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MORPHOMETRY OF FORE WING VENATION FOR IDENTIFICATION OF NET-WINGED INSECTS OF THE UKRAINIAN CARPATHIANS, WITH A FOCUS ON *CHRYSOPA* (NEUROPTERA, CHRYSOPIDAE)

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Morphometry of Fore Wing Venation for Identification of Net-Winged Insects of the Ukrainian Carpathians, with a Focus on *Chrysopa* (Neuroptera, Chrysopidae). Serediuk, H. V. — A method to identify the net-winged insects without preparation of genitalia is proposed. The method is based on morphometric indices of fore wing venation and is applied to Neuroptera of the Ukrainian Carpathians. A key to nine neuropteran families is compiled, with an emphasis on Chrysopidae. Keys to eight genera and eleven species of the genus *Chrysopa* is provided. A statistical analysis of the variability of diagnostic traits is given for each species and possibility of using morphometric indices is substantiated for species identification.
Key words: Neuroptera, Chrysopidae, