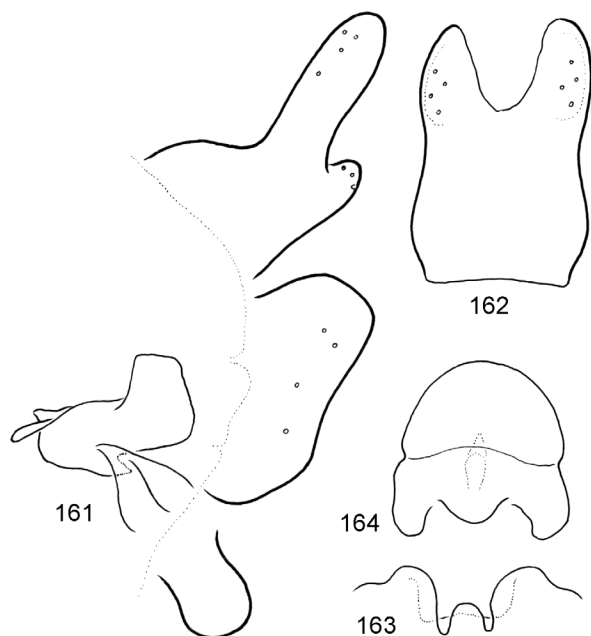
***Allogamus ligonifer* (McLachlan, 1876)**

(Figures 168–171)

**Material examined.** France. Corrèze, Chenaillers Mascheix, Le Chambariol, 28.IX.2010, leg. G. Coppa, (1 male, 1 female, CPC). Pyrénées-Orien-



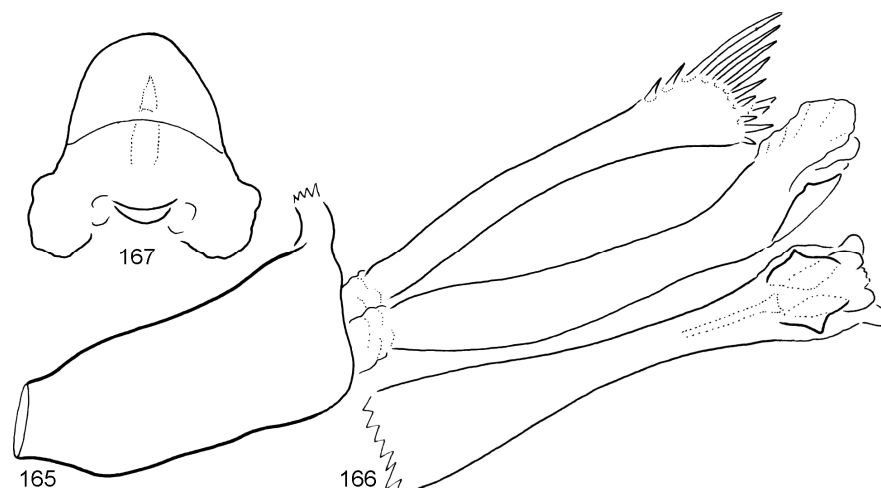
**Figures 158–160.** *Allogamus kefes* Coppa & Oláh sp. nov. 158 = male, phallic organ in left lateral view, 159 = left paramere in dorsal view, 160 = aedeagus in ventral view.



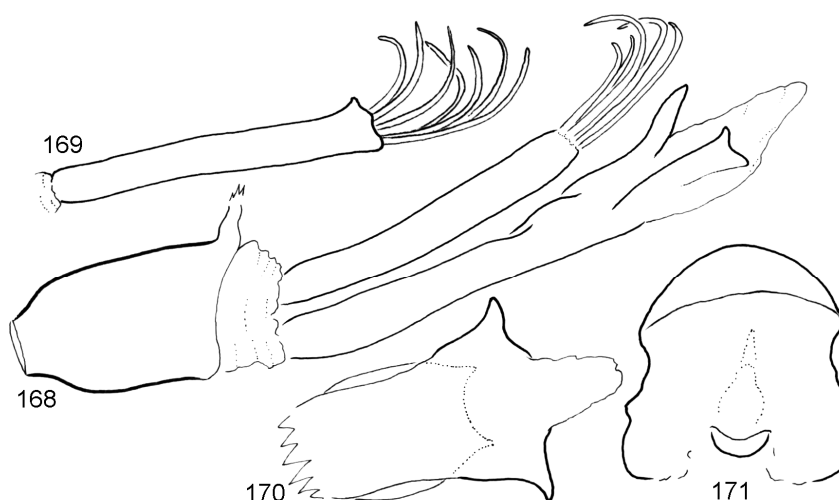
**Figures 161–164.** *Allogamus kefes* Coppa & Oláh sp. nov. 161 = female genitalia in left lateral view with vaginal sclerite complex, 162 = female anal tube in dorsal view, 163 = female vulvar scale (lower lip) in ventral view, 164 = dorsal profile of vaginal sclerite complex.

tales, Cattlar, La Tet Pont D 616, 28.X.2008, leg. G. Coppa (1 male, 1 female; OPC). Cantal Department, Murat, sur l'Alagnon Pont du Camping, 26.X.2005, leg. G. Coppa (1 male, CPC). Puy-de-Dôme Department, Besse et Saint Anastaise, Lac de Bourdouze, 7.X.2007, leg. G. Coppa (1 male, CPC). Puy-de-Dôme Department, Besse et Saint

Anastaise, Lac de Montcineyre, 7.IX.2007, leg. G. Coppa (1 male, 1 female; OPC). Puy-de-Dôme Department, Saint Germain Lembron, Couse d'Ardes pont D909, 28.X.2005, leg. G. Coppa (1 male, CPC). Corrèze Department, Monceau-sur-Dordogne, D12 le Gand Dordogne, 16.XI.1997, leg. G. Coppa (2 males, 1 female; OPC). Corrèze Department, Argentat, D9 Rive Gauche, 6.X.2012, leg. G. Coppa (1 male, 1 female; OPC). Corrèze Department, Bassignac le Bas, D21 Port de Vours, 11.X.2010, leg. G. Coppa (1 male, CPC). Corrèze Department, Monceaux-sur-Dordogne, Le Chambon, 12.XII.2010, leg. G. Coppa (1 female, CPC). Corrèze Department, Argentat, D5 Moulin bas Dordogne, 7.X.2000, leg. G. Coppa (3 males, 1 female; CPC). Corrèze Department, Argentat, D5 Moulin bas Dordogne, 29.X.1999, leg. G. Coppa (1 male, OPC). Corrèze Department, Bassignac, D24 Recoudier Dordogne, 30.X.2012, leg. G. Coppa (2 males, OPC). Corrèze Department, Argentat, Confluence de la Dordogne D9 confluence Maronne, 10.IX.2008, leg. G. Coppa (1 female, CPC). Lozère Department, Meyrueis, Ru de Bethuzon, 27.X.2010, leg. G. Coppa (1 male, CPC). Lozère Department, Saint Bonnet de Chirac, Les Bories ru Romardies, 25.X.2010, leg. G. Coppa (1 male, CPC). Lozère Department, Saint Bonnet de Chirac, Les Bories Lot, 25.X.2010, leg. G. Coppa (1 female, CPC). Lozère Department, Saint Chely d'Apcher, sur le Chapouillet Confluence avec la Truyère, 18.VIII.



**Figures 165–167.** *Allogamus laureatus* (Navas, 1918). 165 = male, phallic organ in left lateral view, 166 = aedeagus in ventral view, 167 = dorsal profile of vaginal sclerite complex.



**Figures 168–171.** *Allogamus ligonifer* (McLachlan, 1876). 168 = male, phallic organ in left lateral view, 169 = left paramere in dorsal view, 170 = aedeagus head in ventral view, 171 = female vaginal sclerite complex profile in dorsal view.

2011, leg. G. Coppa (1 male, CPC). Vosges Department, Valtin, La Meurthe en Amont de l'Etang, 4.X.2010, leg. G. Coppa (1 male, CPC). Vosges, 1883, in Klapalek's collection (1 male, K379, NMPC). No data, in Klapalek's collection, (1 male, K381, NMPC). Vosges, 1886, in Klapalek's collection (1 female, K380, NMPC). Haut-Garonne Department, Galie, pas de précision, 13.X.2006, leg. G. Coppa (1 female, CPC). Haute-Garonne Department, Galie, pas de pré-

cision, 30.IX.2006, leg. G. Coppa (1 male, CPC). Pyrénées-Orientales Department, Cattlar, La Tet Pont D616, 28.X.2008, leg. G. Coppa (5 males, 1 female; CPC). Pyrénées-Atlantiques Department, Montaner, pas de précision, 27.II.2006, leg. G. Coppa (1 male, CPC). Morbihan Department, Inguiniel, sur le Sebrevet le Porz, 22.IV.2010, leg. G. Coppa (1 male, CPC). Languedoc-Roussillon, Dep. Hérault, Saint-Pons-de-Thomières, around camping place, hard leaved forest, at house-

walls and in grassland, 285 m, N43,49037° E 2,78524°, 18.X.2009, leg. A. Schönhofer (3 males; CNSMB).

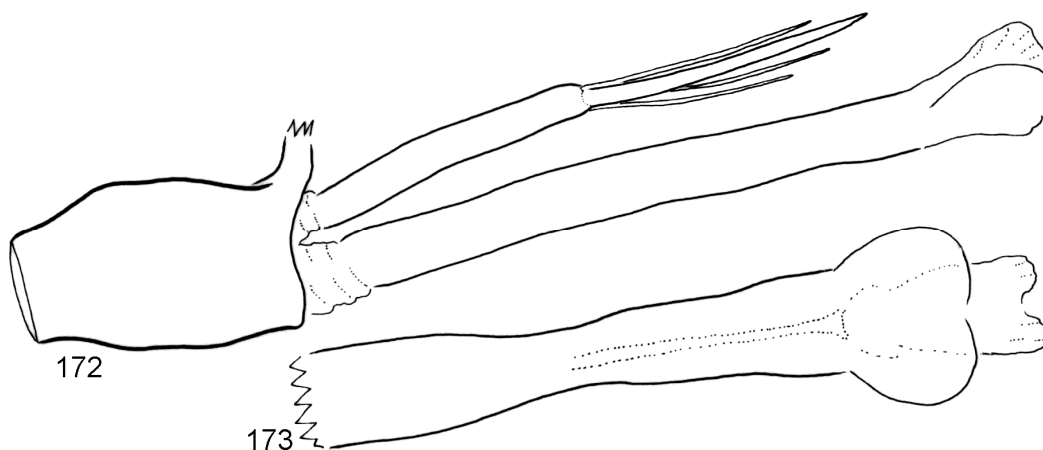
**Remarks.** There is significant currently segregating standing variation among and inside the examined populations in the shape of dorsal sclerite of the aedeagus, in the apical dorsal pattern of the paramere shaft and in the pointedness of the accessory paraproctal process. Populations from Lozere-Cevennes and Correze-Dordogne have dorsal sclerite with deep mesal excavation and more developed lateral pointed lobes in dorsal view, dorsal pattern of paramere shaft with mesal subapical tooth, accessory paraproctal process is more slender and pointed. Specimens from Vosges, Bretagne and Massif Central have more shallow mesal excavation on the dorsal sclerite, dorsal pattern of paramere shaft with mesal apical tooth, accessory paraproctal process is less pointed.

Besides populations with stable diverged fine structure there is variation detectable also inside populations. This may suggest ongoing diversification in sexual selection processes both on phallic structures and on the paraproctal accessory process. There is possibility also for reinforcement processes under the influence of gene flow by immigrants. A more detailed study of structure matrix is required with more specimens in order to quantify the extent of diverged or diverging state of the populations on the entire distributional area of *Allogamus ligonifer* species or species complex.

***Allogamus pertuli* Malicky, 1974**

(Figures 172–173)

**Material examined.** Greece. Karpenision, Mikro Chorio, 700 m, 15.X.1991, leg H. Malicky (1 male, OPC).



**Figures 172-173.** *Allogamus pertuli* Malicky, 1974. 172 = male, phallic organ in left lateral view, 173 = aedeagus head in ventral view.

***Allogamus pupos* Coppa & Oláh sp. nov.**

(Figures 174–175, 176–179)

**Diagnosis.** Similar to *A. kefes* sp. nov. but differs by having smaller body, forewing less distinctly spotted; longer leading seta in the apical seta brush; fused ventral sclerite on the aedeagus differently formed; stem of aedeagus with dorsal hump midway.

**Material examined.** Holotype. France, Alpes-Maritimes Department, Tende, Torneau Aval, 13. XI. 2012, leg. G. Coppa (1 male, CPC). Allotype. Same as holotype (1 female, CPC). Paratypes. Same as holotype (2 males, 1 female, OPC) Vaucluse Department, Fontaine-de-Vaucluse, La Sorgue, 30. X. 2010, leg. G. Coppa (3 males, CPC).

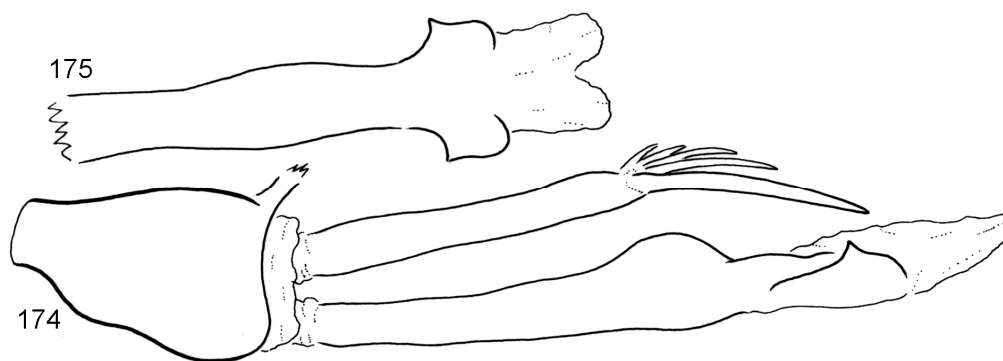
**Description.** In alcohol both male and female have forewing membrane light brown with un-

distinct lighter spots. Forewing length 14 mm. Head, thorax, and appendages brown.

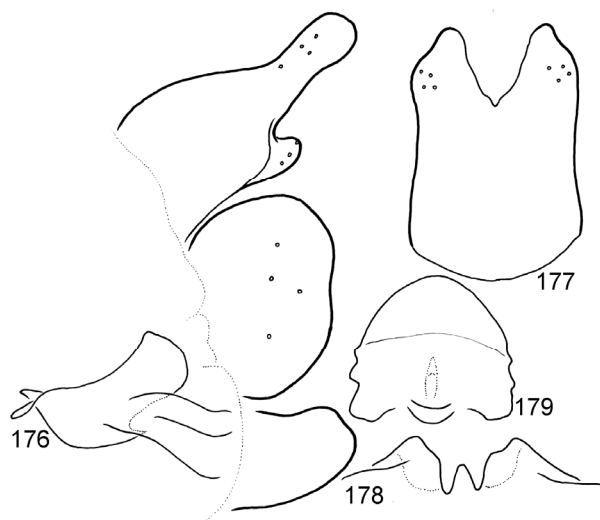
**Male genitalia.** Genital cavity well developed. Cerci rounded. Paraproct triangular in lateral view with small apical hook. Paramere shaft with apical brush of setae, leading seta much longer than the others. The pair of apicoventral sclerites of the aedeagus fused into a ventral quadrangular plate, lateral tooth moved more posterad.

**Female genitalia.** External genital structure similar to the species subgroup. Anterior apodemes of the vaginal sclerite complex with small lobes laterad.

**Etymology.** Epithet *pupos* from “*púpos*” humpy in Hungarian, refers to the dorsal hump on the stem of aedeagus.



**Figures 174–175.** *Allogamus pupos* Coppa & Oláh, sp. nov. 174 = male, phallic organ in left lateral view, 175 = aedeagus in ventral view.



**Figures 176–179.** *Allogamus pupos* Coppa & Oláh sp. nov. 176 = female genitalia in left lateral view with vaginal sclerite complex, 177 = female anal tube in dorsal view, 178 = female vulvar scale (lower lip) in ventral view, 179 = orsal profile of vaginal sclerite complex.

#### *Allogamus mortoni* new species complex

Light species characterized by the neoformation of pointed accessory paraproctal process.

The modified accessory duct of female is lacking. *Allogamus mortoni* species complex is most related to species *Allogamus ligonifer* based on both male and female genital structures, but differs by having genital cavity more deep and the accessory process strongly developed on the ventral branches of the paraproctal complex, almost as long as the dorsal branch of the paraproct itself. The following description of the male and female genital structures of the new species complex characterizes all of the new species. In the new species description we describe only the separating morphological structures of diversified accessory processes and the female vaginal sclerites.

**Male genitalia.** Segment IX medium long with more setose apicomarginal depression on the pleural region. Deep genital cavity produced anteriorly as a continuation of the superanal complex with sclerotized mesal septum. Cerci broad foliiform subdivided with a mesal irregular digitiform arm. Dorsal branch of paraproct, (the paraproct sensu stricto) produced as a pair of heavily sclerotized stout spurs with slightly and shortly hooked apex. Ventral branch or the basal triangulum of the paraproct complex (the vestigium of somite X

and XI) produced a pair of pointed accessory process with morphological diversification of species specific shape. Gonopods single segmented; apex of gonopods, the “apparent harpago” turned in coronal plane is the most varying structure of the species complex.

**Female genitalia.** Anal tube, the fused tergites IX and X bilobed in lateral view and armed ventrobasad with a pair of variously developed or almost reduced setose digitate process. Setose sternite IX large rounded in lateral view flanking the setaless, glabrous supraanal plate, the upper vulval lip. Vulval scale, the lower vulval lip with less produced mesal lobe. The internal genital structure, the well sclerotized vaginal sclerite complex seems species specific, especially the diversified shape of anterior apodemes in dorsal view offers stable trait to separate species. Variability of both external structures and vaginal sclerite complex need more detailed studies on several specimens of more populations. The anterior apodeme of the vaginal sclerite complex may be obscured by residues even after careful clearing and cleaning procedures. The ventrolateral process on female tergite IX seems enlarged (*A. pohos* sp. n., *A. kurtas* sp. n.), thinned (*A. tuskes* sp. n.), abbreviated (*A. kampos* sp. n.), or even vestigial (*A. kettos* sp. n.). However it is probably not stable. Special study is required to examine its stability and its ranges of variability in several populations.

**Morphological variability and stability.** Both male and female phenotypic variation is rather significant in *Allogamus mortoni* species group. Periphallallic organs of cerci and gonopods, the phallic organs of parameres and aedeagus, as well as the external female genital structures are subjects to significant interspecific and intra-specific variabilities.

Detailed molecular genetic survey with neutral markers revealed significant deviations in various *Allogamus mortoni* populations. The measured DNA pattern has not matched the wing or the paramere morphological patterns of the examined populations (Múrria et al. unpublished data). Both

the forewing brown pattern and the paramere apical spine pattern exhibited rather significant random variations among and inside populations. It seems that the parameres are not diverged in *A. mortoni* species complex and its setal pattern not stabilized. Parameres are influenced by neutral non-adaptive processes. The target of the non-neutral adaptive sexual selection processes is not the intromittent phallic organ. We have discovered stable divergences in the shape of the paired accessory processes on the paraproctal complex of the male genitalia. This divergence was accompanied by corresponding morphological diversity on the anterior apodemes of the vaginal sclerite complex of the females.

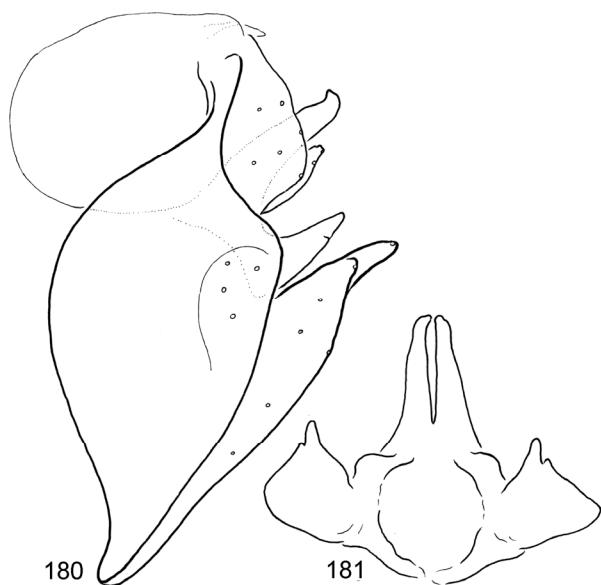
The diverged structure matrices of the pointed accessory process exhibit high stabilities in all the five new species. The fine structure analysis revealed stability, but its high resolution capacity indicates minor deviations for each specimen. There are no two specimens alike. Like every human has different earlobe! Moreover there is possibility to detect reinforcement processes between interacting populations by gene flow of immigrants. All these processes may interfere and can confuse the interpretation of fine structure analysis in routine alpha-taxonomic studies.

### ***Allogamus kampos* Oláh & Ruiz sp. nov.**

(Figures 180–181, 182–184, 185–188, 189–200)

**Diagnosis.** Paraproctal basolateral accessory process on the superanal genital complex with subdivided apex. Ventrolateral process on female tergite IX is vestigial. Most close to *A. kettos* sp. nov., but differs by having paraproctal accessory process with less developed lateral division and the anterior apodemes on the vaginal sclerite complex mesad curving and tapering.

**Material examined.** *Holotype.* Spain, Málaga Province, Rio Hozgarganta, La Saucedá, N36° 31' 50", W5° 35' 08", 510 m, 1.XI.2007, leg. A. Ruiz, (1 male, DZFCUG). *Allotype.* Same as holotype (1 female, DZFCUG). *Paratypes.* Same as holotype (1 male DZFCUG, 1 male, OPC). Cádiz Province, Rio Majaceite, Canuto del Aljibe, N36°



**Figures 180–181.** *Allogamus campos* Oláh & Ruiz sp. nov. 180 = male, genitalia in lateral view, 181 = paraproct with the accessory processes in caudal view.

31' 50", W5° 35' 08", 320 m, 2.XI.2007, leg. A. Ruiz, (2 males DZFCUG, 2 males; OPC). Cádiz Province, Rio Majaceite, Benamahoma, N36° 46' 05", W5° 28' 34", 420 m, 2.XI.2007, leg. A. Ruiz, (2 males DZFCUG, 1 male; OPC). Cádiz Province, Rio Majaceite, Canuto del Aljibe, Guadalete Basin, N36° 32' 21", W5° 38' 11", 320

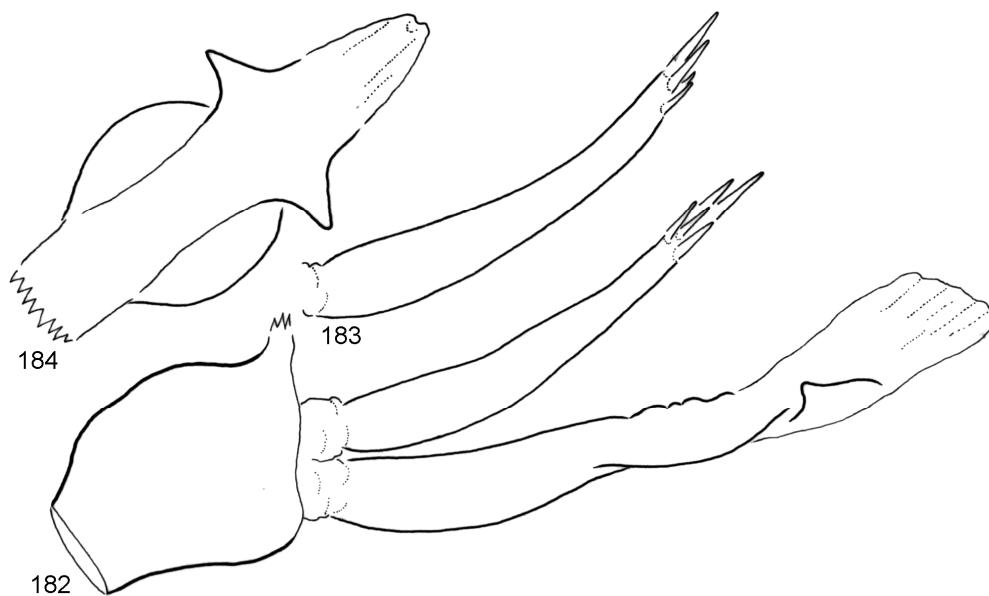
m, 27.X.2013, leg. A. Ruiz, (8 males, 5 females DZFCUG; 8 males, 6 females, OPC). Cádiz Province, Rio del Bosque/Majaceite, Benamahoma, Guadalete, N36° 46' 05", W5° 28' 34", 420 m, 9. XI.2013, leg. A. Ruiz, (8 males, DZFCUG; 8 males, OPC). *Morocco*. Azica, 1600 m, Ketama, 13.XI.2013, leg. W. Graf (2 males, OPC).

**Description.** Male (in alcohol). Both male and female have forewing membrane marbled and speckled, slightly irrorated. This forewing pattern variously developed at specimens, pharate or newly emerged specimens less or not patterned at all. Forewing length 20 mm. Head, thorax and appendages are stramineous.

**Male genitalia.** Periphallic organs as described in the species complex diagnosis. Accessory process on the basal triangulum of the superanal complex with subdivided bifid apex. The lateral division is small, shorter, just discernible.

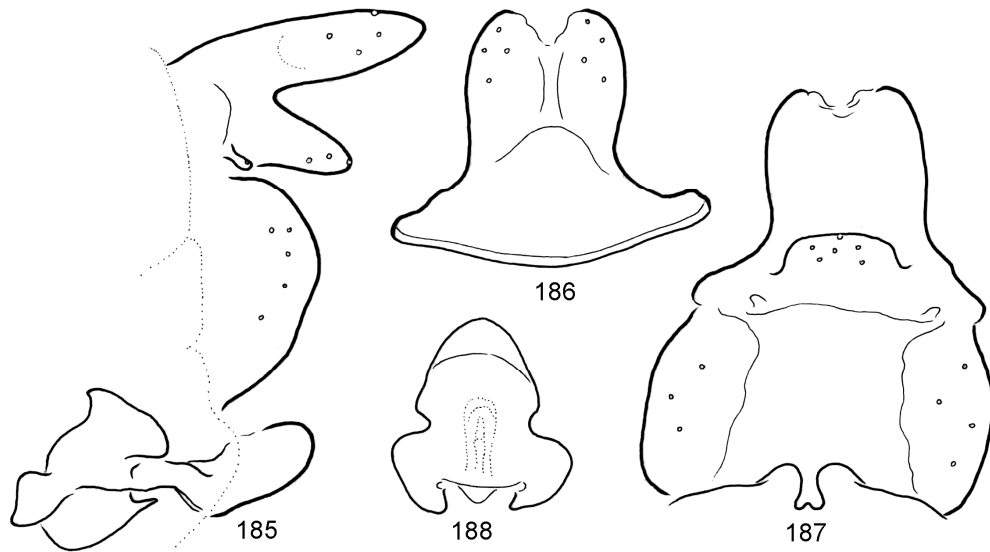
**Female genitalia.** Ventrobasal setose process reduced. Anterior apodemes with tapering and mesad turning apex.

**Etymology.** Epithet *kamos* is from “*kampós*” hooked in Hungarian, refers to the mesad curving shape of the anterior apodemes of the vaginal sclerite complex.

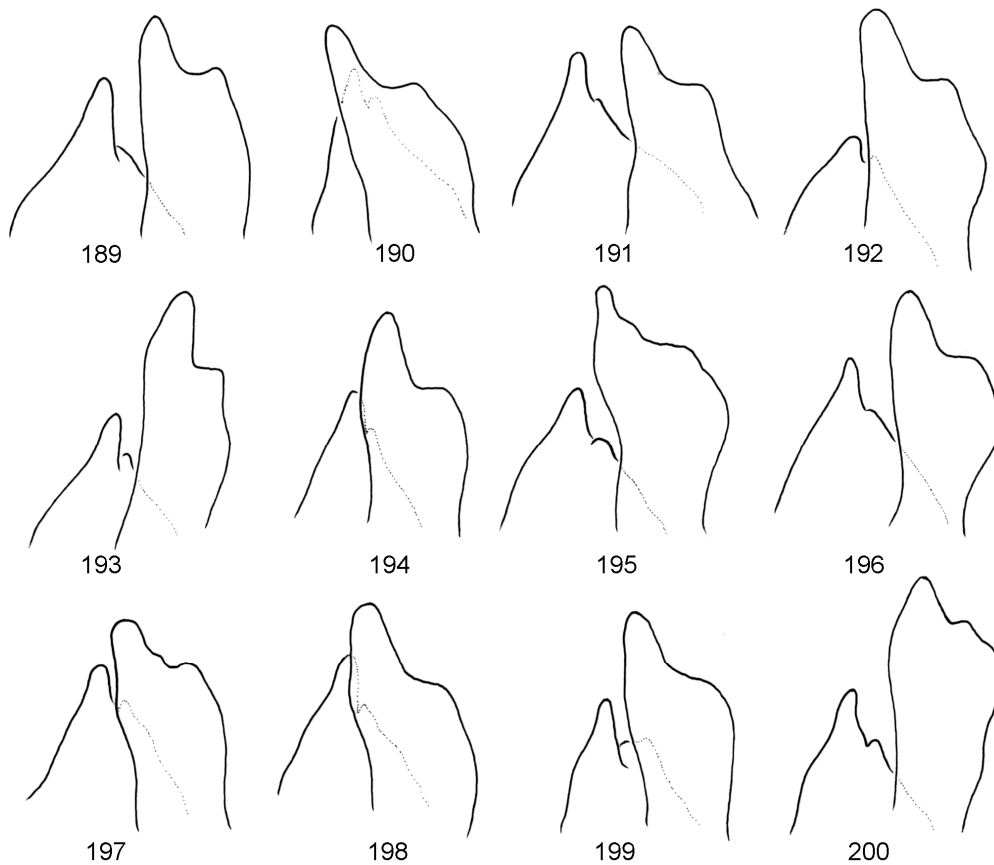


**Figures 182–184.** *Allogamus campos* Oláh & Ruiz sp. nov. 182 = male, phallic organ in left lateral view, 183 = left paramere in dorsal view, 184 = aedeagus head in ventral view,





**Figures 185–188.** *Allogamus campos* Oláh & Ruiz sp. nov. 185 = female genitalia in left lateral view with vaginal sclerite complex, 186 = female anal tube in dorsal view, 187 = female genitalia in ventral view, 188 = dorsal profile of vaginal sclerite complex.



**Figures 189–200.** *Allogamus campos* Oláh & Ruiz sp. nov. Diverged structure matrix of the right accessory process on the basal triangle of the paraproct together with the apex of the right harpago in caudal view.

***Allogamus kettos* Oláh & Ruiz sp. nov.**

(Figures 201–212, 213–214)

**Diagnosis.** Paraproctal basolateral accessory process on the superanal genital complex with subdivided apex. Ventrolateral process on female tergite IX reduced, just discernible. Most close to *A. kampos* sp. n., but differs by having paraproctal accessory process with more developed lateral division and the anterior apodemes on the vaginal sclerite complex not curving mesad and not tapering.

**Material examined.** *Holotype.* Spain, Sevilla Province, Rivera de Huéznar Basin, Isla Margarita (Cazalla de la Sierra), Rio Rivera de Huéznar, N37° 56' 04", W5° 41' 44", 427m, 2.XI.2013, leg. A. Ruiz, (1 male, DZFCUG). *Allotype.* Same as holotype (1 female, DZFCUG). *Paratypes.* Same as holotype (5 males, 3 females DZFCUG;

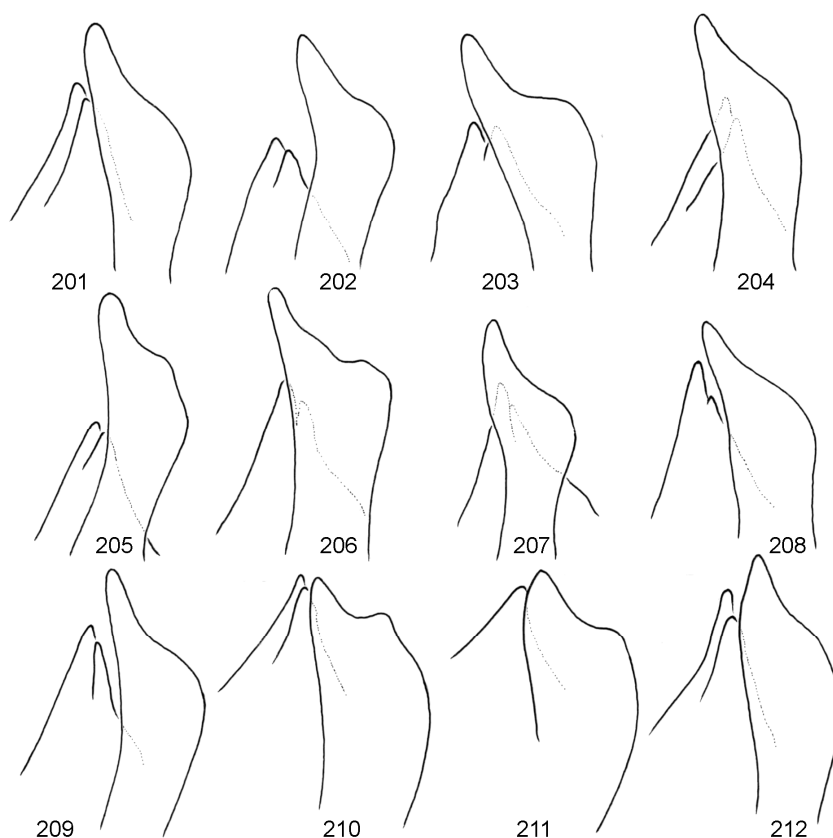
10 males, 5 females, OPC).

**Description.** Male (in alcohol). Both male and female have forewing membrane marbled and speckled, slightly irrorated. This forewing pattern variously developed at specimens, pharate or newly emerged specimens less or not patterned at all. Forewing length 20 mm. Head, thorax, and appendages are stramineous.

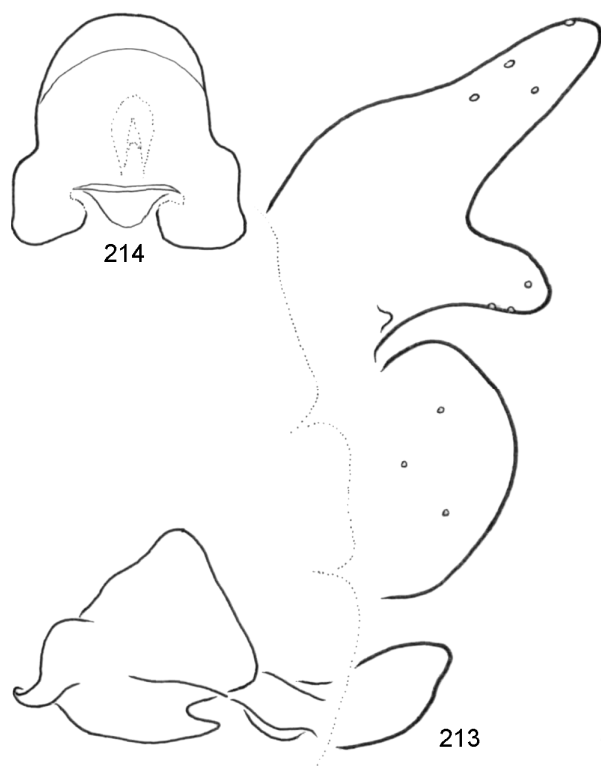
**Male genitalia.** Periphallic organs as described in the species complex diagnosis. Accessory process on the basal triangulum of the superanal complex with subdivided bifid apex. The lateral division is almost equal long than the mesal division.

**Female genitalia.** Ventrobasal setose process almost disappeared. Anterior apodemes subquadrangular.

**Etymology.** Epithet *kettos* is from “*kettős*” doubled in Hungarian, refers to the duplicated tip of the accessory process of the paraproct.



**Figures 201–212.** *Allogamus kettos* Oláh & Ruiz sp. nov. Diverged structure matrix of the right accessory process on the basal triangle of the paraproct together with the apex of the right harpago in caudal view.



**Figures 213–214.** *Allogamus kettos* Oláh & Ruiz sp. nov.  
213 = female genitalia in left lateral view with vaginal sclerite complex, 214 = dorsal profile of vaginal sclerite complex.

***Allogamus kurtas* Oláh & Zamora-Muñoz sp. nov.**

(Figures 215–226, 227–228)

**Diagnosis.** Paraproctal basolateral accessory process on the superanal genital complex short triangular. Ventrolateral process on female tergite IX produced and high. Most close to *A. mortoni* Navas, 1907 but differs by the shorter paraproctal accessory process. The anterior apodemes on the vaginal sclerite complex almost regular quadrangular.

**Material examined.** *Holotype.* Spain, Granada Province, Fardes Basin, Arroyo de Prado Negro stream, Venta del Molinillo, 1201 m, 30.X.2007, leg. C. Zamora-Muñoz (1 male, DZFCUG). *Allotype.* Same as holotype (1 female, DZFCUG). *Paratypes.* Same as holotype (4 males, 1 female;

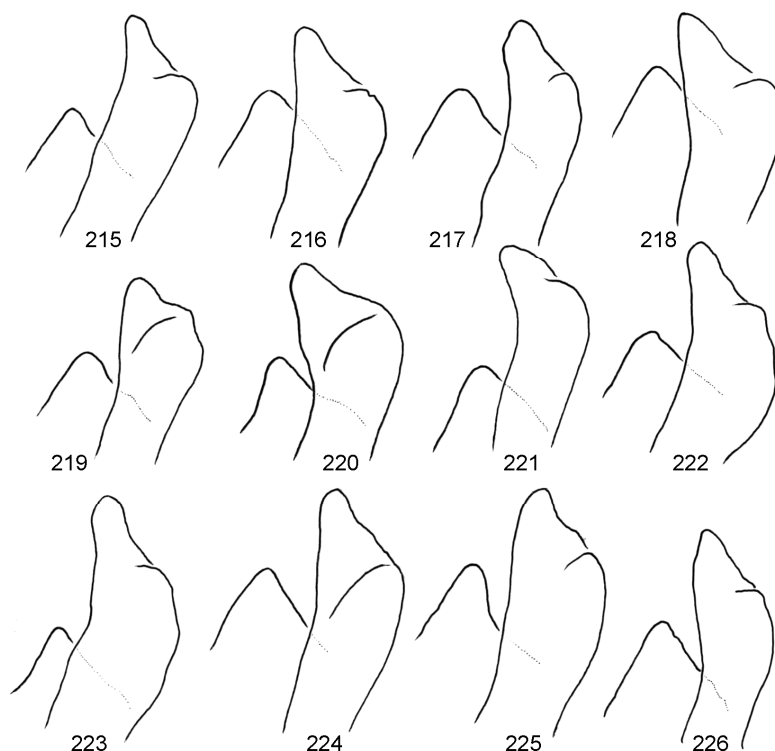
DZFCUG). Granada Province, Fardes Basin, Arroyo de Prado Negro stream, Venta del Molinillo, 1201 m, 9.IX.1995, leg. C. Zamora-Muñoz (3 females, DZFCUG; 3 females OPC). Granada Province, Fardes Basin, Arroyo de Prado Negro stream, Cortijo del Despenadero, N37° 18' 59", W3° 27' 17", 1320 m, 4.X.2000, leg. J. Luzón & P. Jaimez (2 females, OPC). Granada Province, Fardes Basin, Arroyo de Prado Negro stream, Cortijo del Despeñadero, N37° 18' 59", W3° 27' 17", 1320 m, 17.X.1996, leg. J. Luzón & P. Jaimez (1 female, DZFCUG). Granada Province, Fardes Basin, Arroyo de Prado Negro stream, Cortijo del Despeñadero, N37° 18' 59", W3° 27' 17", 1320 m, 19.X.2000, leg. J. Luzón & P. Jaimez (1 female, DZFCUG). Granada Province, Fardes Basin, Barranco de Fuente Grande stream, Fuente de los Potros, N37° 19' 19" W3° 27' 38", 1400 m, 17.X.1996, leg. J. Luzón & P. Jaimez (2 females, DZFCUG). Granada Province, Guadiana Menor Basin, Arroyo Alhorí, Central eléctrica, N37° 8' 59", W3° 11' 57", 1514 m, 14.X.2013, leg. C. Zamora-Muñoz (2 males, DZFCUG). Granada Province, Guadiana Menor Basin, Arroyo Alhorí, Central eléctrica, N37° 8' 59", W3° 11' 57", 1514 m, 18.X.2013, leg. C. Zamora-Muñoz (5 males, 2 females; OPC)

**Description.** Male (in alcohol). Both male and female have forewing membrane marbled and speckled, slightly irrorated. This forewing pattern variously developed at specimens, pharate or newly emerged specimens less or not patterned at all. Forewing length 20 mm. Head, thorax, and appendages stramineous.

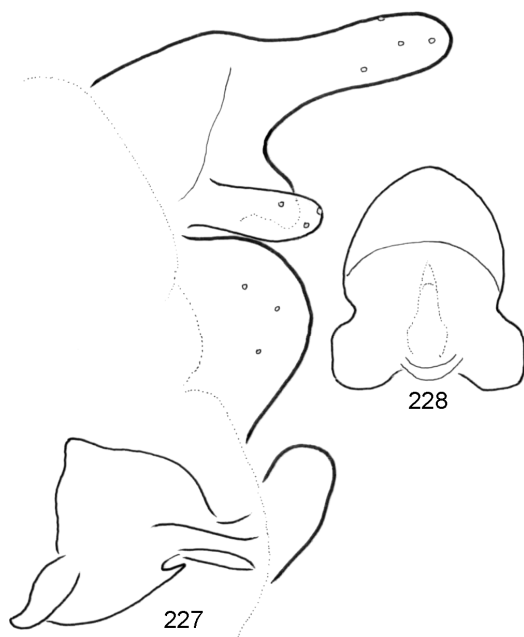
**Male genitalia.** Periphallic organs as described in the species complex diagnosis. Accessory process on the basal triangulum of the superanal complex short.

**Female genitalia.** Ventrobasal setose process much developed. Anterior apodemes regular quadrangular.

**Etymology.** Epithet *kurtas* is from “kurta” curt, cutty in Hungarian refers to the low abbreviated accessory basal process of the paraproct.



**Figures 215–226.** *Allogamus kurtas* Oláh & Zamora-Muñoz sp. nov. Diverged structure matrix of the right accessory process on the basal triangle of the paraproct together with the apex of the right harpago in caudal view.



**Figures 227–228.** *Allogamus kurtas* Oláh & Zamora-Muñoz sp. nov. 227 = female genitalia in left lateral view with vaginal sclerite complex, 228 = dorsal profile of vaginal sclerite complex.

### *Allogamus mortoni* (Navás, 1907)

*Halesus mortoni* Navas, 1907: 194–195. „Patria. San Fiel (Portugal), Diciembre de 1907 (!). Cogido por el R.P. Martins, S.J. He dedicado esta especie al distinguido entomólogo señor Morton, de Edimburgo.”

*Halesus mortoni* Navas, 1907: Schmid 1951a: 46–48. „Le type provient du Portugal: San Fiel XII.1904 (1907 in Navas’s description!). Il est actuellement dans ma collection”

*Allogamus mortoni* (Navas, 1907): Schmid 1955: 195.

**Diagnosis.** Nominate species of the group. Similar to *A. kurtas* sp. n. but accessory process on the superanal complex more developed. Female unknown. Type or newly collected material not available.

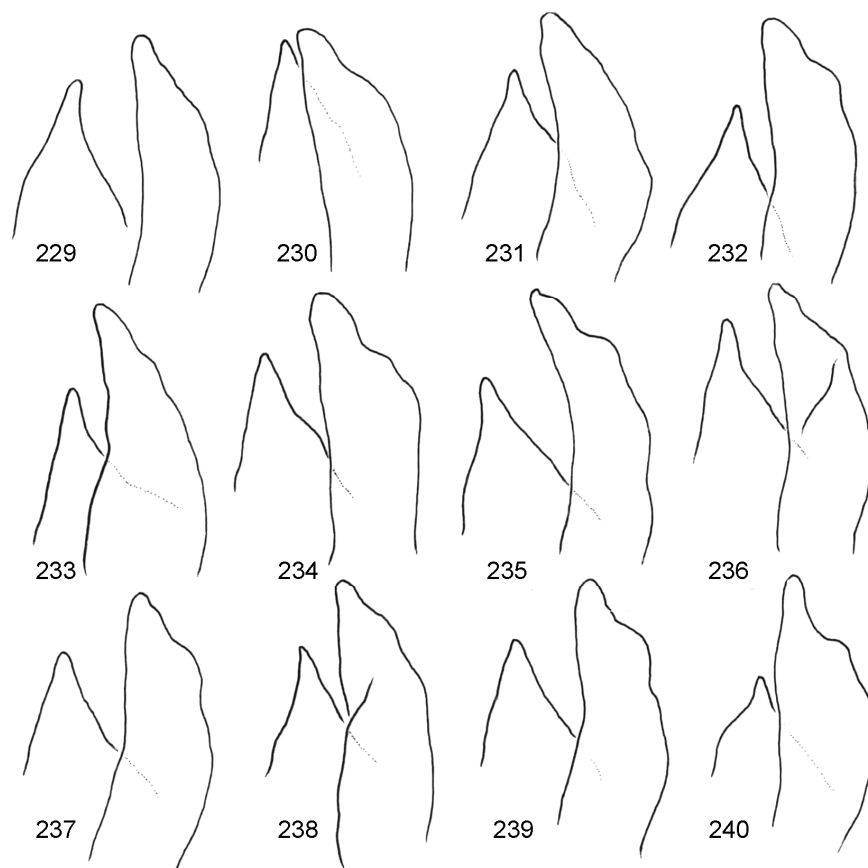
### *Allogamus pohos* Oláh & Zamora-Muñoz sp. nov.

(Figures 229–240, 241–242)

**Diagnosis.** Paraproctal basolateral accessory process on the superanal genital complex long tri-

angular. Most close to *A. mortoni* Navas but differs by having paraproctal accessory process slender, elongated triangular. Close also to *A. tuskes* sp. n. as well, but apex less pointed, apical third longer slender; apex almost reach the apex of the slender mesal cercal process. However, when the two apices compared it is important to realise that the mesal slender process of the cerci moves together with the dorsal branch of the paraproct and as a result its apex position depends on the

copulation dependent functional state of the superanal complex. Ventrolateral process on female tergite IX produced. The anterior apodemes on the vaginal sclerite complex short and wide without lateral wing; this lateral wing frequently visible on the anterior apodemes of *A. tuskes* representing the anterior end of the wing sclerite and fused to the lateral area of the anterior apodeme, this wing sclerite perform a dorsal stretching function to the membranous vagina.

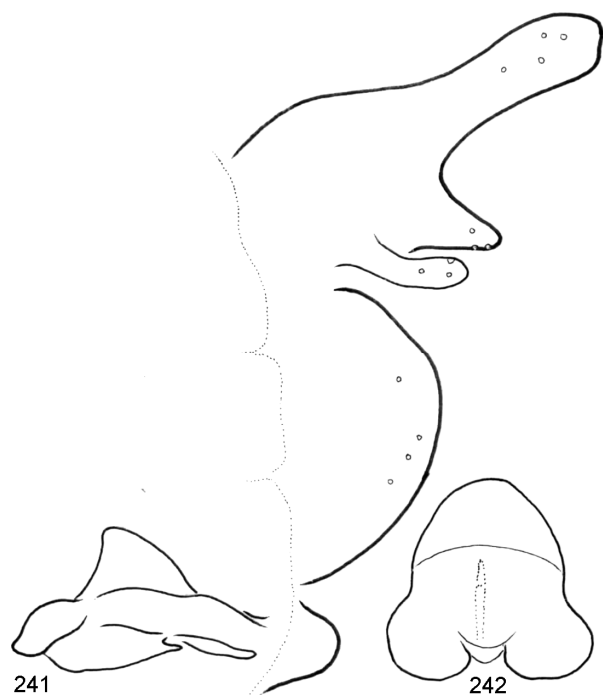


**Figures 229–240.** *Allogamus pohos* Oláh & Zamora-Muñoz sp. nov. Diverged structure matrix of the right accessory process on the basal triangle of the paraproct together with the apex of the right harpago in caudal view.

**Material examined.** *Holotype.* Spain, Jaén Province, Rio Guadalquivir, Nacimiento, N37° 54' 08", W2° 56' 16", 1378 m, 25.IX.2010, leg. C. ZAMORA-MUÑOZ, (1 male, DZFCUG). *Allotype.* Same as holotype, but 5.X.2013 (1 female, DZFCUG). *Paratypes.* Same as holotype (1 male, 1 female, DZFCUG; 1 male OPC). Same as holotype, but 5.X.2013 (7 males, 2 females,

DZFCUG; 7 males, 2 females; OPC). Same as holotype, but 6.X.2013 (6 males, 2 females, DZFCUG).

**Description.** Male (in alcohol). Both male and female have forewing membrane marbled and speckled, slightly irrorated. This forewing pattern variously developed at specimens, pharate or



**Figures 241–242.** *Allogamus pohos* Oláh & Zamora-Muñoz sp. nov. 241 = female genitalia in left lateral view with vaginal sclerite complex, 242 = dorsal profile of vaginal sclerite complex.

newly emerged specimens less or not patterned. Forewing length 20 mm. Head, thorax, and appendages are stramineous.

**Male genitalia.** Periphallic organs as described in the species complex diagnosis. Accessory process on the basal triangulum of the superanal complex elongated triangular.

**Female genitalia.** Ventrobasal setose process well developed. Anterior apodemes of the vaginal sclerite complex short and wide.

**Etymology.** Epithet *pohos* is from “*pohos*” bellied in Hungarian, refers to laterad rounded shape of the anterior apodemes of the vaginal sclerite complex.

***Allogamus tuskes* Oláh & Sáinz-Bariáin sp. nov.**

(Figures 243–254, 255–256)

**Diagnosis.** Paraproctal basolateral accessory process on the superanal genital complex short triangular with needle pointed apex. Most close to

*A. kurtas* sp. n. but differs by having paraproctal accessory process pointed, not blunt. *A. pohos* sp. n. has accessory process similarly narrowing, but not needle-like pointed and much longer. Ventrolateral process on female tergite IX is slender. The anterior apodemes on the vaginal sclerite complex with lateral wing that is the fused anterior end of the wing sclerite; however, its visibility unstable, depends on view angles.

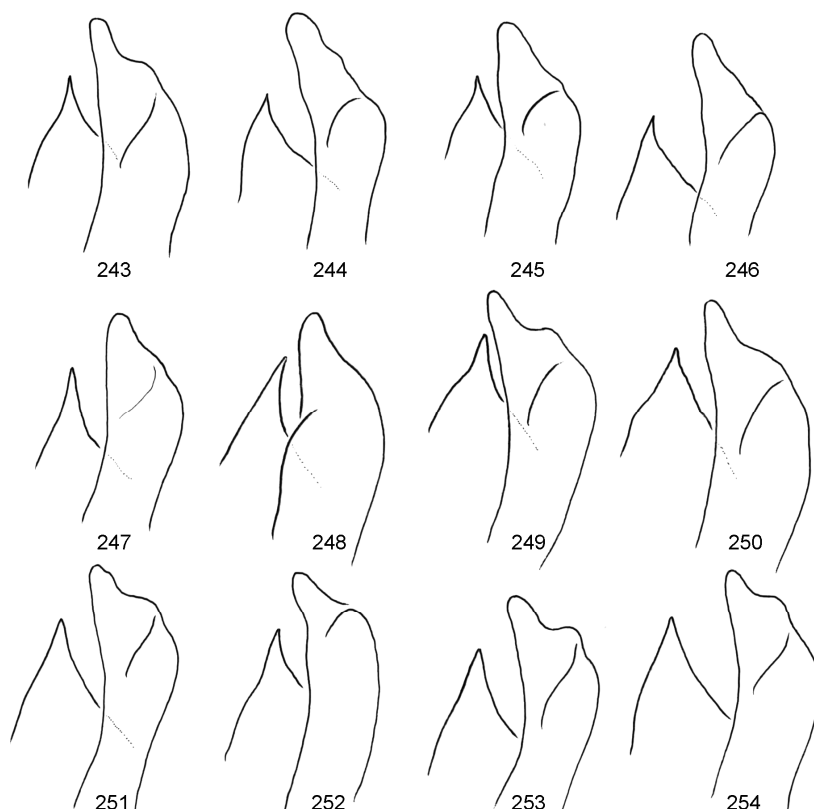
**Material examined.** *Holotype.* Spain, Granada Province, Cacín Basin, Arroyo Añales stream, Arenas del Rey, N36° 55' 05", W3° 53' 32", 970 m, 28.X.2007, leg. C. Zamora-Muñoz & M. Sáinz-Bariáin (1 male, DZFCUG). *Allotype.* Granada Province, Genil Basin, Rio Aguas Blancas, Quéntar, N37° 13' 17", W3° 25' 10", 1096 m, 21.X.1990, leg. C. Zamora-Muñoz (1 female, DZFCUG). *Paratypes.* Same as holotype (3 males, DZFCUG; 6 males, OPC). Granada Province, Genil Basin, Rio Maitena, Desembocadura, N37° 09' 07", W3° 24' 48", 1060 m, 15.X.2013, leg. M. Sáinz-Bariáin (2 males, DZFCUG; 2 males, OPC). Granada Province, Guadiana Menor, Jérez del Marquesado, Rio de Jérez, 1266 m, collected as larvae, 30.IV.2008 and reared in laboratory, leg. C. Zamora-Muñoz (6 males, 6 females; OPC).

**Description.** Male (in alcohol). Both male and female have forewing membrane marbled and speckled, slightly irrorated. This forewing pattern variously developed at specimens, pharate or newly emerged specimens less or not patterned at all. Forewing length 20 mm. Head, thorax, and appendages are stramineous.

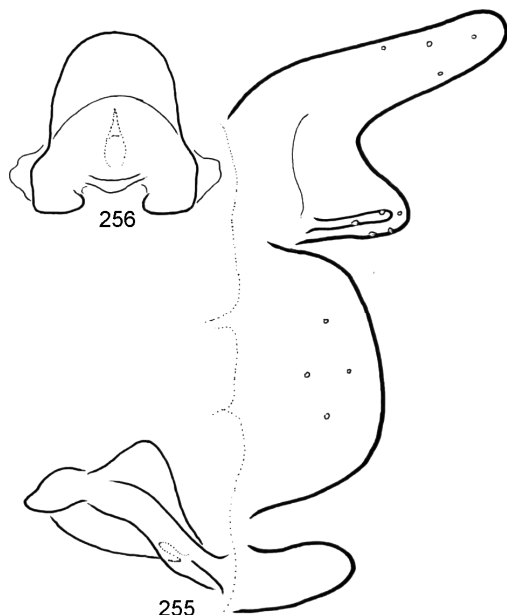
**Male genitalia.** Periphallic organs as described in the species complex diagnosis. Accessory process on the basal triangulum of the superanal complex triangular with pointed needle-shaped apex.

**Female genitalia.** Ventrobasal setose process very thin, slender. Anterior apodemes of the vaginal sclerite complex with lateral wings.

**Etymology.** Epithet *tuskes* is from “*tüskés*” spiny in Hungarian, refers to needle pointed tip of the accessory process of paraproct.



**Figures 243–254.** *Allogamus tuskes* Oláh & Sáinz-Bariáin sp. nov. Diverged structure matrix of the right accessory process on the basal triangle of the paraproct together with the apex of the right harpago in caudal view.



**Figures 255–256.** *Allogamus tuskes* Oláh & Sáinz-Bariáin sp. nov. 255 = female genitalia in left lateral view with vaginal sclerite complex, 256 = dorsal profile of vaginal sclerite complex.

#### *Allogamus corsicus* new species group

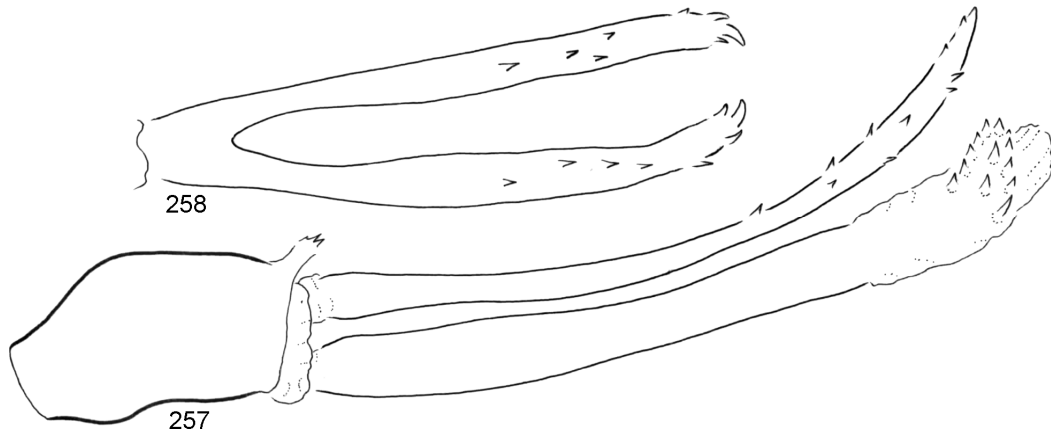
Light species. In this small species group the paired parameres fused basally and diverted apically. Modified female accessory duct lacking.

#### *Allogamus corsicus* Ris, 1897

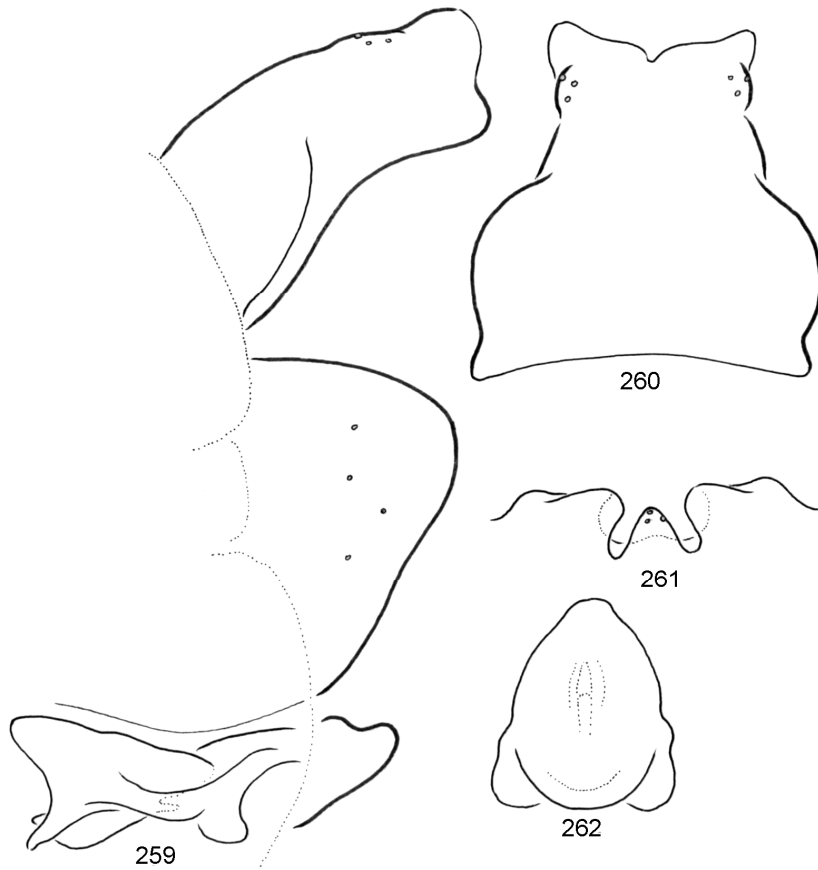
(Figures 257–258, 259–262)

*Allogamus corsicus* Ris, 1897. Sister-species status between *A. corsicus* and *A. illiesorum* has been reported with new drawings by Botosaneanu (2004: 173–175).

**Material examined.** *France.* Corse, Haute-Corse, Mausoleo, fiume Tartagine, 1100 m, N 42.4758° E8.9515°, 28.IX.2000 leg. B. Salmini (74 males, 15 females, CNSMB; 14 males, 7 females; OPC). Corse-Haute Corse, Mausoleo, fiume Tartagine, 1100 m, light trap, N42,4758° E8,9515°, 6.X.1999, leg. S. Benedetta (27 males, 2 females; CNSMB). Corse-Haute Corse, Mausoleo



**Figures 257–258.** *Allogamus corsicus* Ris, 1897. 257 = male, phallic organ in left lateral view, 258 = the basally fused parameres in dorsal view.



**Figures 259–262.** *Allogamus corsicus* Ris 1897. 259 = female genitalia in left lateral view with vaginal sclerite complex, 260 = anal tube in dorsal view, 261 = female vulvar scale (lower lip) in ventral view, 262 = dorsal profile of vaginal sclerite complex.



leo, fiume Tartagine, 1100 m, light trap, N 42,4758° E 8,9515°, 28.IX.2000, leg. S. Benedetta (88 males, 22 females; CNSMB). Corse-Haute Corse, Mausoleo, sorgente Tartagine, 1450 m, light trap, N42,4691° E 8,9293°, 6.X.1999, leg. S. Benedetta (11 males, 4 females; CNSMB). Corse-Haute Corse, Mausoleo, sorgente Tartagine, 1450 m, light trap, N42,4691° E 8,9293°, 28.IX.2000, leg. S. Benedetta (33 males, 21 females; CNSMB). Corse-Haute Corse, Mausoleo, P.te sul Melaja, 740 m, light trap, N42,5044° E 8,9777°, 5.X.2000, leg. S. Benedetta (38 males, 18 females; CNSMB). Corse-Haute Corse, Restonica, c/o camping, 650 m, N42,3015° E 9,1522°, 13.XI.2002, leg. L. Dapporto (3 males, 1 female; CNSMB). *Italy*. Sardegna-Sassari, torrente c/o sorg. Monte Limbara, 9.XII.2004, leg. O. Lodovici, P. Pantini (1 male, 2 females CNSMB; 1 male, 2 females; OPC).

*Remarks.* *A. corsicus* is distinguished from *A. illiesorum* by stable diverged fine structure of parameres and aedeagus head in male and by female tergum IX with rounded lateral shoulders.

***Allogamus illiesorum* Botosaneanu, 1980 stat. rev.**

(Figures 263–264, 265–268)

*Allogamus illiesorum* Botosaneanu, 1980: 76–77, 80.

*Allogamus illiesorum* Botosaneanu, 1980. Sister-species status between *A. corsicus* and *A. illiesorum* was confirmed with new drawings by Botosaneanu (2004:173–175).

*Allogamus corsicus illiesorum* Botosaneanu, 1980. Downgraded to subspecies status by Malicky (2005: 575), without any diagnosis.

*Material examined. Italy.* Sardegna-Nuoro, Desulo, Rio Melantiagu, N40.0383° E 9.2530°, 970 m, 7.XII.2004, light trap, leg. O. Lodovici & P. Pantini (2 females, CNSMB). Sardegna-Nuoro, Aritzo, 1100 m, 6.X.2002, light trap, leg. F. Fiumi (1 female, CNSMB; 6 males, 1 female; OPC). Sardegna-Nuoro, Fonni, Gennargentu, Rifugio, N40.0424° E 9.3005°, 1550 m, 24.X.2006, trap-pola a vino, leg. F. Fiori (2 males, 1 female, CNSMB). Sardegna-Cagliari, Maracalagonis, Rio

Dominigheddu sopra Geremeas, N39.2516° E 9.4266°, 380 m, 6.XII.2004, leg. O. Lodovici & P. Pantini (8 males, CNSMB; 2 males, 2 females; OPC).

*Remarks.* *A. illiesorum* is distinguished from *A. corsicus* by stable diverged fine structure of parameres and aedeagus head in male and by female tergum IX with pointed lateral shoulders.

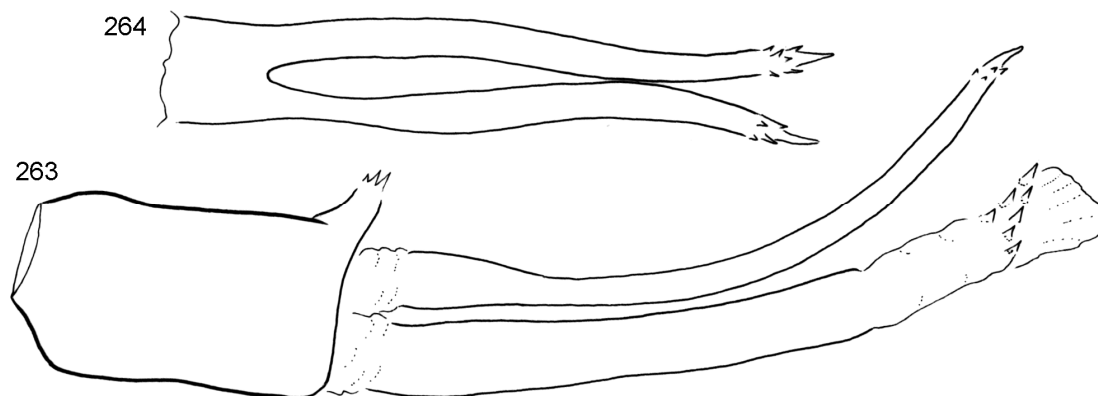
***Allogamus uncatus* species group, rediagnosed**

Schmid (1951a) has separated the „uncatus group” within the *Halesus* genus with all the known species of the present *Allogamus* genus. This species group of the genus *Halesus* was later raised to genus level under the newly erected genus *Allogamus* (Schmid 1955) and the species were listed in the *uncatus* and *auricollis* groups without any group diagnoses. The *Allogamus uncatus* rediagnosed species group has basally fused and apically adhering parameres and a dorsal pair of heavily sclerotized rod-shaped apomorphic processes on the aedeagus. Female anal tube fused, compact.

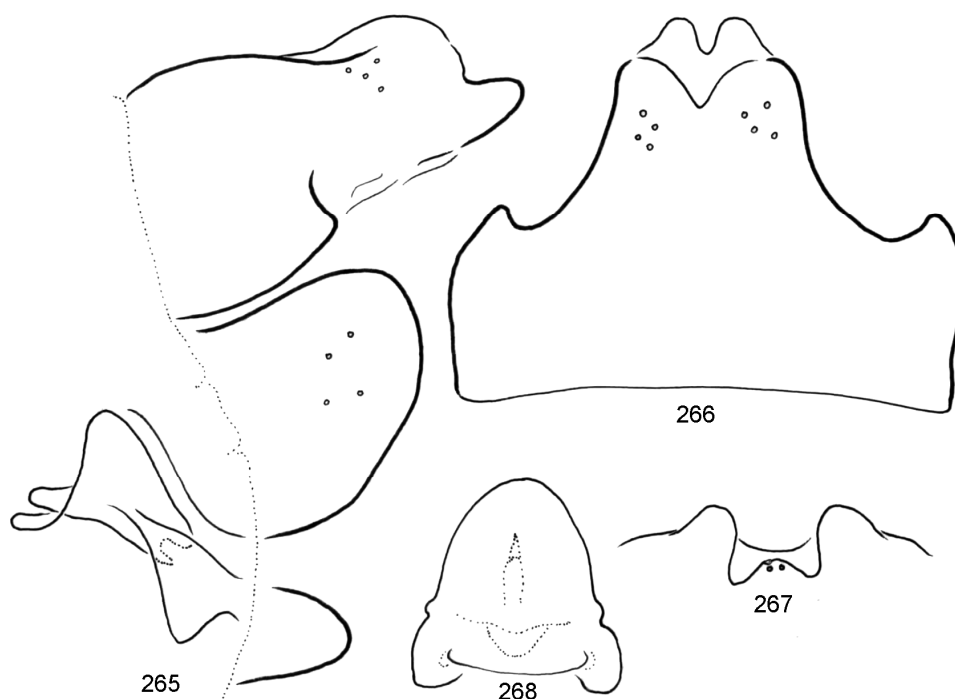
***Allogamus botosaneanui* Moretti, 1991**

(Figures 274, 294)

*Material examined. Italy.* Toscana-Firenze, Marradi, Monte Bruno, 700 m, N44.0259° E 11.6786°, 6.X.2002 leg. A. Usvelli (10 males, 1 female, CNSMB; 5 males, 4 females; OPC). Toscana-Firenze, Marradi, Monte Bruno, 700 m, N44.0259° E 11.6786°, 26.X.2002 leg. A. Usvelli (1 male; FMNHU). Toscana-Firenze, Marradi, Monte Bruno, 900 m, N 44,0259° E 11.6786°, 28. X.1999 leg. A. Usvelli (1 male; FMNHU). Toscana-Firenze, Marradi, Monte Bruno, rio Canneto, 700 m, N44,0259° E 11,6786°, 13.IX. 2003, leg. A. Usvelli (1 male; CNSMB). Toscana-Firenze, Marradi, Monte Bruno, rio Canneto, 700 m, light trap, N44,0259° E 11,6786°, 30.IX.2003, leg. A. Usvelli (2 males; CNSMB). Toscana-Firenze, Marradi, Monte Bruno, rio Canneto, 700 m, light trap, N44,0259° E 11,6786°, 21.X.2003, leg. A. Usvelli (1 Male; CNSMB). Liguria-Genova, Mezzanego, passo del Bocco, Parco Aveto - Foresta Demaniale Monte Zatta, 1000 m, light



**Figures 263–264.** *Allogamus illiesorum* Botosaneanu, 1980 stat. rev. 263 = male, phallic organ in left lateral view, 264 = the basally fused parameres in dorsal view.



**Figures 265–268.** *Allogamus illiesorum* Botosaneanu, 1980 stat. rev. 265 = female genitalia in left lateral view with vaginal sclerite complex, 266 = anal tube in dorsal view, 267 = female vulvar scale (lower lip) in ventral view, 268 = dorsal profile of vaginal sclerite complex.

trap, N44,4055° E9,4513°, 31.X.2009, leg. V. Raineri (2 males; CNSMB). Liguria-Genova, Mezzanego, passo del Bocco, Parco Aveto-Foresta Demaniale Monte Zatta, 1000 m, light trap, N 44,4055° E9,4513°, 2.X.2009, leg. V. Raineri (1 male; CNSMB). Liguria-Genova, Mezzanego,

passo del Bocco, Parco Aveto-Foresta Demaniale Monte Zatta, 1000 m, light trap, N44,4055° E 9,4513°, 30.X.2009, leg. O. Lodovici, V. Raineri, M. Valle (1 male, 1 female; CNSMB). Marche-Fermo, fiume Tenna, 6.XI.1977, leg. Romagnoli, D'Alessandro (1 male; n°1593 CC).

***Allogamus dacicus* (Schmid, 1951)**

(Figures 279, 285, 292)

*Material examined.* Romania. Argeş county, Făgăraş Mts, Căpătânenii Ungureni, small spring-lake by the Capra Stream along road No.7C, N45°34.605' E24°37.060', 1405m, 29.VIII.2012 leg. T. Kovács, D. Murányi, J. Oláh (1 male, 1 female; OPC). Braşov county, Făgăraş Mts, Dejani, right sidebrook of Dejani stream, N45°35.446' E24°56.348', 1755m, 30.VIII.2012 leg. T. Kovács, D. Murányi, J. Oláh (1 male, OPC).

***Allogamus fuesunae* Malicky, 2004**

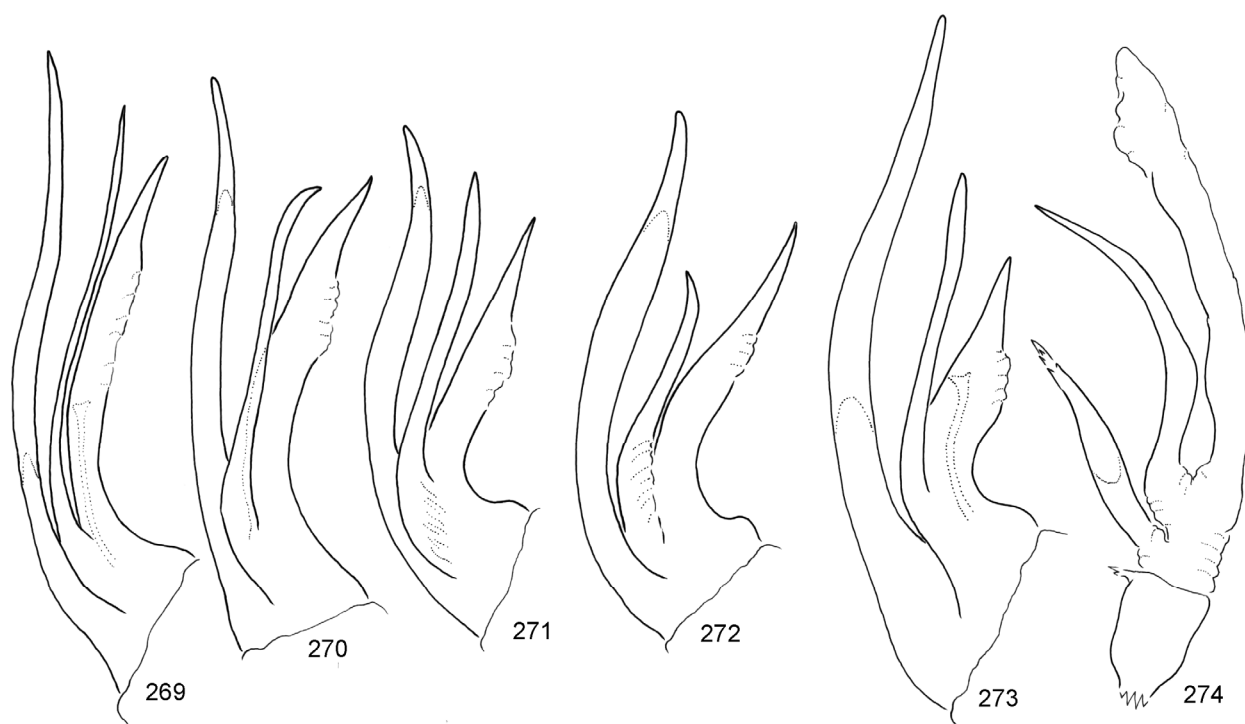
(Figure 275)

*Material examined.* Andorra. Vall de Ramsol, Riu dels Meners, 1966 m, N42°36.44777' E1°38.2116' 10.IX.1986, leg. M. González (1 male, OPC).

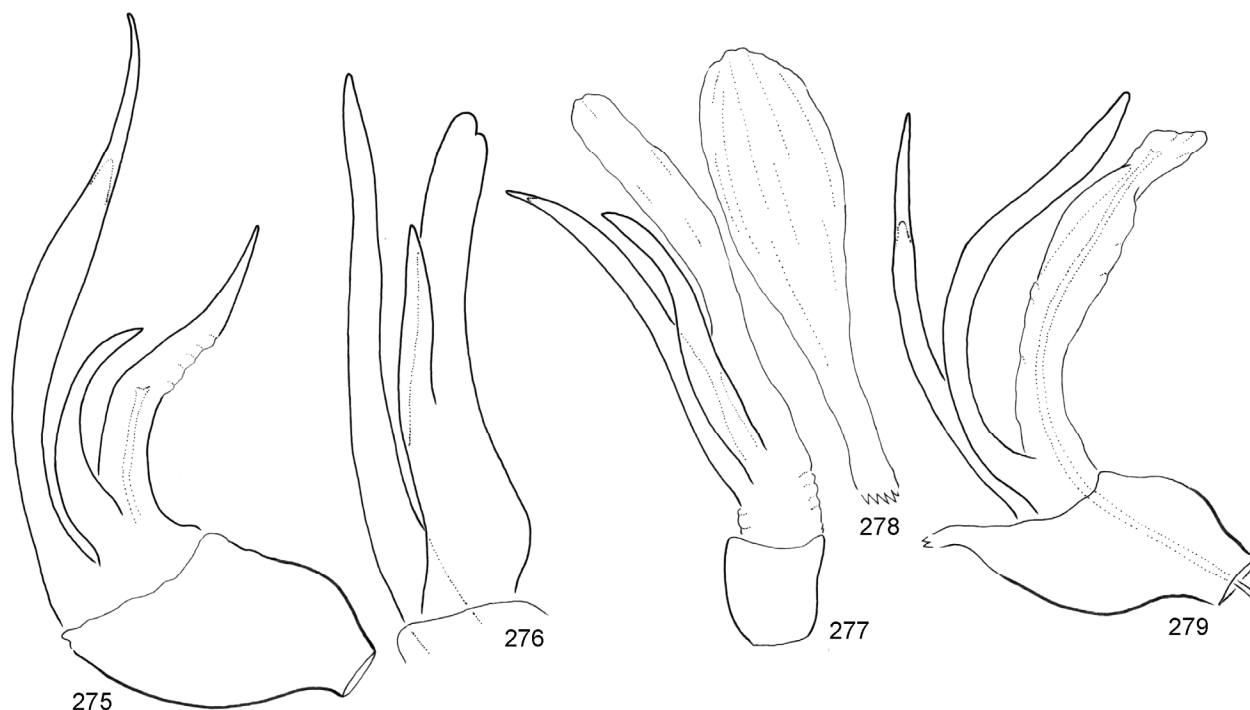
***Allogamus mendax* (McLachlan, 1876)**

(Figures 271, 282, 289)

*Material examined.* France. Alpes-de-Haute-Provence, Uvernet, Bachelard zone humide, 21. IX.2009, leg. G. Coppa, (2 males, 3 females; OPC). Italy. Piemonte-Cuneo, Crissolo, Pian del Re, fiume Po, N44.7005° E7.0934°, 2020 m, 22. IX.1998, light trap, leg. O. Lodovici (24 males, CNSMB; 12 males, OPC). Piemonte-Cuneo, Crissolo, Pian del Re, fiume Po, N44.7005° E7.0934°, 2020 m, 1.X.1997, light trap, leg. O. Lodovici (8 females, OPC). Piemonte-Torino, Prali, Ribba torrente Germanasca, 1800 m, N44.8575° E7.0372°, 29.IX.2002, leg. G.B. Delmastro, G Vincon (3 males, CNSMB). Valle d'Aosta-Aosta, Cogne, Parco Nazionale Gran Paradiso, 1500 m, 4.X. 1975, leg. M. Valle (1 female, CNSMB). Valle d'Aosta-Aosta, Valsavaranche, Pont, 1980 m, 27.VII.1980, leg. Faraci (4 males, CNHNV).



**Figures 269–274.** Male, phallic organ of the *Allogamus uncatus* species group in left lateral view. 269 = *Allogamus uncatus* (Brauer, 1857), 270 = *Allogamus stadleri* (Schmid, 1951), 271 = *Allogamus mendax* (McLachlan, 1876), 272 = *Allogamus pantinii* Oláh, Lodovici & Valle sp. nov. 273 = *Allogamus tomor* Oláh, 2012, 274 = *Allogamus botosaneanui* Moretti, 1991.



**Figures 275–279.** Male, phallic organ of the *Allogamus uncatus* species group in left lateral view. 275 = *Allogamus fuesunae* Malicky, 2004, 276 = *Allogamus periphetes* Malicky, 2004, 277 = *Allogamus starmachi* Szczesny, 1967, 278 = *Allogamus starmachi* Szczesny, 1967, membranous aedeagus in erected state, 279 = *Allogamus dacicus* (Schmid, 1951).

***Allogamus pantinii* Oláh, Lodovici & Valle sp. nov.**

(Figures 272, 283, 290, 295–303)

**Diagnosis.** This new species with almost uni-colour light brown forewing without any distinct pattern is most close to *A. mendax*, but differs by having fused paramere with different arching and longer separated apical portion; paired dorsal branches of the aedeagus shorter and with distinctly laterad arching pattern; aedeagus apex turning slightly upward, not straight; dorsal profile of the vaginal sclerite complex different and the modified accessory duct shorter.

**Material examined.** *Holotype.* Italy, Piemonte-Cuneo, Briga Alta, affluente Torrente Negrone, N44.1109° E7.7252°, 1600 m, 10.X.2001, light trap, leg. Museo Caffi, Bergamo (1 male, CNS MB). *Allotype.* Same as holotype (1 female, CNS MB). *Paratype.* Same as holotype (1 male,

CNSMB; 1 male, OPC).

**Description.** Male (in alcohol). Both male and female have forewing membrane light brown without any distinct pattern. Forewing length 19 mm. Head, thorax, and appendages are stramineous.

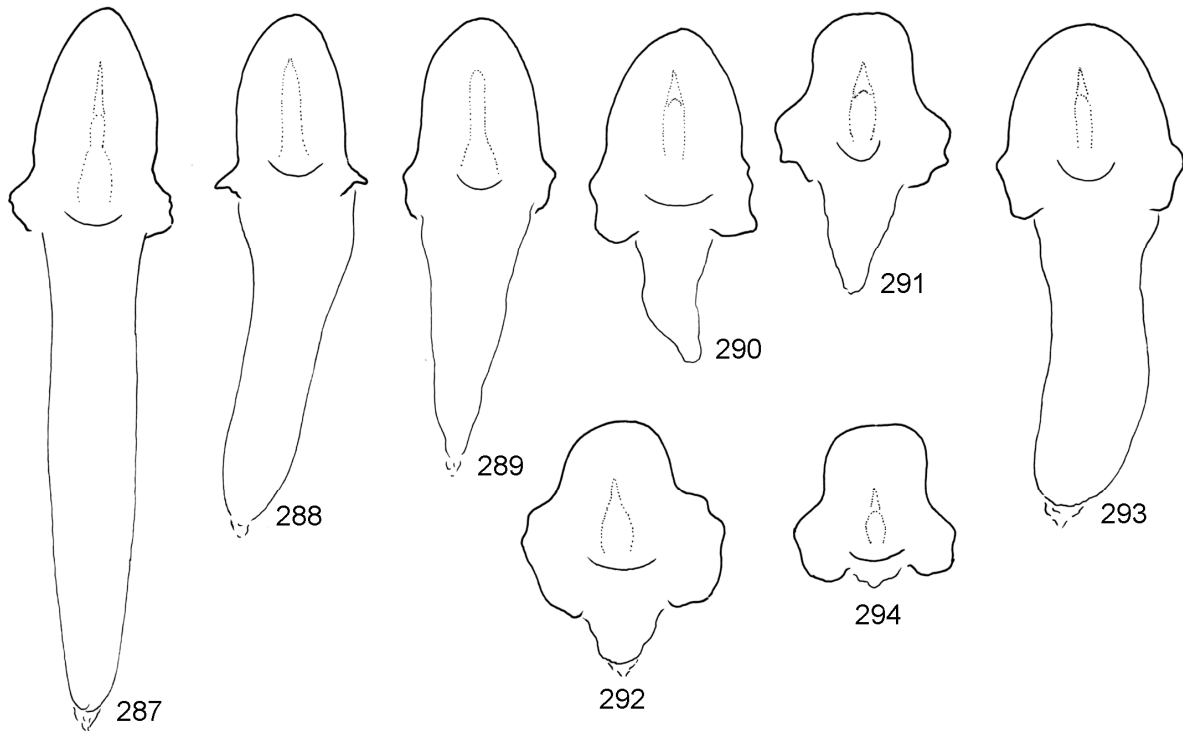
**Male genitalia.** Periphallallic organs as described in the species group rediagnosis. The fused parameres of the phallic organ rather stout, the free bifid apex is short. Dorsal arms of aedeagus with laterad arching apical third. Sclerotized dorsum of aedeagus upward arching.

**Female genitalia.** Anal tube with rounded basal half in dorsal view. Anterior apodemes of vaginal sclerite complex slightly bilobed laterad, modified accessory duct medium long.

**Etymology.** The species is dedicated to our colleague and friend Paolo Pantini who, for several years, collaborates with us in collecting caddisflies.



**Figures 280–286.** Female, anal tube of the *Allogamus uncatus* species group in left lateral view. 280 = *Allogamus uncatus* (Brauer, 1857), 281 = *Allogamus stadleri* (Schmid, 1951), 282 = *Allogamus mendax* (McLachlan, 1876, 283 = *Allogamus pantinii* Oláh, Lodovici & Valle sp. nov. 284 = *Allogamus starmachi* Szczesny, 1967, 285 = *Allogamus dacicus* (Schmid, 1951), 286 = *Allogamus tomor* Oláh, 2012.



**Figures 287–294.** Female, dorsal profile of the vaginal sclerite complex with the modified accessory duct of the *Allogamus uncatus* species group. 287 = *Allogamus uncatus* (Brauer, 1857), 288 = *Allogamus stadleri* (Schmid, 1951), 289 = *Allogamus mendax* (McLachlan, 1876, 290 = *Allogamus pantinii* Oláh, Lodovici & Valle sp. nov., 291 = *Allogamus starmachi* SZCZESNY 1967, 292 = *Allogamus dacicus* (Schmid, 1951), 293 = *Allogamus tomor* Oláh 2012, 294 = *Allogamus botosaneanui* Moretti 1991.

***Allogamus periphetes* Malicky, 2004**

(Figure 276)

*Remarks.* Holotype described from Italy, Piemonte and the single paratype from Switzerland. Types were not available for study. In spite of repeated intense collecting effort new material is lacking. Phallic organ is redrawn from the original drawings and description.

***Allogamus stadleri* (Schmid, 1951)**

(Figures 270, 281, 288)

*Material examined.* France. Puy-de-Dôme, Mont-Dore, Val-de-Courre, 10.X.2007, leg. G. Coppa, (1 male, 2 females, OPC).

***Allogamus starmachi* Szczesny, 1967**

(Figures 277–278, 284, 291)

*Allogamus starmachi* Szczesny, 1967: 479.

*Allogamus lazarei* Szczesny, 1967: 480–481. (Botosaneanu & Malicky 1978: 353.)

*Allogamus tatricus* Szczesny, 1967: 481–482. (Botosaneanu & Malicky 1978: 353.)

*Material examined.* Poland. High Tatras, Hliny Valley, 29.IX.1977 leg. Nagy (4 males, 1 female; OPC). High Tatras, above 1000 m, leg. B. Szczesny (11 males, 6 females, OPC).

***Allogamus tomor* Oláh, 2012**

(Figures 273, 286, 293)

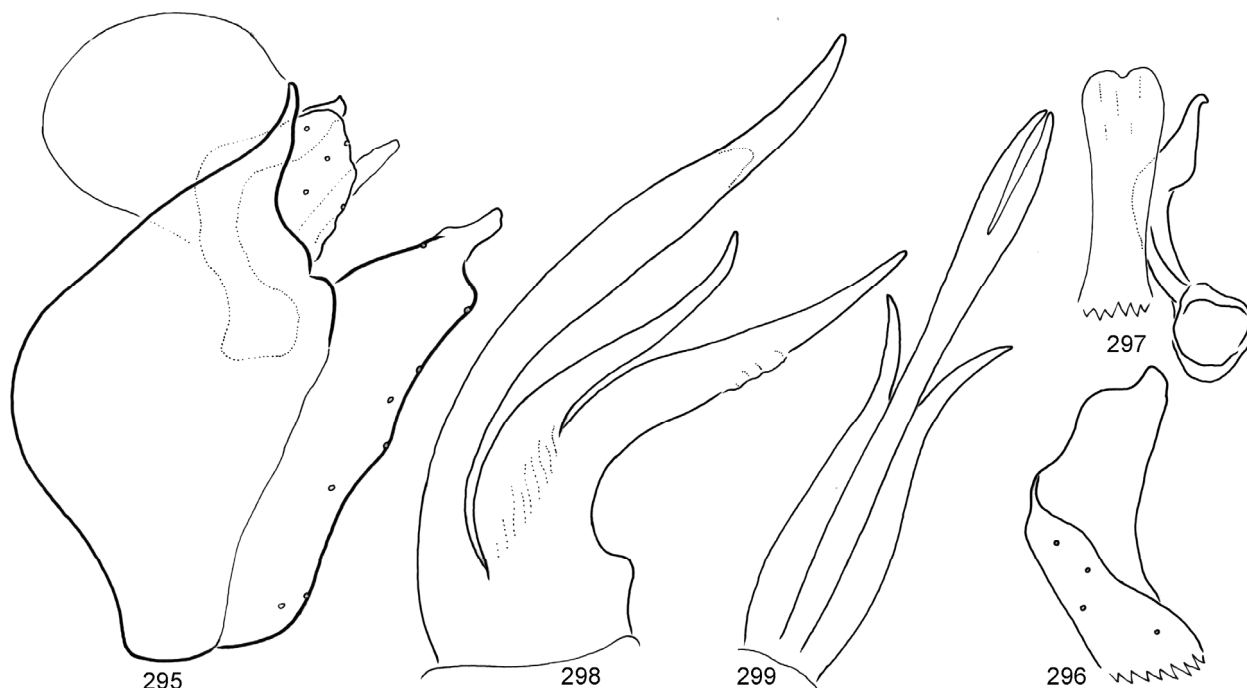
*Material examined.* Holotyp. Albania, Skrapar district, Ostrovicë Mts, Backë, Krojmbret Spring and its outlet brook NE of the village, N 40° 31.753' E20°25.152', 1965 m, 12.X.2012, leg. P. Juhász, T. Kovács, D. Murányi, G. Puskás (1 male, OPC). Allotype. Same as holotype (1 female, OPC).

***Allogamus uncatus* (Brauer, 1857)**

(Figures 269, 287)

*Material examined.* Albania. Bulqizë district, Çermenikë Mts, open brook beneath Mt. Kaptinë, N41°23.212' E20°17.506', 1610 m, 10.X.2012,

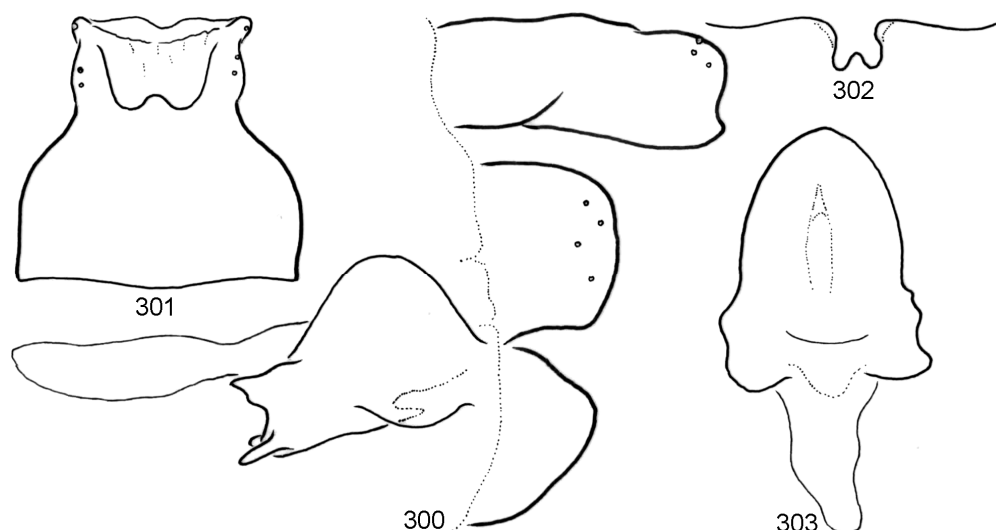
leg. P. Juhász, T. Kovács, D. Murányi, G. Puskás (1 male, OPC). Dibër district, Korab Mts, spring brooks of the bog beneath Mt. Korab, N41° 47.913' E20°33.561', 2165 m, 07.X.2012, leg. P. Juhász, T. Kovács, D. Murányi, G. Puskás (2 females, OPC). Korçë district, Vallamarë Mts, open brook above Lower Lenija Lake, SE of Vallamarë Peak, N40°47.374' E20°28.250', 2100 m, 10.X.2013, P. Juhász, T. Kovács, D. Murányi, G. Puskás, (16 males, 21 females; OPC). Austria. Gleinalpe, springs and springbrook 1.4 km above restaurant Krautwaschl, 1172 m, N47°12'15.31", E15°8' 22.14", 22.X.2012, leg. J. Oláh & I. Szivák (1 female; OPC). Koralpe, Handalm, springs near Gösler Hütte (Weinebene), 1784m, N46° 50'35.89", E15°01'18.53", 21.X.2012, leg. J. Oláh & I. Szivák (1 male, OPC). Bulgaria. Rila Mts., Borovets, Zavrachitsa hut, Prava Maritsa, 42°10' 04.9", 23°38'28.1", 2200 m, 05.X.2011, light, leg. Á. Ecsedi, T. Kovács, G. Puskás, (2♂, 14♀, OPC). Blagoevgrad province, Pirin Mts, Bansko, stream in pine shrub above the Vihren hut, N41°45.293' E23°24.933', 1995 m, 24.X.2013, leg. J. Kontschán, D. Murányi, T. Szederjesi, (3 females, HNHM). Pazardzhik province, Bataska planina, Batak, forest brook SW of the village, 1520 m, N41°53.412' E24°10.366', 25.X.2013, leg. J. Kontschán, D. Murányi, T. Szederjesi, (1 female; HNHM). Czech Republic. Western Bohemia, Krušné hory Mts, brook W of Jelení (NW of Nové Hamry), 900 m, N50°23'47" E12°39'00", 20.X.1993, P. Chvojka leg. (4 males, 4 females, NMPC). Northern Bohemia, Jizerské hory Mts, Ješkrabec brook, Rejdice, 670–750 m, N50°43'58" E15°21'55", 29.IX.2006, P. Chvojka leg. (2 males, 2 females, NMPC). Eastern Bohemia, Orlické hory Mts, brooks, NPR Trčkov reserve SE of Šerlich Mt., 800–850 m, N50°18'50" E16°24'55", 28.X.1994, P. Chvojka leg. (2 males, 3 females, NMPC). Eastern Bohemia, Orlické hory Mts, brook, NPR Bukačka reserve NW of Šerlich Mt., 930–970 m, N50°20'06" E16°22'31", 26.X.1994, P. Chvojka leg. (2 males, 3 females, NMPC). Northern Moravia, Králický Sněžník Mt., Morava river, 750–1100 m, N50°10'00" E16° 49'14", 19.X.2000, P. Chvojka leg. (5 males, 4 females, NMPC). Italy. Friuli Venezia Giulia-Udine, Raccolana, Sella Nevea, 1030 m, 23.IX.1995,



**Figures 295–299.** *Allogamus pantinii* Oláh, Lodovici & Valle sp. nov. Male, 295 = genitalia in left lateral view, 296 = apparent harpago in caudal view, 297 = right paraproct and subanal plate in caudal view, 298 = phallic organ in lateral view, 299 = fused paramere and the dorsal arms of aedeagus in dorsal view.

leg. Á. Uherkovich (1 male, 1 female; OPC). Friuli Venezia Giulia-Udine, Resia, Ucea, rio Bianco, N46.3108 E13.3575, 800 m, 20.IX.1996, leg. P. Pantini & M. Valle (10 males, 7 females, OPC). Friuli Venezia Giulia-Udine, Resia, Alpi Giulie, Sella Carnizza, spring area of River Ucea, N46°20'11.4" E13°19'46.8", 1105 m, 9.XI.2012, leg. T. Kovács & G. Magos (1 female, OPC). Lombardia-Bergamo, Foppolo, epirhitral-sopra il paese, 1700 m, 17.X.2004, leg. P. Pantini, S. Simula (5 females, CNSMB). Lombardia-Bergamo, Premolo, sorgenti torrente Parina, N 45.9240° E9.8246°, 1750 m, 1.X.2003, light trap, leg. O. Lodovici, M. Massaro (125 males, 30 females, CNSMB; 20 males, 10 females; OPC). Lombardia-Bergamo, Valbondione, Val Cerviera, 2050 m, light trap, N46,0562° E10,0598°, 2.IX. 2003, leg. R. Calandrina (5 males; CNSMB). Lombardia-Bergamo, Parre, c/o Baita di Leten, 1765 m, light trap, N45,9242° E9,8541°, 29.IX. 2004, leg. O. Lodovici, M. Massaro, M. Valle (15 males; CNSMB). Lombardia-Brescia, Vione, Val Cané, Rio Cortebona, 1800 m, light trap, N 46,2765° E10,4521°, 20.IX.1982, leg. A. Bona-

cina, M. Valle (1 male; CNSMB). Lombardia-Sondrio, Val Masino, La Rasica, 1150 m, N46.2638° E9.6774°, 21.X.2007, leg. M. Valle (13 males, 1 female; CNSMB). Lombardia-Sondrio, Valfurva, Passo Gavia, bordo lago, 2650 m, N46,3446° E10,4916°, 10.IX.2011, leg. W. Zucchelli (3 males; CNSMB). Veneto-Belluno, Feltre, sorgenti torrente Colmeda, N46.0764° E11.8709°, 750 m, 14.X.2002, light trap, leg. O. Lodovici, P. Pantini (2 males, OPC). Macedonia. Pelagonia region, Pelister Mts, Nižepole, open brook at the ski station, N40°58.787' E21°15.218', 1375m, 2.X.2013, leg. T. Kovács, D. Murányi, (19 males, 16 females; OPC). Montenegro. Prokletije Mts. Vusanje S 2 km, Oko spring and grlja stream, 1034 m, N42° 30.704' E19° 50.088', 12.X.2008, leg. L. Dányi Z. Fehér, J. Kotschán & D. Murányi (1 male, HNHM). Velika E, Murino 18 km toward Čakor-pass, N42° 40.001' E19° 59.800', 1554 m, 5.X.2005, leg. T. Deli, Z. Erőss, Z. Fehér & D. Murányi (1 male, HNHM). Vojnik Mts. Mokro, ca. 5 km S of Savnik, spring and its outlet brook in beech forest, 1062m, N42° 56.858' E19° 05.463', 9.X.2008, leg. L. Dányi, Z. Fehér,



**Figures 300–303.** *Allogamus pantinii* Oláh, Lodovici & Valle sp. nov. Female, 300 = genitalia in left lateral view with the vaginal sclerite complex, 301 = anal tube in dorsal view, 302 = vulvar scale (lower lip), 303 = dorsal profile of vaginal sclerite complex with the modified accessory duct.

J. Kontschán & D. Murányi (1 male, HNHM). Bjelasica Mts, Stevanovac, Lepešnica, 42°59' 28.2", 19°32'48.8", 1050 m, 04.11.2011, leg. KOVÁCS, T. MAGOS, G. (2 males, 2 females; OPC). *Poland*. Koscielsko, Chocholowska Valley, 15.IX.1989, leg. S. Nógrádi & Á. Uherkovich (1 female; OPC). *Romania*. Transylvania, leg. L. Peregovits & L. Ronkay (1 male, OPC). *Slovakia*. Stratena valley, toward Hrabusice, 26.IX.1984, leg. Á. Uherkovich (2 females, OPC). Svermovo (=Telgárt), Hron Spring, 19.IX.1985, leg. Á. Uherkovich (8 males, OPC). Podbanske, 14.X. 1989, leg. S. Nógrádi & Á. Uherkovich (1 male, 1 female; OPC). Stratena, Dobsínska Ladova Jaskyna, 11.X.1987, leg. Á. Uherkovich (1 male, 1 female; OPC). Tatranska Polianka, 10.X.1987, leg. Á. Uherkovich (3 males, OPC). High Tatra, Hliny Valley, 29.IX.1977, leg. Nagy (8 males, females, OPC). Oravské Beskydy Mts, left tributary of Bystrá stream below Babia hora Mt., 1000–1300 m, N49°33'39" E19°30'47", 15.X. 1991, leg. P. Chvojka (13 males, 5 females, NMPC). High Tatras, brook W of Biely Váh river, 1320 m, N49°08'00" E20°01'00", 07.X. 1990, leg. P. Chvojka (3 males, 1 female, NMPC). High Tatras, Biely Váh river, 1280 m, N49°08' E20°01', 07.X.1990, leg. P. Chvojka (4 males, 2 females, NMPC). High Tatras, Biely Váh river,

1350 m + 1440 m, N49°08'10" E20°01'04", 07.X. 1990, leg. P. Chvojka (5 males, 4 females, NMPC). Belianske Tatras, Čierna voda stream S of Tatranská Kotlina, 860 m, N49°12'32" E20° 18'36", 13.X.1990, P. Chvojka leg. (4 males, 7 females, NMPC). Tributary River Lupcianska, Liptovská Luzna, Narodny Park Nízke Tatry, 830 m, 11.X.2008, leg. Richabun team (1 male, OPC). Rejdova (Sajóréde), Mlynna stream, below spring, at bridge, N48°46'16" E20°13'31" 1250 m, 3. X. 2013, singled leg. J. Oláh & J. Kecskés (2 females; OPC). Rejdova (Sajóréde), right tributary of Mlynna stream, at bridge, N48°46' 16" E20°13'31" 1250 m, 3. X. 2013, singled leg. J. Oláh & J. Kecskés (5 males, 4 females; OPC). Rejdova (Sajóréde), Slana (Sajó) stream, below spring, N48°47'6" E20°12'18", 1120 m, 3.X. 2013, singled leg. J. Oláh & J. Kecskés (2males, OPC). Rejdova (Sajóréde), right tributary of Slana (Sajó) stream, lower reach, N48°48'53" E20°15' 51" 680 m, 3. X. 2013, singled leg. J. Oláh & J. Kecskés (1 male, 4 females, OPC). Rejdova (Sajóréde), Slana (Sajó) stream, lower reach, N48°48'15" E20°13'33" 910 m, 3. X. 2013, singled leg. J. Oláh & J. Kecskés (1 male, OPC). Banskobystrický region, Poľana Mts, Hriňová, Bystré, spring brook of Bystrý Stream, N48° 37.569' E19°29.261', 1025 m 8.X.2013, singled



leg. J. OLÁH & L. SZÉL (2 males, OPC). *Slovenia*. Pohorje Mt., below Pesek, spring area of river Oplotnica, 1345 m, 46°28'24,8" 15°20'55,9", 8. XI.2012, leg. T. Kovács & G. Magos (1 female, OPC). *Ukraine*. Ukrainian Carpathians, Pod Dancierz, 11.IX. 1908 (2 males, K375, K376; NMPC). Ukrainian Carpathians, Forestanka, 12 IX. 1908 (1 male, K377; NMPC)

**Acknowledgements** – Valuable materials have been provided and our studies supported by Fernanda Cianficconi and Carla Corallini University of Perugia; by Dmitri Logunov, The Manchester Museum, University of Manchester; by Hans Malicky, Lunz-am See, Austria; by Benjamin Price, Natural History Museum, London; by Ian Wallace National Museums Liverpool; by Marcos Gonzalez, University of Santiago de Compostela. Some specimens were collected as outcome of a funded project (reference 039/2007) from the Organismo Autónomo de Parques Nacionales (O.A.P.N.) of the Spanish Ministerio de Agricultura, Alimentación y Medio Ambiente and project CGL2007-60163/BOS ('RICHAB UN') funded by the Spanish Ministry of Education and Science/FEDER.

## REFERENCES

- ADAMI, C., OFRIA, C. & COLLIER, T. C. (2000): Evolution of biological complexity. *Proceedings of the National Academy of Sciences of the United State of America*, 97(9): 4463–4468.
- ADAMS, D. C., ROHLF, F. J. & SLICE, D. E. (2004): Geometric morphometrics: ten years of progress following the “revolution”. *Italian Journal of Zoology*, 71: 5–16.
- ARIEW, A. (2008): *Population thinking*. In: RUSE, M. (ed.) *Oxford Handbook of Philosophy of Biology*. Oxford University Press, pp. 64–86.
- BARETT, M., CLATTERBUCK, H., GOLDSBY, M., HELGESON, C., MCLOONE, B. PEARCE, T., SOBER, E., STERN, R. & WEINBERGER, N. (2012): Puzzles for ZFEL, McShea and Brandon's zero force evolutionary law. *Biology and Philosophy*, 27: 723–735.
- BOLTZMANN, L. (1886): *The second law of thermodynamics*. In: MCGINNES, B. (ed.) *Ludwig Boltzmann, theoretical physics and philosophical problems*, (1974). D. Reidel, New York.
- BOTOSANEANU, L. (1980): Quelques Trichoptères nouveaux du Pourtour de la Méditerranée (Trichoptera). *Bulletin Zoologisch Museum Universiteit van Amsterdam*, 7(8): 73–80.
- BOTOSANEANU, L. (2004): Western Palaearctic miscellaneous (Insecta: Trichoptera). *Travaux du Muséum National d'Histoire Naturelle „Grigore Antipa”*, 46: 161–179.
- BOTOSANEANU, L. & MALICKY, H. (1978): *Trichoptera*. In: ILLIES, J. (ed.) *Limnofauna Europaea*. Second edition. Gustav Fischer Verlag, Stuttgart, pp. 333–359.
- CHARLESWORTH, B. (2009): Effective population size and patterns of molecular evolution and variation. *Nature Reviews Genetics*, 10: 194–205.
- CHEN, S., KRINSKY, B. H. & LONG, M. (2013): New genes as drivers of phenotypic evolution. *Nature Review Genetics*, 14: 645–660.
- DECAMPS, H. (1967): *Allogamus despaxi* n. sp., Trichoptère nouveau des Pyrénées (Trichoptera, Limnephilidae). *Annales de Limnologie*, 3(1): 99–100.
- DE PIETRO, R. & CIANFICCONI, F. (2001): A new species of *Allogamus* from Sicily (Trichoptera Limnephilidae). *Bollettino della Societa Entomologica Italiana*, 133(1): 61–66.
- ESTEVE-ALTAVA, B., MARUGAN-LOBON, J., BOTELLA, H., & RASSKIN-GUTMAN, D. (2013): Structural constraints in the evolution of the tetrapod skull complexity: Williston's law revisited using network models. *Evolutionary Biology*, 40: 209–219.
- EVENHUIS, N. L. (2007): Helping solve the "other" taxonomic impediment: completing the eight steps to total enlightenment and taxonomic Nirvana. *Zootaxa*, 1407: 3–12.
- GONZALEZ, M. A. & RUIZ, A. (2001): Une nouvelle espèce de Trichoptère du Sud de l'Espagne: *Allogamus gibraltaricus* n. sp. (Trichoptera: Limnephilidae). *Annales de Limnologie – International Journal of Limnology*, 37: 219–221.
- GREGORY, W. K. (1935): Reduplication in evolution. *Quarterly Review of Biology*, 10: 272–290.
- GREGORY, T. R. (2004): Insertion-deletion biases and the evolution of genome size. *Gene*, 324: 15–34.
- KUMANSKI, K. P. (1968): *Chaetopteryx maximus* n. sp. aus Bulgarien (Trichoptera, Limnephilidae). *Comptes rendus de l'Académie bulgare des Sciences* 21(1): 59–61.
- KUMANSKI, K. P. (1969): *Chaetopteryx bulgaricus* – ein neue Art aus der maximus-Gruppe (Trichoptera, Limnephilidae). *Reichenbachia*, 12(3): 21–27.

- KUMANSKI, K. P. (1987): A new genus of the Chaetopterygini-tribe (Trichoptera: Limnephilidae). *Trichoptera Newsletter* (Lunz, Austria), 14: 17–19.
- LYNCH, M. (2006): The origins of eukaryotic gene structure. *Molecular Biology and Evolution*, 23: 450–468.
- MAYR, E. (1959): *Typological versus population thinking*. In: MEGGERS, B. J. (ed.) *Evolution and anthropology: a centennial appraisal*. Anthropological Society of Washington. Washington, D. C. pp. 409–412.
- MALICKY, H. (1974): Die Köcherfliegen (Trichoptera) Griechenlands. Übersicht und Neubeschreibungen. *Annales Musei Goulandris*, 2: 105–135.
- MALICKY, H. (2004): Neue Köcherfliegen aus Europa und Asien. *Braueria*, 31:36–42.
- MALICKY, H. (2005): Ein kommentiertes Verzeichnis der Köcherfliegen (Trichoptera) Europas und des Mittelmeergebietes. *Linzer biologische Beiträge*, 37(1): 533–596.
- MC SHEA, D. W. (2005): The evolution of complexity without natural selection, a possible large-scale trend of the fourt kind. *Paleobiology*, 31(Supplement 2): 146–156.
- MC SHEA, D. W. & BRANDON, R. (2010): *Biology's first law*. University of Chicago Press, Chicago.
- MC SHEA, D. W. & HORDIJK, W. (2013): Complexity by substruction. *Evolutionary Biology*, 40: 504–520.
- MORETTI, G. P. (1991): *Nouvelles espèces et sous-espèces de Trichoptères italiens et exemples de variabilité des populations des Alpes meridionales et des Appenins*. In: TOMASZEWSKI, C. (ed.) *Proceedings of the 6th International Symposium on Trichoptera*, AMU Press, Poznan, pp. 385–402.
- NAVAS, L. (1907): Notas Zoológicas XIII. Insectos nuevos ó recientemente descritos de la peninsula ibérica. *Boletín de la Sociedad Aragonesa de Ciencias Naturales*, 6: 194–200.
- NEI, M., SUZUKI, Y. & NOZAWA, M. (1910): The neutral theory of molecular evolution in the genomic era. *Annual Review of Genomics and Human Genetics* 11: 265–289.
- OLÁH J. & JOHANSON K. A. (2008): Reasoning an appendicular and functional caddisfly genital terminology. *Braueria*, 35: 29–40.
- OLÁH, J., KOVÁCS, T., SIVEC, I., SZIVÁK, I. & URBANIC, G. (2012): Seven new species in the *Chaetopteryx rugulosa* species group: applying the phylogenetic species concept and the sexual selection theory (Trichoptera, Limnephilidae). *Folia Historico Naturalia Musei Matraensis*, 36: 51–79.
- OLÁH, J., KOVÁCS, T. (2012): New species and records of autumnal Trichoptera from Albania. *Folia Historico Naturalia Musei Matraensis*, 36: 89–104.
- OLÁH, J. & ITO, T. (2013): Synopsis of the *Oxyethira flavicornis* species group with new Japanese *Oxyethira* species (Trichoptera, Hydroptilidae). *Opuscula Zoologica, Budapest*, 44(1): 23–46.
- OLÁH, J., ANDERSEN, T., CHVOJKA, P., COPPA, G., GRAF, W., IBRAHIMI, H., LODOVICI, O., PREVIŠIĆ, A. & VALLE, M. (2013a): The *Potamophylax nigricornis* group (Trichoptera, Limnephilidae): resolution of phylogenetic species by fine structure analysis. *Opuscula Zoologica, Budapest*, 44(2): 167–200.
- OLÁH, J., IBRAHIMI, H. & KOVÁCS, T. (2013b): The *Chaetopteroides* genus (Trichoptera, Limnephilidae) revised by fine structure analysis of parameres. *Folia Historico Naturalia Musei Matraensis*, 37: 93–108.
- PIGLIUCCI, M. (2006): Genetic variance-covariance matrices: a critique of the evolutionary quantitative genetics research program. *Biology and Philosophy*, 21: 1–23.
- ROHLF, F. J. & L. F. MARCUS 1993. A revolution in morphometrics. *Trends in Ecology and Evolution* 8:129–132.
- ROSS, H. H. (1956): *Evolution and classification of the mountain caddisflies*. The University of Illinois Press, Urbana.
- SCHMID, F. (1951a): Monographie du genre *Halesus* (Trich.). *Trabajos del Museo de Ciencias Naturales de Barcelona, Nueva Serie Zoologica*, 1(3): 1–71.
- SCHMID, F. (1951b): Notes sur quelques *Halesus* (Trich. Limnoph.). *Bulletin de la Société Vaudoise des Sciences Naturelles*, 65(278): 63–71.
- SCHMID, F. (1955): Contribution à l'étude des Limnephilidae (Trichoptera). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, 28: 1–245.
- SCHMID, F. (1958): A propos de deux récents ouvrages sur la phylogénie et la zoogéographie des Trichoptères. *Miscellanea Zoologica Barcelona*, 1: 1–27.

- SCHMID, F. (1968): La famille des Arctopsychides (Trichoptera). *Mémoires de la Société Entomologique du Québec*, 1: 1–84.
- SCHMID, F. (1970): Le genre *Rhyacophila* et la famille des Rhyacophilidae (Trichoptera). *Mémoires de la Société Entomologique du Canada*, 102(S66): 5–334.
- SCHMID, F. (1979): On some new trends in Trichopterology. *Bulletin of the Entomological Society of Canada*, 11: 48–57.
- SCHMID, F. (1998): *The insects and arachnids of Canada*. Part 7. Genera of the Trichoptera of Canada and adjoining or Adjacent United States. NRC Research Press, Ottawa, Ontario, Canada.
- SCHNEIDER, E. D. & KAY, J. J. (1995): *Order from disorder: the thermodynamics of complexity in biology*. In: MURPHY, M. P. & O'NEILL, L. A. J. (eds.) *What is life: the next fifty years. Reflections on the future of biology*. Cambridge University Press, pp. 161–172.
- SCHRÖDINGER, E. (1944): *What is life?* Cambridge University Press, London.
- SORBER, E. (1994): *Evolution, population thinking, and essentialism*. In: Sorber, E. (ed.) *Conceptual issues in evolutionary biology*. 2nd ed. Cambridge, Massachusetts, MIT Press.
- SZCZESNY, B. (1967): Notes sur quelques espèces d'*Allogamus* (Trichoptera, Limnephilidae) dans les Tatras. *Bulletin de l'Académie Polonaise des Sciences. Série des Sciences biologiques*, 15(8): 479–482.
- VSHIVKOVA T. S. (2007): *Phylogeny of family Limnephilidae (Insecta: Trichoptera) with emphasis on tribe Limnephilini (Subfamily Limnephilinae)*. Ph.D. Thesis. Clemson University.
- WILLISTON, S. W. (1914): *Water Reptiles of the past and present*. University of Chicago Press, Chicago.
- YI, S. V. (2006): Non-adaptive evolution of genome complexity. *Bioessays*, 28: 979–982.

# Faunal diversity of Cladocera (Crustacea: Branchiopoda) in wetlands of Majuli (the largest river island), Assam, northeast India

B. K. SHARMA<sup>1</sup> and S. SHARMA<sup>2</sup>

Prof. B. K. Sharma and Dr. Sumita Sharma, Freshwater Biology Laboratory, Department of Zoology,  
North-Eastern Hill University, Permanent Campus, Shillong-793022, Meghalaya, India  
E-mail: <sup>1</sup>probksharma@gmail.com (corresponding author), <sup>2</sup>sumitasharma.nehu@gmail.com

**Abstract.** Our collections from the wetlands of Majuli, the largest river island of the world and a unique fluvial landform of the Brahmaputra river basin of northeast India, reveal 55 Cladocera species belonging to 36 genera. These represent ~46.0% and ~79.0% of the freshwater species and genera of the taxon known from India, respectively. The Indo-Chinese *Alona kotovi* is new record from India and the Indo-Chinese *Chydorus angustirostris* is new to northeast India. The Australasian *Disperalona caudata*, the Indo-Chinese *Alona cheni*, and the Oriental *Celsinotum macronyx* and *Kurzia* (*Rostrokurzia*) *brevilabris* are other biogeographically notable elements while several species are of regional interest. The speciose and diverse Cladocera reflect habitat diversity and environmental heterogeneity of the sampled ecosystems. The fauna records rich diversity of the littoral-periphytonic taxa in general and the Chydoridae in particular. Majuli Cladocera is characterized by lack of *Leydigiopsis*, *Daphnia* spp. and *Acroperus harpae*; fewer *Diaphanosoma* spp., and uncommon occurrence of the Bosminidae and Moinidae as compared with our samples elsewhere from the floodplains of the Brahmaputra basin.

**Keywords.** Biodiversity, Brahmaputra basin, fluvial floodplain, distribution, Cladocera biogeography.

## INTRODUCTION

Majuli, the largest river island of the world (Wikipedia) situated in the upper reaches of the river Brahmaputra in Upper Assam, is an interesting landform of fluvial geomorphology and of unique geographical occurrence resulting from the dynamics of this vast river system. This hotspot for flora and fauna and one of the globally important cultural heritage sites is under serious threat of its extinction due to alarming erosion of its landmass. Various wetlands ranging from small *dobas* or *dubies* to large floodplain lakes (*beels*) form an important part of its landscape and socio-economy due to their significant fishery production potential.

This first report on diversity of Cladocera, an integral link in aquatic food-webs, of floodplains of the Majuli River Island merits special biogeography value. It assumes biodiversity inter-

est in light of our hypothesis (Sharma and Sharma 2008, 2012) on the floodplain wetlands of the Brahmaputra river basin as one of the globally rich habitats for aquatic biodiversity due to their habitat diversity and environmental heterogeneity.

Here, we present an inventory of cladoceran species examined from the floodplains of Majuli with comments on the nature and composition of the fauna, occurrence of interesting elements and distribution of different species.

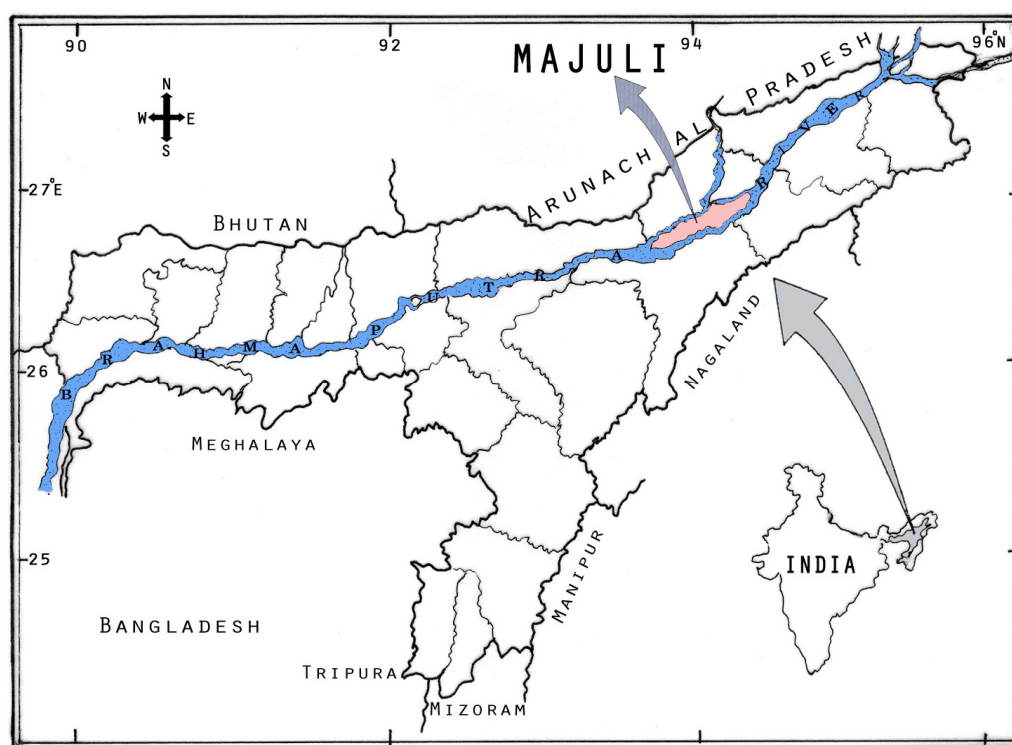
## MATERIALS AND METHODS

This study is based on plankton samples collected, during 2010–2012, from 20+ floodplain lakes (*beels*) and 30+ small wetlands (*dobas* or *dubies*) of Majuli River Island (Long.: 93°–95° E, Lat.: 25°–27° N), upper Assam (Fig.1). The beels (area: 10–120 ha; average depth: 0.90–3.0 m) sampled are summarized in Table 1.

**Table 1.** Geographical data of the beels sampled.

Bhereki Beel*	26°57'09.1''(N)	94°12'23.0''(E)	Altitude 67 m ASL
Chela Beel*	27°04'58.2''(N)	94°17'51.9''(E)	Altitude 89 m ASL
Ghotonga Beel*	27°01'52.7''(N)	94°15'28.7''(E)	Altitude 73 m ASL
Holmari Beel*	26°59'17.3''(N)	94°12'30.6''(E)	Altitude 75 m ASL
Khorkhoria Beel*	26°56'47.4''(N)	94°12'28.8''(E)	Altitude 74 m ASL
Chakuli Beel*	26°56'40.3''(N)	94°09'01.9''(E)	Altitude 69 m ASL
Baatomaari Beel	26°59'25.9''(N)	94°13'08.0''(E)	Altitude 71 m ASL
Tuni Beel:	26°58'35.3''(N)	94°15'57.8''(E)	Altitude 67 m ASL
Noldunga Beel	26°58'09.4''(N)	94°03'03.4''(E)	Altitude 74 m ASL
Kakorikata Beel	26°57'19.1''(N)	94°08'35.7''(E)	Altitude 74 m ASL
Bor Beel	27°05'13.2''(N)	94°22'41.8''(E)	Altitude 75 m ASL
Doriya Beel	26°57'27.7''(N)	94°10'02.4''(E)	Altitude 70 m ASL
Dighaliya Beel	26°56'15.5''(N)	94°03'45.7''(E)	Altitude 68 m ASL
Lingri Beel	26°57'02.7''(N)	94°05'05.3''(E)	Altitude 69 m ASL
Jur Beel:	26°59'45.3''(N)	94°14'34.4''(E)	Altitude 71 m ASL
Puronibaari Beel	26°59'23.7''(N)	94°11'16.8''(E)	Altitude 96 m ASL
Chereki Beel	26°58'25.4''(N)	94°10'38.7''(E)	Altitude 67 m ASL
Gukhai Beel	26°57'07.0''(N)	94°09'04.2''(E)	Altitude 70 m ASL
Baalichapori Beel	26°55'42.0''(N)	94°02'44.7''(E)	Altitude 75 m ASL
Mohorichuk Beel	26°55'40.4''(N)	94°01'47.7''(E)	Altitude 89 m ASL
Dubori Beel	26°57'01.9''(N)	94°16'13.8''(E)	Altitude 70 m ASL
Karatipar Beel:	26°56'39.4''(N)	94°04'13.5''(E)	Altitude 74 m ASL

\* Sampled monthly between August 2010–July 2011 while other *dobas* or *dubies* (area: 0.5 ha–1.20 ha; average depth: 0.70–1.5m) are sampled randomly during winter (December/January), pre-monsoon (March–May), monsoon (June–August) and post-monsoon (September–October) between August 2010–July 2012.



**Figure 1.** District map of Assam state indicating location of Majuli River Island (insert Map of India indicating Assam state of northeast India)

The sampled beels possessed different aquatic macrophytes' compositions consisting of such species as *Eichhornia crassipes*, *Hydrilla verticillata*, *Utricularia flexuosa*, *Trapa natans*, *Lemna major*, *L. minor*, *Pistia striates*, *Salvinia* sp., *Nymphaea* spp., *Nymphoides* spp., *Potamogeton* spp., *Azolla pinnata*, *Euryale ferox*, and *Sagittaria* sp.

The collections were made from the littoral and semi-limnetic / limnetic regions of different ecosystems by towing plankton net (# 50 µm) and were preserved in 5% formalin. All the samples (~250) were screened with a Wild-stereoscopic binocular microscope, various cladocerans and their disarticulated appendages were mounted in Polyvinyl alcohol-lactophenol mixture, and observed with a Leica (DM 1000) stereoscopic phase contrast microscope fitted with an image analyzer. Cladocera species were identified following the works of Smirnov (1971, 1976, 1992, 1996), Michael & Sharma (1988), Korovchinsky (1992), Sharma & Sharma (1999, 2008), Orlova-Bienkowskaja (2001) and Korinek (2002). The reference collections are deposited in the holdings of Freshwater Biology Laboratory, Department of Zoology, North-Eastern Hill University, Shillong.

## RESULTS

We examined 55 species belonging to 36 genera and seven families in our collections from Majuli River Island and their detailed systematic list is presented below:

### Systematic list of the examined Cladocera

#### Super-class: Crustacea

#### Class: Branchiopoda

#### Super-order: Cladocera (*sensu strictu*)

#### Order: Ctenopoda

#### Family: Sididae

1. *Diaphanosoma excisum* Sars, 1885
2. *D. sarsi* Richard, 1895
3. *D. senegal* Gauthier, 1951
4. *Pseudosida szalayii* (Daday, 1898)

5. *Sarsilatona serricaudata* (Sars, 1901)
6. *Sida crystallina* (O. F. Muller, 1776)

#### Order: Anomopoda

#### Family: Daphniidae

7. *Ceriodaphnia cornuta* Sars, 1885
8. *Scapholeberis kingi* Sars, 1901
9. *Simocephalus (Echinocaudus) acutirostratus* (King, 1853)
10. *S. (Echinocaudus) exspinosus* (De Geer, 1778)
11. *S. (Coronocephalus) serrulatus* (Koch, 1841)
12. *S. (Simocephalus) mixtus* Sars, 1903

#### Family: Bosminidae

13. *Bosmina longirostris* (O. F. Muller, 1776) s. lato
14. *Bosminopsis deitersi* Richard, 1895

#### Family: Moinidae

15. *Moina micrura* Kurz, 1874
16. *Moinodaphnia macleayi* (King, 1853)

#### Family: Macrothricidae

17. *Macrothrix laticornis* (Fischer, 1857)
18. *M. spinosa* King, 1853
19. *M. triserialis* (Brady, 1886)
20. *Guernella raphaelis* Richard, 1892
21. *Grimaldina brazzai* Richard, 1892

#### Family: Ilyocryptidae

22. *Ilyocryptus spinifer* Herrick, 1882

#### Family: Chydoridae

#### Subfamily: Chydorinae

23. *Alonella (Alonella) clathratula* Sars, 1886
24. *A. (Alonella) excisa* (Fischer, 1854)
25. *Chydorus angustirostris* Frey, 1987
26. *C. reticulatus* Daday, 1898
27. *C. sphaericus* (O. F. Muller, 1776) s. lato
28. *C. ventricosus* Daday, 1898
29. *Dadaya macrops* (Daday, 1898)
30. *Disperalona caudata* Smirnov, 1996
31. *Dunhevedia crassa* King, 1853
32. *D. serrata* Daday, 1898
33. *Ephemeroporus barroisi* (Richard, 1894)
34. *Picripleuroxus laevis* Sars, 1862
35. *P. similis* Vavra, 1900
36. *Pseudochydorus globosus* (Baird, 1843)

Subfamily: Aloninae

37. *Alona affinis* (Leydig, 1860) s.lat
38. *A. cheni* Sinev, 1999
39. *A. guttata tuberculata* Kurz, 1875
40. *A. kotovi* Sinev, 2012
41. *Anthalona harti* Van Damme et al. 2011
42. *Celsinotum macronyx* (Daday, 1898)
43. *Coronatella monacantha* (Sars, 1901) s.lat.
44. *C. rectangula* (Sars, 1862) s.lat
45. *Camptocercus uncinatus* Smirnov, 1973
46. *Euryalona orientalis* (Daday, 1898)
47. *Graptoleberis testudinaria* (Fischer, 1854)
48. *Karualona karua* (King, 1853)
49. *Kurzia* (Kurzia) latissima Kurz, 1874
50. *K. (Rostrokurzia) brevilabris* Rajapaksa & Fernando, 1986
51. *K. (Rostrokurzia) longirostris* (Daday, 1898)
52. *Leberis diphanus* (King, 1853)
53. *Leydigia acanthocercoides* (Fischer, 1854)
54. *Notoalona globulosa* (Daday, 1898)
55. *Oxyurella singalensis* (Daday, 1898)

## REMARKS AND DISCUSSION

Fifty-five Cladocera species observed in our collections from Majuli reveal speciose nature of their assemblage. The richness represents ~46.0% of the faunal diversity of Indian freshwater Cladocera (BKS unpublished) though Chatterjee *et al.* (2013) listed 130 freshwater species including certain records yet warranting confirmation. Further, these form ~77.0% of species of these micro-crustaceans examined from Assam (BKS unpublished). Though based on sampling from limited geographical area of this island, our report merits biodiversity value in view of a conservative estimate of occurrence of up to 60 – 65 cladoceran species from tropical and subtropical parts of India (Fernando & Kanduru 1984, Sharma & Michael 1987). This report broadly corresponds with 58 and 56 species recorded from fairly well studied cladoceran faunas of Meghalaya (Sharma & Sharma 1999, Sharma 2008) and West Bengal (Venkataraman 1999) respectively; the richness is higher than 49 species listed from Tripura (Venkataraman & Das 2000) while incomplete species inventories from other states of India facilitate no such comparisons. We also register rich higher-taxa diversity (36 genera and seven

families); the former form about ~79.0% of the freshwater genera of the group known from India (BKS unpublished) and the latter include all families represented from northeast India. The species-rich and diverse Cladocera reflect habitat diversity and environmental heterogeneity of the wetlands of this interesting River Island. Besides, our study supports the hypothesis of Sharma & Sharma (2008, 2013) on the floodplains of the Brahmaputra basin to be Cladocera rich habitats.

The species richness compares well with 56 species examined from various floodplain lakes (*beels*) of Assam (Sharma & Sharma 2008) and with 58 species observed from Deepor Beel, a Ramsar site and a biodiversity hot-spot (Sharma & Sharma 2013). On the other hand, the number of species examined from Majuli is distinctly higher than the record of 14 species from 37 floodplain lakes (Sarma 2000) of Assam; 9 species from 65 wetlands of 24-Parganas district (Nandi *et al.* 1993) as well as 36 species from 20 wetlands of Southeastern West Bengal (Khan 2003); 39 species from 30 wetlands of the Keoladeo National Park, Rajasthan (Venkataraman 1992) and 29 species from 25 water bodies of Melaghat Tiger reserve, Maharashtra (Rane 2005).

This study also presents a distinct contrast to the reports of five species from a wetland (Yousuf *et al.* 1986) and eleven species from two floodplain lakes (Khan 1987) of Kashmir; one (Baruah *et al.* 1993), four (Sinha *et al.* 1994) and 12 species (Sanjer & Sharma 1995) from a floodplain lake of Bihar; and only three species from Mori Beel (Goswami & Goswami 2001) of Assam. We caution against over-emphasis on comparisons with poor richness of several Indian studies because of inadequate sampling or incomplete species inventories due to lack of adequate taxonomic expertise.

*Alona kotovi* Sinev, 2012 (Figs. 2–3), described from South Vietnam, is an interesting addition to the Indian Cladocera. It forms a notable example of connection between South American and Australasian faunas of Chydoridae (Sinev 2012) and differs from the other species of *Alona* s. str. (the *quadrangularis*-group) by the morph-

ology of its postabdomen, labrum and thoracic limbs. Our report of *A. kotovi* from northeast India extends its distribution from Vietnam to the Indian subregion. We also propose re-examination of earlier Indian reports of *A. quadrangularis* as *A. kotovi* is likely to occur elsewhere in this country instead of *A. quadrangularis* s. str. particularly in light of pleas for validation of its non-Palaearctic populations (Sinev & Coronel 2006, Van Damme & Dumont 2008) and also its populations from North America, Australia and Tropical Asia, including Indochina (Sinev & Elmoor-Loureiro 2010).

*Chydorus angustirostris* is a new record from northeast India (Figs. 4–5). Originally described from Madhya Pradesh (Frey 1987) and also examined from Jammu & Kashmir, it is not reported since its description as this publication is overlooked in general cladocera studies from this country. On the other hand, the Indian populations of honeycombed *Chydorus* are invariably confused on general appearance and erroneously identified as *C. faviformis* – a North American species. Following Frey's excellent review of this species-group, identification of our specimens from Majuli as *C. angustirostris* extends the distribution of this endemic taxon to eastern Himalayas. In light of this report, we propose re-examination of all Indian reports of *C. faviformis*. With its recent report from South Vietnam (Sinev & Korovchinsky 2013), this erstwhile Indian endemic is now an Indo-Chinese element.

The Australasian *Disperalona caudata* (Figs. 6–7); the Indo-Chinese *Alona cheni* (Figs. 8–9); the Oriental *Celsinotum macronyx* (Figs. 10–11) and *Kurzia* (*Rostrokurzia*) *brevilabris* (Figs. 12–13) are biogeographically interesting elements. Of these, *D. caudata* is an important link between the Cladocera faunas of northeast India, South East Asia and Australia while the rest endorse affinity of northeast Cladocera with SE Asia. Their presence holds parallel to the reports of several such elements of Rotifera from northeast India (Sharma 2005, Sharma & Sharma 2005, 2013) and thus endorses our earlier remarks (Sharma & Sharma 2008) on the affinities of zooplankton communities of this region of India in general.

The Indo-Chinese *Alona cheni*, a member of *A. costata*-complex was described by Sinev (1999) based on the material examined from Aiwa Reservoir, Ahmedabad (Gujarat). Its occurrence in northeast India is recently confirmed from Deepor Beel (Sharma & Sharma 2013). According to (Sinev 1999), *A. costata* in (sub) tropical Asia seem to actually belong to *A. cheni*, likely a tropical congener failing to occur in temperate regions, while *A. costata* s. str. inhabits all Europe and much of North Asia, reaching East Siberia and central Mongolia in the east, as well as the Caucasus and northern Kazakhstan in the southeast. We endorse Sinev's remarks and thus propose re-examination of all earlier Indian records of *A. costata*.

The Oriental *Alona macronyx* was recorded from northeast India from Meghalaya (Sharma, 2008) and is a recent addition to Assam Cladocera (Sharma & Sharma, 2012). Its first Indian report, however, referred to *Indialona jabalpurensis*, a new species described by Rane (1983) from Madhya Pradesh, which was designated as a synonym (Sharma and Sharma 1990) of *A. macronyx*. We assign our specimens of the taxon to *Celsinotum* following Sinev & Kotov (2012); it is widely distributed in the Oriental zone, inhabiting India and Sri Lanka, Indochina, Indonesia, Philippines, Vietnam and South China. *Kurzia brevilabris*, another Oriental endemic, was described from Sri Lanka (Rajapaksa & Fernando 1986) who also examined its specimens from south India while Hudec (2000) allocated it to the subgenus *Rostrokurzia*. The second Indian report of this interesting chydorid from Deepor Beel (Sharma & Sharma 2012) recently extended its distribution to northeast India.

We follow Van Damme *et al.* (2011) for their revision of status of *Alona verrucosa*-group and identify our specimens from Majuli as *Anthalona harti*. This species is recently reported from India from Deepor Beel (Sharma & Sharma 2013) while all earlier reports of *A. verrucosa*-group from this country need re-examination in view of restricted global distribution of *A. verrucosa* s. str. Our report of *Kurzia latissima* from Majuli



deserves mention; initially considered as a Palaearctic element, it is known from India from by its disjunct populations from Assam, Manipur, Madhya Pradesh, Maharashtra and West Bengal. *Alona monacantha* specimens from Majuli are presently assigned to genus *Coronatella* following Van Damme *et al.* (2010). This species is known from Neotropical, Afrotropical and Oriental zones (Sinev 2004).

We prefer to identify tuberculate morphotypes of *Alona guttata* from Majuli as *A. guttata tuberculata* in view of consistent characteristic tubercles in all our populations as well its different distribution than cosmopolitan nominate taxon (Sharma & Sharma 2008). *A. guttata tuberculata* is documented from India from Meghalaya state (Sharma 2008); this report further extends its distribution within northeast India. In addition, *Sarsilatona serricaudata*, *Simocephalus* (*Echinocaudus*) *acutirostratus*, *Guernella raphaelis*, *Grimaldina brazzai*, *Alonella clathrata*, *Picripleuroxus laevis*, *Graptoleberis testudinaria*, *Leberis diphanus* and *Notoalona globulosa* are examples of regional distribution interest observed in our Majuli collections.

Lack of the Neotropical genus *Leydigopsis* in Majuli Cladocera is noteworthy in particular as *L. curvirostris*, its sole Indian species, is exclusively observed from floodplains of the Brahmaputra river basin, northeast India (Sharma & Sharma 2007, 2008, 2012). Other interesting departures from Cladocera of the floodplains elsewhere from Assam state include lack of *Daphnia* spp. and *Acroperus harpae*, occurrence of relatively fewer species of *Diaphanosoma*, and uncommon nature of *Grimaldina brazzai*, *Graptoleberis testudinaria* and members of the families Bosminidae and Moinidae. The first feature is of special interest in light of earlier remarks (Sharma 1991) on much restricted distribution of the Daphniidae in northeast India while Sharma & Sharma (2013) reported on the presence of *D. lumholtzi* and *D. pulex* in Deepor beel – a Ramasar site and an important

floodplain lake of this region. This coupled with general paucity of limnetic taxa may be attributed to lack of definite limnetic regions as well as presence of various aquatic macrophytes in the sampled wetlands. The last feature explains occurrence of weed-associated biota in general and member of the family Chydoridae in particular which, in turn, comprise an important fraction (60.0%) of Cladocera richness documented from Majuli.

The common occurrence of the members of Macrothricidae and Sidiidae is also attributed to the prevalence of the littoral-periphytonic conditions. The importance of these three families concurs with the report from inland swamps of Southern Thailand (Van Damme *et al.* 2013). Besides, this study registers common occurrence of *Macrothrix* spp., *Simocephalus mixtus* and *Guernella raphaelis*.

To sum up, the species-rich and diverse nature of Majuli Cladocera indicating environmental heterogeneity of the wetlands of this river islands of the Brahmaputra basin merits biodiversity value. The occurrence of several globally interesting elements adds to our knowledge on Cladocera biogeography. Certain notable differences of their composition than other floodplain communities elsewhere from Assam state as well occurrence of a number of species of regional interest are other interesting aspects of the fauna. In general, this study adds valuable information to the diversity and distribution of Cladocera in the Indian floodplains.

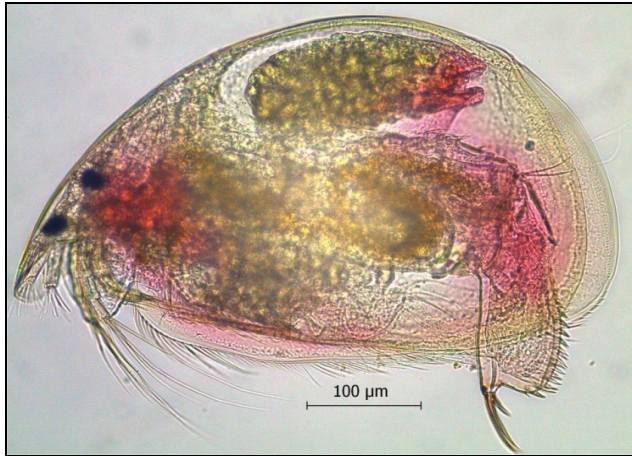
**Acknowledgements** – The senior author is grateful to the Ministry of Environment & Forests (Govt. of India) sanction of a research project No. 22018-09/2010-CS (Tax) under its AICOPTAX program under which the present study is undertaken. Thanks are also due to the Head, Department of Zoology, NEHU, Shillong, for laboratory facilities and Mrs. M. K. Hatimuria for help in field collections. We also extend our sincerest thanks to Dr. Alexey A. Kotov, A. N. Severtsov Institute of Ecology and Evolution, Leninsky Prospect 33, Moscow 119071, Russia for confirmation of our identification of *Alona kotovi*. We thank our anonymous reviewers for their useful comments.

## REFERENCES

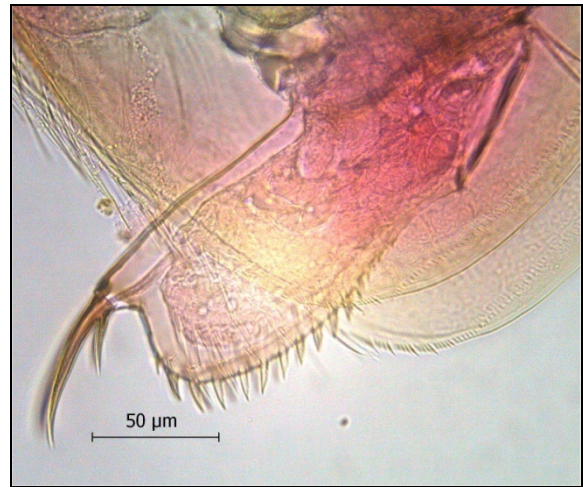
- BARUAH, A., SINHA, A. A. & SHARMA, U. P. (1993): Plankton variability of a tropical wetland, Kawar (Begusarai), Bihar. *Journal of Freshwater Biology*, 5: 27–32.
- CHATTERJEE, T., KOTOV, A. A., VAN DAMME, K., CHANDRASEKHAR, S. V. A. & PADHYA, S. (2013): An annotated checklist of the Cladocera (Crustacea: Branchiopoda) from India. *Zootaxa*, 3667(1): 1–89.
- FERNANDO, C. H. & KANDURU, A. (1984): Some remarks on the latitudinal distribution of Cladocera on the Indian subcontinent. *Hydrobiologia*, 113: 69–76.
- FREY, D. G. (1987): The North American *Chydorus faviformis* (Cladocera, Chydoridae) and the honey-combed taxa of other continents. *Philosophical Transactions of the Royal Society of London, Series B*, 315: 353–402.
- GOSWAMI, M. M. & GOSWAMI, N. (2001): Studies on productivity indicators in Mori beel of Assam. *Tropical Zoology*, 2 & 3: 1–9.
- HUDEC, I. (2000): Subgeneric differentiation within *Kurzia* (Crustacea: Anomopoda: Chydoridae) and a new species from Central America. *Hydrobiologia*, 421: 165–178.
- KHAN, M. A. (1987): Observations on Zooplankton composition, abundance and periodicity in two flood-plain lakes of the Kashmir Himalayan valley. *Acta Hydrochemica Hydrobiologica*, 15: 167–174.
- KHAN, R. A. (2003): Faunal diversity of zooplankton in freshwater wetlands of Southeastern West Bengal. *Records of the Zoological Survey of India, Occasional Paper No.* 204: 1–107.
- KORINEK, V. (2002): *Cladocera*. In: FERNANDO, C. H. (Ed.) *A Guide to Tropical Freshwater Zooplankton*. Identification, ecology and impact on fisheries. Backhuys Publishers, Leiden, The Netherlands, p. 72–122.
- KOROVCHINSKY, N. M. (1992): *Sididae and Holopedidae*. In: Guides to the identification of the Microinvertebrates of the continental waters of the world. Vol.3. SPB Academic Publishers, The Hague, 82 pp.
- MICHAEL, R. G. & SHARMA, B. K. (1988): *Indian Cladocera*. (Crustacea: Branchiopoda Cladocera). Fauna of India and adjacent countries Series, Zoological Survey of India, Calcutta, 262 pp.
- NANDI, N. C., DAS, S. R., BHUIYAN, S. & DASGUPTA, J. M. (1993): Wetland faunal resources of West Bengal. I. North and South 24-Parganas district. *Records of the Zoological Survey of India, Occasional Paper No.* 150: 1–50.
- ORLOVA-BIENKOWSKAJA, M. Y. (2001): *Cladocera: Anomopoda. Daphniidae: genus Simocephalus*. In: Guides to the identification of the Microinvertebrates of the continental waters of the world. Vol. 17. Backhuys Publishers, Leiden, the Netherlands, 130 pp.
- RAJAPAKSA, R. & FERNANDO, C. H. (1986): Tropical species of *Kurzia* (Crustacea, Cladocera) with a description of *Kurzia brevilabris* sp. nov. *Canadian Journal of Zoology*, 64: 250–260.
- RANE, P. (1983): A new species of Cladocera of genus *Indialona* Petkovski, 1966 (Family Chydoridae) from India. *Journal of the Bombay Natural History Society*, 80: 194–195.
- RANE, P. D. (2005): Cladocera (Crustacea). In: Fauna of Melaghat Tiger Reserve: Fauna of Conservation Area Series 24, Zoological Survey of India, Kolkata, p. 451–500.
- SANJER, L. R. & SHARMA, U. P. (1995): Community structure of plankton in Kawar lake wetland, Begusarai, Bihar: II. Zooplankton. *Journal of Freshwater Biology*, 7: 165–167.
- SARMA, P. K. (2000): *Systematics, distribution and ecology of zooplankton of some floodplain wetlands of Assam, India*. Ph. D thesis, Gauhati University, Assam.
- SHARMA, B. K. (1991): *Cladocera*. In: Animal Resources of India: Protozoa to Mammalia: State of the Art. Zoological Survey of India, Calcutta, p. 205–223.
- SHARMA, B. K. (2005): Rotifer communities of flood-plain lakes of the Brahmaputra basin of lower Assam (N. E. India): biodiversity, distribution and ecology. *Hydrobiologia*, 533: 209–221.
- SHARMA, B. K. & MICHAEL, R. G. (1987): Review of taxonomic studies on freshwater Cladocera from India with remarks on biogeography. *Hydrobiologia*, 145: 29–33.
- SHARMA, B. K. & SHARMA, S. (1990): On the taxonomic status of some cladoceran taxa (Crustacea: Cladocera) from Central India. *Revue Hydrobiologie Tropicale*, 23: 105–133.
- SHARMA, B. K. & SHARMA, S. (1999): Freshwater Cla-

- docerans (Crustacea: Branchiopoda: Cladocera). *Fauna of Meghalaya. State Fauna Series, Zoological Survey of India, Calcutta*, 4 (9): 469–550.
- SHARMA, B. K. & SHARMA, S. (2005): Biodiversity of freshwater rotifers (Rotifera: Eurotatoria) from North-Eastern India. *Mitteilungen aus dem Museum für Naturkunde Berlin, Zoologische Reihe*, 81: 81–88.
- SHARMA, B. K. & SHARMA, S. (2007): New records of two interesting Chydorid Cladocerans (Branchiopoda: Cladocera: Chydoridae) from floodplain lakes of Assam (N. E. India). *Zoos' Print Journal*, 22(8): 2799–2801.
- SHARMA, B. K. & SHARMA, S. (2012): Notes on some rare and interesting Cladocera (Crustacea: Branchiopoda: Anomopoda: Chydoridae) from Deepor Beel, Assam, India. *Journal of Threatened Taxa*, 4 (1): 2304–2309.
- SHARMA, S. (2008): Notes on some rare and interesting Cladocerans (Crustacea: Branchiopoda) from Meghalaya. *Record of the Zoological Survey of India*, 108: 111–122.
- SHARMA, S. & SHARMA, B. K. (2008): Zooplankton diversity in floodplain lakes of Assam. *Records of the Zoological Survey of India, Occasional Paper No. 290*: 1–307.
- SHARMA, S. & SHARMA, B. K. (2013): Faunal Diversity of Aquatic Invertebrates of Deepor Beel (a Ramsar site), Assam, northeast India. *Wetland Ecosystem Series, Zoological Survey of India, Kolkata*, 17:1–226.
- SINHA, A. K., BARUAH, A., SINGH, D. K. & SHARMA, U. P. (1994): Biodiversity and pollution status in relation to physico-chemical factors of Kawar lake (Begusarai), North Bihar. *Journal of Freshwater Biology*, 6: 309–331.
- SINEV, A. Y. (1999): *Alona costata* Sars, 1862 versus related palaeotropical species: the first example of close relations between species with a different number of main head pores among Chydoridae (Crustacea: Anomopoda). *Arthropoda Selecta*, 8(3): 131–148.
- SINEV, A. Y. (2004): Redescription of a South American cladocera, *Alona monacantha* Sars, 1901 (Branchiopoda, Anomopoda, Chydoridae). *Arthropoda Selecta*, 13(1/2): 7–12.
- SINEV, A. Y. (2012): *Alona kotovi* sp. nov., a new species of Aloninae (Cladocera: Anomopoda: Chydoridae) from South Vietnam. *Zootaxa*, 3475: 45–54.
- SINEV, A. Y. & CORONEL, J.C. (2006): A new species of genus *Alona* Baird, 1843 (Cladocera: Anomopoda: Chydoridae) from the Bolivian Andes. *Archiv für Hydrobiologie, Supplement*, 151: 395–408.
- SINEV, A. Y. & ELMOOR-LOUREIRO, L. M. A. (2010): Three new species of chydorid cladocerans of subfamily Aloninae (Branchiopoda: Anomopoda: Chydoridae) from Brazil. *Zootaxa*, 2390: 1–25.
- SINEV, A. Y. & KOTOV, A. A. (2012): New and rare Aloninae (Cladocera: Anomopoda: Chydoridae) from Indochina. *Zootaxa*, 3334: 1–28.
- SINEV, A. Y. & KOROVCHINSKY, N. (2013): Cladocera (Crustacea: Branchiopoda) of Cat Tien National park, South Vietnam. *Journal of Limnology*, 72(2): 125–141.
- SMIRNOV, N. N. (1971): Chydoridae of the world fauna. *Fauna SSSR. Rakoobraznie*, 1(2): 1–531. (in Russian).
- SMIRNOV, N. N. (1976): Macrothricidae and Moinidae of the World fauna. *Fauna SSSR, novaya seriya. Rakoobraznye*, 1(3): 1–237. (in Russian).
- SMIRNOV, N. N. (1992): *The Macrothricidae of the world*. In: Guides to the identification of the Microinvertebrates of the Continental waters of the World, Vol. 1. SPB Academic Publishers, The Hague, 143 pp.
- SMIRNOV, N. N. (1996): *Cladocera: the Chydorinae and Sayciinae (Chydoridae) of the world*. In: Guides to the identification of the Microinvertebrates of the Continental waters of the World, Vol. 11. SPB Academic Publishers, the Hague, 197 pp.
- VAN DAMME, K. & DUMONT, H. J. (2008): Further division of *Alona* Baird, 1843: separation and position of *Coronatella* Dybowski & Grochowski and *Ovalona* gen. n. (Crustacea: Cladocera). *Zootaxa*, 1960: 1–44.
- VAN DAMME, K., KOTOV, A. A. & DUMONT, H. J. (2010): A checklist of names in *Alona* Baird, 1843 (Crustacea: Cladocera: Chydoridae) and their current status: an analysis of the taxonomy of a lump genus. *Zootaxa*, 2330: 1–63.
- VAN DAMME, K., SINEV, A. Y. & DUMONT, H. J. (2011): Separation of *Anthalona* gen.n. from *Alona* Baird, 1843 (Branchiopoda: Cladocera: Anomopoda): morphology and evolution of scraping

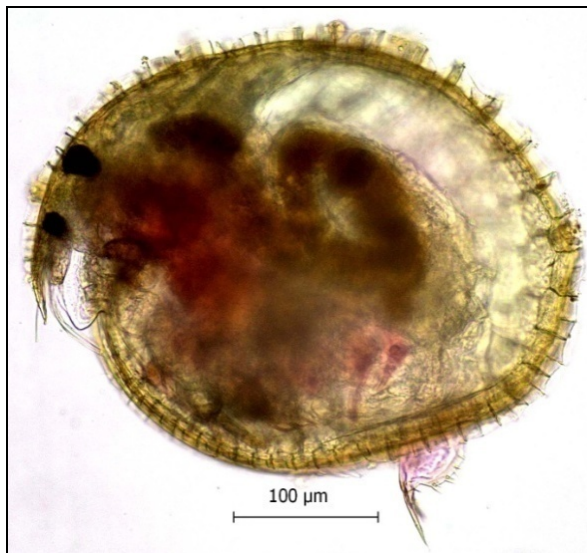
- stenothermic alonines. *Zootaxa*, 2875: 1–63.
- VAN DAMME, K., MAIPHAIE, S. & SA-ARDRIT, P. (2013). Inland swamps in South East Asia harbor hidden cladoceran diversities: species richness and the description of new paludal Chydoridae (Crustacea: Branchiopoda: Cladocera) from Southern Thailand. *Journal of limnology*, 73(2): 174–208.
- VENKATARAMAN, K. (1992): I. Cladocera of Keoladeo national park, Bhagalpur and its environs. *Journal of the Bombay Natural History Society*, 89 (1): 17–26.
- VENKATARAMAN, K. (1999): The freshwater Cladocera (Crustacea : Branchiopoda). *Fauna of West Bengal. State Fauna Series, Zoological Survey of India, Calcutta*, 3(10): 251–284.
- VENKATARAMAN, K. & DASH, S. R. (2000): Cladocera. *Fauna of Tripura. State Fauna Series, Zoological Survey of India, Calcutta*, 7(4): 277–316.
- YOUSUF, A. R., MUSTAFA SHAH, G. & QADRI, M. Y. (1986): Some limnological aspects of Mirgund wetland. *Geobios new Reports*, 5: 27–30.



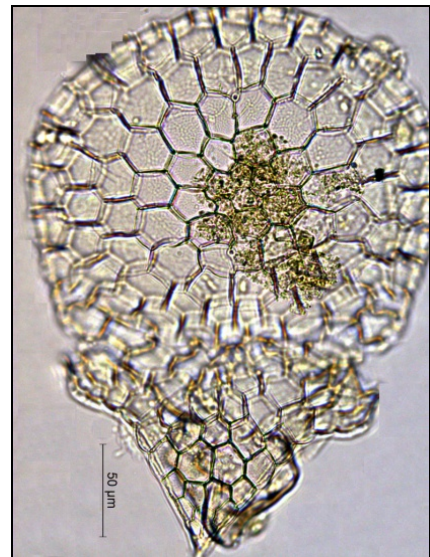
**Figure 2.** *Alona kotovi* Sinev: parthenogenetic female.



**Figure 3.** *A. kotovi* Sinev, postabdomen.

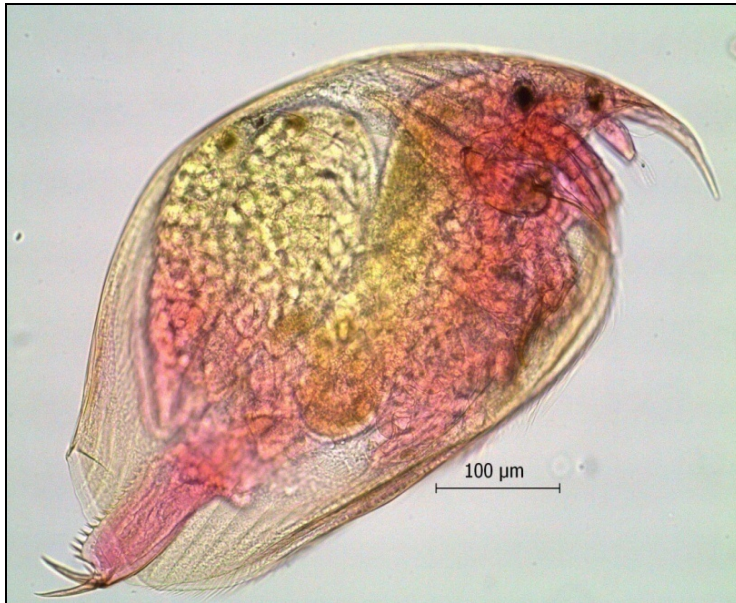


**Figure 4.** *Chydorus angustirostris* Frey, parthenogenetic female.

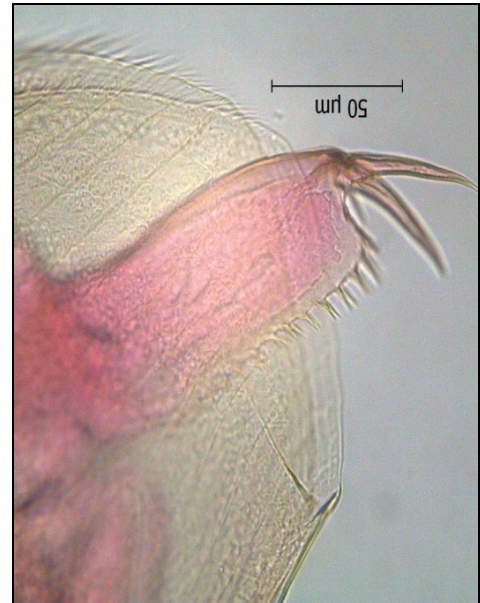


**Figure 5.** *Ch. angustirostris* Frey, postabdomen.

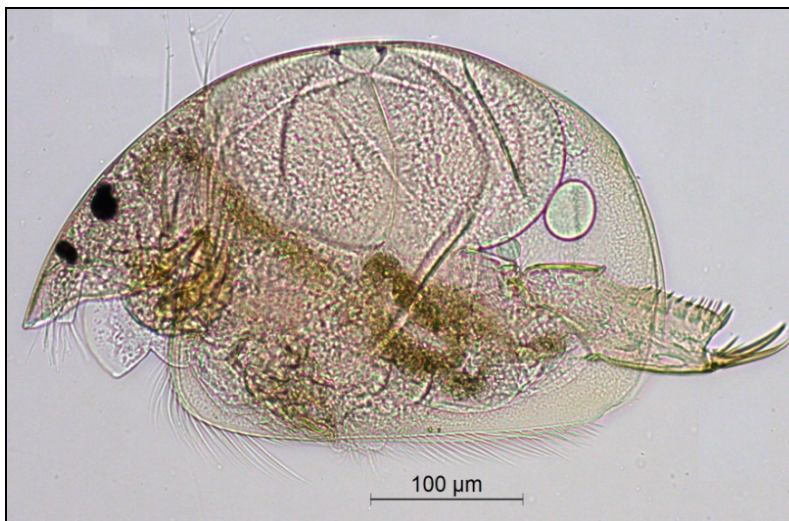




**Figure 6.** *Disperalona caudata* Smirnov, parthenogenetic female.



**Figure 7.** *D. caudata* Smirnov, postabdomen.

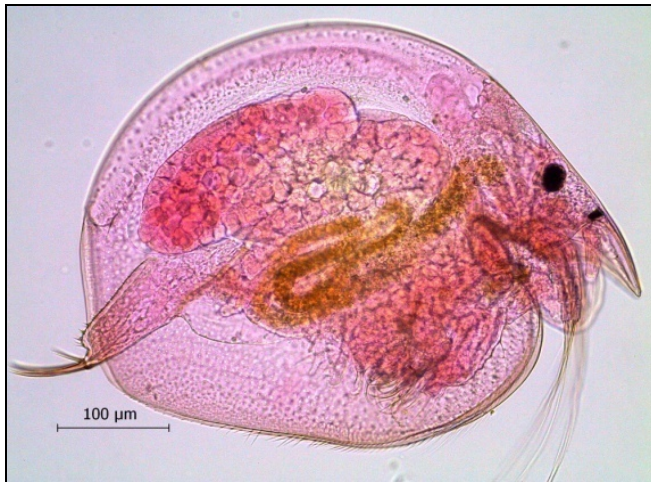


**Figure 8.** *Alona cheni* Sinev, parthenogenetic female.

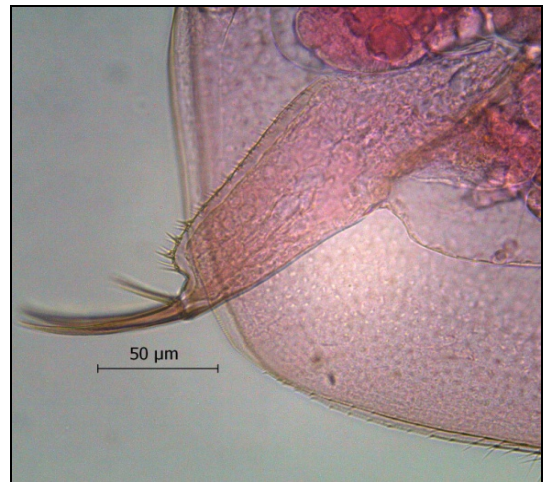


**Figure 9.** *A. cheni* Sinev, postabdomen.





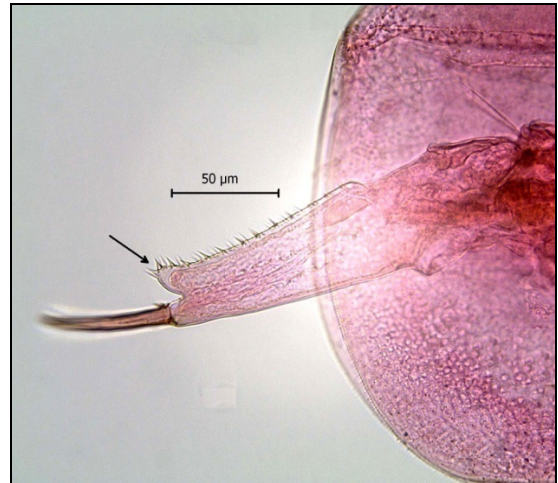
**Figure 10.** *Celsinotum macronyx* (Daday) parthenogenetic female.



**Figure 11.** *C. macronyx* (Daday) postabdomen.



**Figure 12.** *Kurzia brevilabris* Rajapaksa & Fernando, parthenogenetic female.



**Figure 13.** *K. brevilabris* Rajapaksa & Fernando, postabdomen.

## Criteria of sustainable management of large river systems – ecological aspects and challenges of the 21<sup>st</sup> century

G. GUTI and Á. BERCZIK,

*Dr. Gábor Guti & Prof. Árpád Berczik, Danube Research Institute, Centre for Ecological Research,  
Hungarian Academy of Sciences H-2131 Göd, Jávorka S. u. 21. E-mails: [guti.gabor@okologia.mta.hu](mailto:guti.gabor@okologia.mta.hu)  
[arpad.berczik@okologia.mta.hu](mailto:arpad.berczik@okologia.mta.hu)*

**Abstract.** River systems maintain unique biotic resources and provide essential renewable water supplies for humankind. Flood pulses are the key natural drivers of species richness and productivity of the large river-floodplain ecosystems, but traditional water management has sought to reduce the natural variability of river flows to achieve more stable water supplies for socio-economic water needs. The increasing human pressure on river systems directly threatens the biodiversity of fluvial ecosystems across the world. Ecologically sustainable river management is aimed at maintaining the ecological integrity of the affected ecosystems while meeting the intergenerational human needs and sustaining the full array of other goods and services provided by natural river ecosystems. Several criteria of ecologically sustainable water management are outlined, such as the assessment of the reference status, the documentation of the deficiencies of the baseline conditions, the identification of the causes of ecosystem degradation using the DPSIR framework, the analysis of the compatibility of water needs, the definition of the target vision, etc.

**Keywords.** Sustainability, DPSIR framework, floodplain ecosystem, restoration, ecological integrity

### INTRODUCTION

Water and air are the two essential mediums that allow existence of life in the biosphere. It is well known that more than 70% of the surface of the Earth is covered with water. The total volume of the hydrosphere is 1.4 billion km<sup>3</sup>, which is 0.02% of total mass of the Earth. Continental waters are 3.5% of the Earth's water resources, out of which about 69% is in ice caps and glaciers, and about 30% is groundwater. Liquid continental surface freshwaters (lakes, swamps and rivers), which are essential for terrestrial life and form a decisive precondition for social-economic development, constitute less than 0.3% of continental waters, and the total volume of the river systems amounts to only 2% of these (Shiklomanov 1993).

River systems maintain unique biotic resources and provide the most essential renewable water supplies for the livelihood of human communities. Water is indispensable in all the sectors of economy and parallel to social-technical-economic

development, the utilisation of river systems has become more extensive. Since the Industrial Revolution, the growth rate of the human population has accelerated, and the world's population increased fourfold in the 20<sup>th</sup> century, whereas global water withdrawal has increased eightfold in the same period (Gleick 1998). A significant part of the human population is struggling with problems related to insufficient water supply, which may be exacerbated by climate change. In the future, annual global water withdrawal is expected to grow by about 10–12% every 10 years (UNEP 2008), therefore the water-crisis may become an escalating source of social-economic conflicts in the 21<sup>st</sup> century. The increasing human pressure on river systems has been directly threatening the water security for people and the biodiversity of river ecosystems across the world (Vörösmarty *et al.* 2010).

This study summarizes the main elements of environmental changes generated by the human interventions imposed on large rivers, and outlines some criteria of ecologically sustainable river management.



## ALTERATION OF RIVER ECOSYSTEMS

River systems, as part of the global hydrologic cycle, collect surface runoffs from their basins and flow to the seas and oceans with significant landscape forming impact. Their ecosystems, including floodplains, belong to the most diverse, dynamic and complex ecosystems of the Earth, and play a key role in the maintenance of the biodiversity of the landscape (Naiman *et al.* 1993). The river biota is adapted to living among various flow conditions, and the high degree of spatial and temporal heterogeneity which characterises the river systems. The considerable differences in the numbers of species inhabiting the various river systems are largely attributable to the size of the river and its basin area (Welcomme 1985).

The remarkable global biodiversity of the fluvial ecosystems is particularly obvious, when evaluated in relation to the area and volume of the river systems. For example, 13,000 strictly freshwater fish species live in lakes and rivers that cover only 1% of the Earth's surface, while the remaining 16,000 marine species live in oceans and seas covering a full 70% (Lévêque *et al.* 2008). Most of the freshwater fish species occur in rivers or their floodplains (Bayley & Li 1996), but the global volume of river systems is about eighty times less than the volume of the lakes of the Earth (Shiklomanov 1993).

Considerable modifications have been carried out in many river systems around the world (Dynesius & Nilson 1994) since the early human communities were established along the rivers about 5,000 years ago, and the systematic colonisation of floodplains lead to the development of the earliest civilizations. The ever increasing use of floodplains and the inherent risks of the seasonal flooding of such areas resulted in the widespread application of flood control measures (levee and canal constructions), and the associated development of in-stream structures (dams, impoundments, etc.). Rivers are disturbed not only by events occurring within their channel or

the connected floodplains, but are also subject to a range of external influences. The changing conditions of the catchment basin can produce variations of the quality and quantity of water, as well as changes in its loading with a variety of materials including silt, which can affect river morphology.

The increasing human activity (related to industry, agriculture, urbanisation, transportation, etc.) throughout the catchment basins exert various types of additional pressures on the fluvial ecosystems, such as emissions of waste and contaminants, spreading of invasive species, etc. The water demand of humanity for agricultural, industrial, and communal uses continues to grow along with the economic development, rising populations and increased urbanization. These multiple pressures threaten river systems that serve 80% of the world's population, and endanger the biodiversity of 65% of the world's river habitats, putting thousands of aquatic wildlife species at the risk of extinction (Vörösmarty *et al.* 2010).

The ecological degradation of fluvial systems has been an unintended consequence of extensive river management. The unique species richness and productivity of large river-floodplain ecosystems is strongly dependent on the natural variability of the hydrologic and morphologic conditions (Sparks 1995), but traditional water management has sought to reduce the natural variability of river flows to achieve more stable water supply for industry, households, irrigation, navigation and hydropower exploitation, and to mitigate extreme situations, such as floods and droughts (Richter *et al.* 2003).

## ECOLOGICALLY SUSTAINABLE MANAGEMENT OF LARGE RIVERS

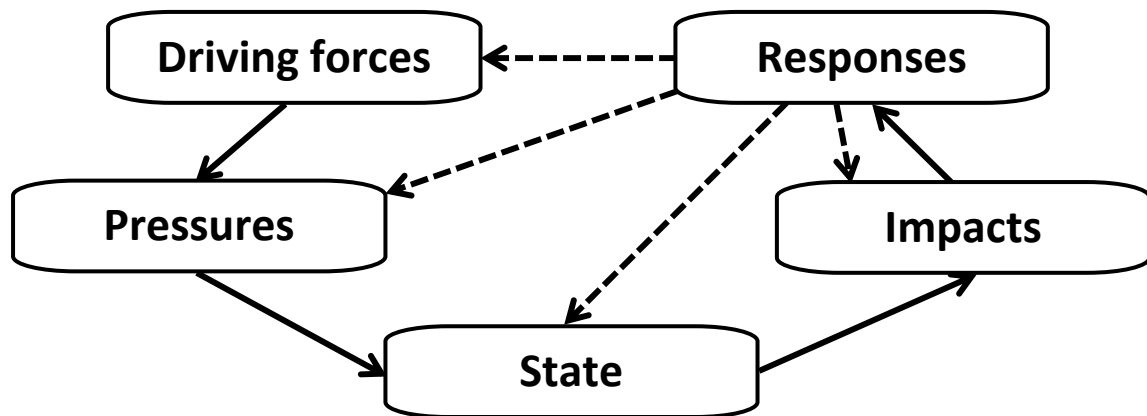
Because of the degradation of the fluvial ecosystems, ecologically sustainable river management has become an increasingly widespread intension. Its goal should be to maintain the ecological integrity of the affected ecosystems, while

also meeting the intergenerational human needs, and sustaining the full array of other goods and services provided by natural river ecosystems (Sparks 1995, Richter *et al.* 2003). The ecological integrity includes structural elements (landscape, habitats, assemblages, populations, species, genes, etc.) and functional processes that generate and maintain these elements (water and sediment regime, disturbance, succession, selection, nutrient cycling, etc.) (Angermeier & Karr 1994).

The concept of sustainability often appears in various directives and laws related to river management, but its implementation has not been able to effectively influence the drivers exerting pressures on fluvial ecosystems and the loss of

aquatic biodiversity. Most of the recent action plans and projects focus on the state of the environment and the negative impacts of degradation, and are not aimed at modifying the socio-economic driving forces of the unfavourable processes.

The series of causal factors of river ecosystem degradation can be determined by comprehensive assessment of the environmental changes generated by human activities. As the basis for any such assessment, the application of the *DPSIR* framework (Gabrielsen & Bosch 2003) is recommended to describe and interpret the interactions between the economy/society and the environment (Fig. 1).



**Figure 1.** Overview of the continuous feedback process in the DPSIR framework

- *Driving forces (D)* of river utilisation are the social and individual needs, exerted by social, demographic, and economic development. Driving forces (river engineering, navigation, hydropower utilisation, fishery, irrigation, gravel mining, sewage disposal, etc.) provoke changes in the overall levels of economic production and consumption processes, and through these changes, the driving forces put pressure on the riverine environment.
- The *pressures (P)* are generated by a number of human activities (driving forces), which meet the needs of the economy and provide several benefits for the society. However,

these human activities result in the excessive use and alteration of the river system, the transformation of the environmental conditions (connectivity, gradient, hydraulics, etc.), as well as changes of the natural resources (discharge, riparian forest, fish stock, etc.) and natural processes (water regime, bed load transport, ecological succession, etc.).

- The *state (S)* of the river depends on the pressures on the environment. State indicators describe the quantity and quality of the physical, chemical, hydrological, morphological, and biological elements and processes of the river system.

- The *impact (I)* indicators describe the impacts of the altered state of river on the functions of the river ecosystem and its resource availability. The alteration of a river ecosystem ensues from a series of causal factors. For example, the fragmentation of river continuity by a dam causes changes in bed load transport (primary effect, but it is a state indicator), which may in turn cause a river bed incision and the decline of low water levels in the downstream of the dam (secondary effect, but also a state indicator), which may provoke a progressive restriction of lateral connectivity between the river and the floodplain backwaters (tertiary effect, but still a state indicator), and this habitat change causes a loss of aquatic biodiversity and biological production. Only this last effect is the impact indicator. The change in the availability of riverine species (fish stock) influences the human usability of the natural resources. Strictly speaking, only those metrics or parameters that directly reflecting the environmental changes are called impacts which are important for human welfare (Gabrielsen & Bosch 2003).
- The *response (R)* by society or policy makers is the consequence of an undesired impact and is directed at any elements of the DPSIR causal chain from driving forces to impacts, in order to prevent, mitigate, restore, compensate or adapt to environmental changes.

The links between the DPSIR elements reveals a number of processes and the dynamics of the interactions in the framework. This information can be used in predictions of future changes in pressures, states, impacts, and responses.

The ecologically sustainable water management depends on a balance between the water requirements for ecosystem integrity and the social-economic water demands. In the last decades, a number of case studies (Buijse *et al.* 2002, Jungwirth *et al.* 2002, Richter & Thomas 2007) have shown that ecological integrity of fluvial ecosystems can be improved as well with the long-term fulfilment of human water needs. In order to achieve ecological sustainability in river

management, the following criteria have to be taken into account:

#### 1) Problem definition

- Assessment of the reference status of the river ecosystem functioning without or before human intervention. The reference status may refer to a historical period and is comparable to the “good ecological status” of the EU Water Framework Directive for natural water bodies.
- Documentation of the baseline (and the predictable future) situation with definition of the socio-economical water needs.
- Assessment of the deficiencies of the baseline conditions and identification of the causes of ecosystem degradation using the DPSIR framework, in order to better understand the effects of socio-economic drivers and pressures on the structural elements and functional processes of river ecosystems.
- Analysing the compatibility of the water needs for maintaining the ecological integrity and the socio-economical water demand, with respect to their spatial and temporal differences.

#### 2) Search for solution

- Comparison of different approaches and searching for solutions for the uncovered problems of the incompatibilities of ecological and socio-economical water demands.
- Detailed analysis of the factors limiting the harmonization of ecological and socio-economical water needs, as well as assessment of other constraints through water- and land use obligations.

#### 3) Development of an adaptive management plan, with the realization of ecological sustainability

- Developing an action plan on the basis of the definition of the target vision (environmental objectives), to be reached via the ecologically sustainable management of the river system.
- Formulate practicable indicators and assessment criteria for evaluating the ecological integrity and the sustainability of river management (within the DPSIR framework).

## CLOSING REMARKS

Ecologically sustainable river management is an iterative process, in which both human water demands and ecosystem requirements can be refined and harmonized in the future (Richter *et al.* 2003). This includes a continual search for compatibility between the water needs of the ecosystem and the humans, and requires the active cooperation of an interdisciplinary group of scientists familiar with the hydrologic, geomorphic and landscape processes that influence habitat development and maintain natural biodiversity in river-floodplain ecosystems.

## REFERENCES

- ANGERMEIER, P. L. & KARR, J. R. (1994): Biological integrity versus biological diversity as policy directives. Protecting biotic resources. *BioSciences*, 44: 690–697.
- BAYLEY, P. B. & LI, H. W. (1996): *Riverine Fishes*. In: G. PETTS, P. CALOW (eds.) *River Biota*. Blackwell Sciences Ltd., Oxford and Northampton.
- BUIJSE, A. D., COOPS, H., STARAS, M., JANS, L. H., VAN GEEST, G. J., GRIFT, R. E., IBELINGS, B. W., OOSTERBERG, W. & ROOZEN, F. C. J. M. (2002): Restoration strategies for river floodplains along large lowland rivers in Europe. *Freshwater Biology*, 47: 889–907.
- DYNESIUS, M. & NILSSON, C. (1994): Fragmentation and flow regulation of river systems in the northern third of the world. *Science*, 266: 753–762.
- GABRIELSEN, P. & BOSCH, P. (2003): Environmental Indicators: Typology and Use in Reporting. *EEA internal working paper*
- GLEICK, P. H. (1998): *The world's water 1998–1999: the biennial report on freshwater resources*. Island Press, Washington, D.C., USA.
- JUNGWIRTH, M., MUHAR, S. & SCHMUTZ, S. (2002): Re-establishing and assessing ecological integrity in riverine landscape. *Freshwater Biology*, 47: 867–887.
- LÉVÊQUE, C., T. OBERDORFF, D. PAUGY, M. L. J. STIASSNY, P. A. TEDESCO (2008): Global diversity of fish (Pisces) in freshwater. *Hydrobiologia*, 595: 545–567.
- NAIMAN, R. J., DECAMPS, H. & POLLOCK, M. (1993): The role of riparian corridors in maintaining regional biodiversity. *Ecological applications*, 3(2): 209–212.
- RICHTER, B. D., MATHEWS, R., HARRISON, D. L. & WIGINGTON, R. (2003): Ecologically sustainable water management: Managing river flows for ecological integrity. *Ecological Applications*, 13(1): 206–224.
- RICHTER, B. D. & THOMAS, G. A. (2007): Restoring environmental flows by modifying dam operations. *Ecology and Society*, 12(1): 12. URL: <http://www.ecologyandsociety.org/vol12/iss1/art12/>
- SHIKLOMANOV, I. A. (1993): *World freshwater resources*. In: GLEICK, P. H. (ed.) *Water in Crisis: A Guide to the World's Fresh Water Resources*, Oxford University Press, New York.
- SPARKS, R. E. (1995): Need for ecosystem management of large rivers and their floodplains. *BioScience*, 45: 168–182.
- UNEP (2008): Water withdrawal and consumption: the big gap. [www.unep.org/dewa/vitalwater/article42](http://www.unep.org/dewa/vitalwater/article42)
- VÖRÖSMARTY, C. J., MCINTYRE, P. B., GESSNER, M. O., DUDGEON, D., PRUSEVICH, A., GREEN, P., GLIDDEN, S., BUNN, S. E., SULLIVAN, C. A., REIDY LIERMANN, C. & DAVIES P. M. (2010): Global threats to human water security and river biodiversity. *Nature*, 467: 555–561.
- WELCOMME, R. L. (1985): River fisheries. *FAO Fisheries Technical Paper*, 262.

## A new species of the genus *Neogalumna* (Acari, Oribatida, Galumnidae) from China

W. LIANG, M. YANG\* and Q. TANG

Dr. Wenqin Liang, Qiuxiao Tang & Prof. Maofa Yang, Institute of Entomology, Guizhou University;  
Guizhou Provincial Key Laboratory for Agricultural Pest Management of the Mountainous Region,  
Guiyang, Guizhou, 550025, China. \*Corresponding author: yangmaofa@sohu.com

**Abstract.** A new species of oribatid mites of the family Galumnidae, *Neogalumna longiporosa* sp. nov., is described from dark loamy soil collected under moss in North Eastern China. It is the first identified member of the genus *Neogalumna* recorded for China. An identification key to the known species of *Neogalumna* is also given.

**Keywords.** Oribatida, Galumnidae, *Neogalumna*, new species, new record.

### INTRODUCTION

The genus *Neogalumna* was proposed by Hammer (1973) with *Neogalumna antenniger* Hammer, 1973 as type species. Currently, it comprises five species in the world (Subías 2004). The generic diagnosis of the genus *Neogalumna* is already summarized by Hammer (1973) Balogh & Balogh (1992) and not repeated here.

In the course of a faunistic survey of oribatid mites in Beiling Park, Shenyang, Liaoning province, North Eastern China, several specimens belonging to the genus *Neogalumna* were found, representing the first record of the genus in China. The species found is herewith described as *Neogalumna longiporosa* sp. nov., and also a key to all species of the genus is provided.

### MATERIAL AND METHODS

Specimens were examined in lactic acid, mounted on temporary cavity slides for the duration of the study, and then stored in vials in 75% ethanol. All measurements are presented in micrometers. Body length was measured in lateral view, from the tip of the rostrum to the posterior edge of the ventral plate. Notogastral width refers to the maximum width in dorsal aspect. Lengths of body

setae were measured in lateral aspect. Formula for leg setation is given in parentheses according to the sequence trochanter–femur–genu–tibia–tarsus (femulus included). Formula for leg solenidia is given in square brackets according to the sequence genu–tibia–tarsus. General terminology used in this paper follows that of Grandjean (1956, 1957, 1966), Engelbrecht (1969, 1972a), and Norton & Behan-Pelletier (2009).

### TAXONOMY

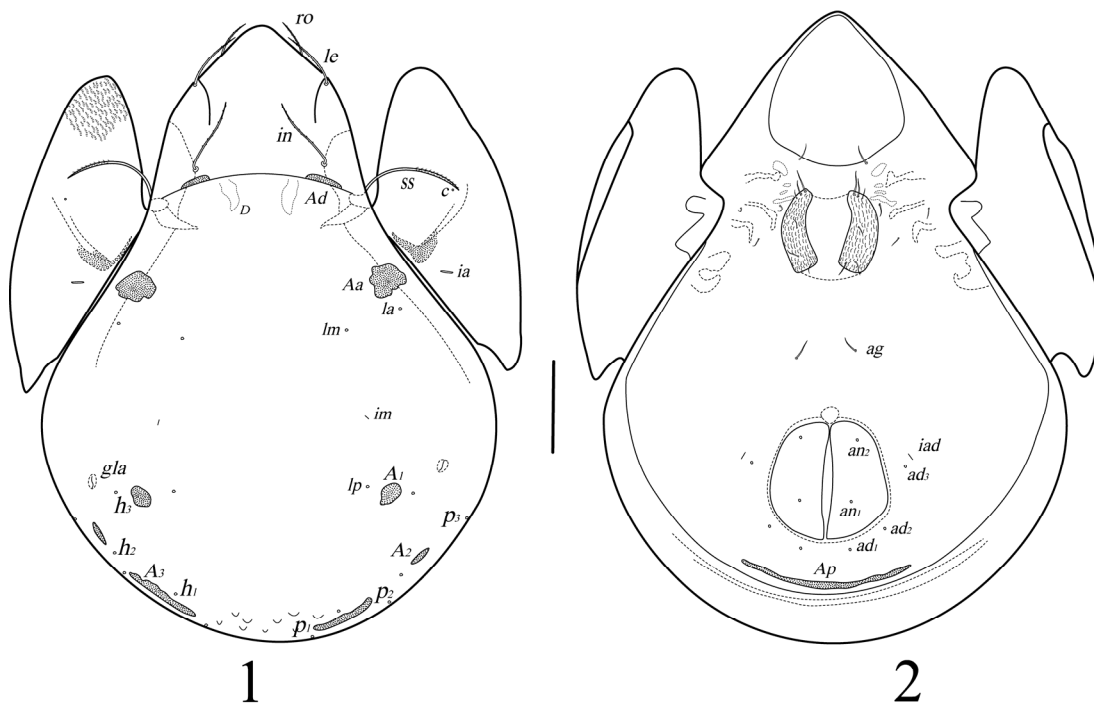
#### *Neogalumna longiporosa* sp. nov.

(Figures 1–8)

**Material examined.** Holotype (female) and 45 paratypes (19 males and 26 females) from soil and moss, Beiling Park in Shenyang (41°50'50.56"N, 123°25'18.09"E), Liaoning province, North Eastern China, 90 m above sea level. Collected by Lixia Xie, Rong Huang, Daxing Yang and Bin Li, 11. August, 2010.

**Type deposition.** All examined specimens are deposited in the Institute of Entomology, Guizhou University, Guiyang, Guizhou, China (GUGC).

**Diagnosis.** Body size: 700–780 × 500–565. Surface smooth. Prodorsal setae setiform, slightly



Figures 1–2. *Neogalumna longipora* sp. nov. 1 = dorsal view, 2 = ventral view. Scale bars 100µm.

Table 1. Leg setation and solenidia of *Neogalumna longiporosa* sp. nov.

Leg	Trochanter	Femur	Genu	Tibia	Tarsus
I	v'	d, (l), bv''	(l), v', σ	(l), (v), φ <sub>1</sub> , φ <sub>2</sub>	(ft), (tc), (it), (p), (u), (a), s, (pv), v', (pl), l'', e, ω <sub>1</sub> , ω <sub>2</sub>
II	v'	d, (l), bv''	(l), v', σ	(l), (v), φ	(ft), (tc), (it), (p), (u), (a), s, (pv), ω <sub>1</sub> , ω <sub>2</sub>
III	v'	d, ev'	l', σ	l', (v), φ	(ft), (tc), (it), (p), (u), (a), s, (pv)
IV	v'	d, ev'	d, l'	l', (v), φ	ft'', (tc), (p), (u), (a), s, (pv)

\*Roman letters refer to normal setae (e–famulus), Greek letters refer to solenidia. A prime marks (') anterolateral setae and a double prime (') posterolateral setae of the given leg segment. Parentheses refer to a pair of setae.

barbed. Lamellar setae longer than rostral and interlamellar setae. Sensilli setiform, slightly fusiform sensillar head indistinct. Lamellar lines well developed, parallel to sublamellar lines. Dorso-sejugal suture complete. Pteromorphs and genital plates with distinctly thin wrinkles. Four pairs of oval notogastral porose areas developed. Median pores absent. Postanal porose area elongated.

**Measurements.** Body length 700 (holotype), 700–780 (paratypes); body width 500 (holotype), 500–565 (paratypes).

**Integument.** Body color brown to dark brown. Surface of body smooth; pteromorphs and genital plates with distinctly thin wrinkles.

**Prodorsum** (Figs. 1, 3, 4). Rostrum widely rounded. Rostral (ro, 60, 72), lamellar (le, 105, 118) and interlamellar (in, 80, 98) setae setiform, slightly barbed. Sensilli (ss, 160, 180) setiform, slightly fusiform sensillar head indistinct, median and distal parts with several barbs. Exobothridial setae absent. Lamellar lines long, parallel to sublamellar lines. Sublamellar lines distinct. One pair

of porose areas *Ad* large, oval, located posterior to interlamellar setae.

*Notogaster* (Figs. 1, 5, 6). Anterior notogastral margin weakly developed. Dorsophragmata (*D*) of medium size, elongate. Notogastral setae represented by 10 pairs of alveoli. Four pairs of porose areas, *Aa* irregular rounded or oval (20–36 × 50–58), largest; *A<sub>1</sub>* irregular rounded (25–29 × 30–36); *A<sub>2</sub>* oval (9–13 × 20–28), smallest; *A<sub>3</sub>* irregular elongate oval (9–17 × 30–60). Alveoli of setae *la* inserted posteriorly to *Aa*. Lyrifissures *im* located between setal alveoli *lm* and *lp*. Median pore absent.

*Gnathosoma*. Morphology of subcapitulum, palps and chelicerae typical for *Neogalumna* (for example: Ermilov and Anichkin 2010).

*Epimeral region* (Fig. 2). Epimeres smooth. Only four pairs of setiform, thin epimeral (9–22) setae observed. Epimeral setal formula: 1–0–1–2.

*Anogenital region* (Figs. 2, 7). Six pairs of genital (*g<sub>1</sub>–g<sub>2</sub>*, 20–26; *g<sub>3</sub>–g<sub>6</sub>*, 10–14), one pair of aggenital setae (*ag*, 20–23) setiform, smooth. Anterior edge of genital plates with three setae. Two pairs of anal and three pairs of adanal setae alveoli. Adanal lyrifissures *iad* located anterior-laterally to adanal setae *ad<sub>3</sub>*. Postanal porose area (*Ap*, 4–9 × 196–200) irregularly elongate.

*Legs* (Fig. 8). Three claws of each leg, smooth. Morphology of leg segments, setae and solenidia typical for *Neogalumna* (see Ermilov & Anichkin 2010). Formulae of leg setation and solenidia: I (1–4–3–4–20) [1–2–2], II (1–4–3–4–15) [1–1–2], III (1–2–1–3–15) [1–1–0], IV (1–2–2–3–12) [0–1–0]; homology of setae and solenidia indicated in Table 1.

*Etymology*. The specific epithet “*longiporosa*” refers to the elongate postanal porose area (*Ap*).

*Remarks*. *Neogalumna longiporosa* sp. nov. is clearly distinguishable from the other known species of the genus *Neogalumna* by the combination of the following characters: pteromorphs and genital plates with distinctly thin wrinkles; lamellar setae longer than rostral and interlamellar setae; sensilli setiform, slightly fusiform, sensillar

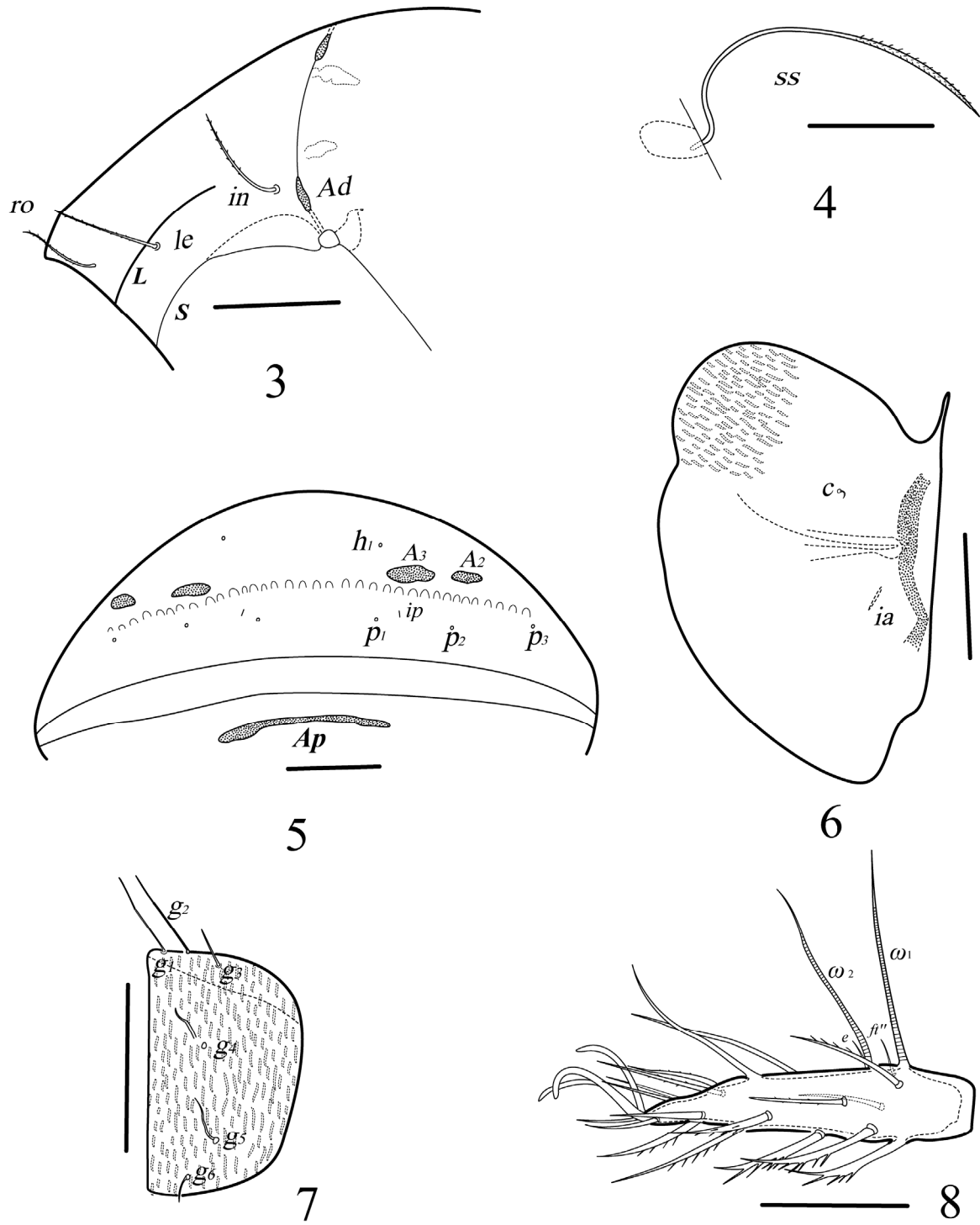
head indistinct; lamellar lines well developed; postanal porose area irregularly elongate.

In having the prodorsal setae long, setiform; sensilli setiform, slightly fusiform, sensillar head indistinct and anterior notogastral margin developed, the new species is similar to *N. seniczaki* Ermilov & Anichkin, 2010 described from Vietnam, but clearly differs from the latter by the larger body size (700–780 × 500–565 versus 381–398 × 265–282 in *N. seniczaki*); the length of lamellar lines (lamellar lines medium long, parallel to sublamellar lines versus very short and straight in *N. seniczaki*) and the structure of postanal porose area (irregularly elongate versus oval in *N. seniczaki*).

### Key to known species of *Neogalumna*

- 1 Interlamellar setae long.....2  
Interlamellar setae very short or absent .....4
- 2 Sensilli with a short stalk and lanceolate head .....  
..... *N. curviporosa* Balakrishnan  
Sensilli nearly setiform, indistinctly fusiform .....3
- 3 Lamellar lines very short and straight; surface of pteromorphs and genital plates smooth, postanal porose area short, oval .....  
..... *N. seniczaki* Ermilov & Anichkin  
Lamellar lines well developed, parallel to sublamellar lines; surface of pteromorphs and genital plates with distinctly thin wrinkles; postanal porose area irregularly elongate ..... *N. longiporosa* sp. nov.
- 4 Areae porose *Aa* wedge-shaped, transversely elongate..... *N. araujo* (Pérez-Íñigo & Baggio)  
Areae porose *Aa* rounded or oval.....5
- 5 Interlamellar setae absent; sensilli extremely long, with smooth head..... *N. antenniger* Hammer  
Interlamellar setae very short, but observable; sensilli average long, with barbed head.....  
..... *N. aethiopica* Mahunka & Mahunka-Papp

**Acknowledgements** – We cordially thank Dr. Lixia Xie, Rong Huang, Daxing Yang and Bin Li (Guizhou University, Guizhou, China) for their help in oribatid mite material gathering and Dr. Sergey G. Ermilov (Tyumen State University, Tyumen, Russia; Joint Russian-Vietnamese Tropical Research and Technological Center, Hanoi-Ho Chi Minh, Vietnam) for his help in document delivery.



**Figures 3–8.** *Neogalumna longiporosa* sp. nov. 3 = dorso-lateral view of prodorsum, 4 = sensillus, 5 = posterior view, 6 = pteromopha, 7 = left anal plate, 8 = tarsus of leg I, left, antiaxial view.  
Scale bars (3, 5, 6) 100  $\mu$ m; (4, 7, 8) = 50  $\mu$ m.



## REFERENCES

- BALAKRISHNAN, M. M. (1986): Two new species of oribatids (Arachnida: Acarina) from south India. *Journal of the Bombay Natural History Society*, 83(3): 645–649.
- BALOGH, J. & BALOGH, P. (1992): *The Oribatid Mites Genera of the World*. Vol. I. Hungarian National Museum Press, Budapest, 166 pp.
- ENGELBRECHT, C. M. (1969): Some South African species of the genus *Galumna* von Heyden, 1826 (Acari: Galumnidae). *Journal of the Entomological Society of Southern Africa*, 32(1): 99–122.
- ENGELBRECHT, C. M. (1972a): Galumnids from South Africa (Galumnidae, Oribatei). *Acarologia*, 14(1): 109–140.
- ERMILOV, S. G. & NIEDBALA, W. (2013): Contribution to the knowledge of the oribatid mite fauna of Bolivia, Zambia, Cambodia and Vietnam, with descriptions of two new species. *Spixiana*, 36(1): 9–19.
- ERMILOV, S. G. & ANICHKIN, A. E. (2010): Three new species of Galumnidae (Acari: Oribatida) from Cat Tien National Park, southern Vietnam. *Zootaxa*, 2681: 20–34.
- GRANDJEAN, F. (1956): Observations sur les Galumnidae. 1<sup>re</sup> série (Acariens, Oribates). *Revue Française d'Entomologie*, 23(3): 137–146.
- GRANDJEAN, F. (1957): Galumnidae sans carènes lamellaires (Acariens, Oribates) 2<sup>e</sup> série. *Bulletin de la Société Zoologique de France*, 82(1): 57–71.
- GRANDJEAN, F. (1966): *Erogalumna zeucta* n. g., n. sp. *Acarologia*, 8(3): 475–498.
- HAMMER, M. (1973): Oribatids from Tongatapu and Eua, the Tonga Islands, and from Upolu, Western Samoa. *Det Kongelige Danske Videnskabernes Selskab Biologiske Skrifter*, 20(3): 1–70.
- MAHUNKA, S. & MAHUNKA-PAPP, L. (2009): New and little known oribatids from Kenya, with descriptions of two new genera (Acari: Oribatida). *Journal of Natural History*, 43(9–12): 737–768.
- NORTON, R. A. & BEHAN-PELLETIER, V. M. (2009): *Oribatida. Chapter 15*. In: G. W. KRANTZ & D. E. WALTER (Eds.) *A Manual of Acarology*. Texas Technical University Press, Lubbock, p. 430–564.
- PÉREZ-ÍÑIGO, C. & BAGGIO, D. (1994): Oribates édaphiques du Brésil (VIII). Oribates de l'état de São Paulo (Cinquième partie). *Acarologia*, 35(2): 181–198.
- SUBÍAS, L. S. (2004): Listado sistemático, sinonímico y biogeográfico de los ácaros oribátidos (Acariformes: Oribatida) del mundo (excepto fósiles). *Graellsia* 60 (número extraordinario): 3–305. Actualized electronic version in Feb 2014, <http://www.ucm.es/info/zoo/Artropodos/Catalogo.pdf>, 448 pp.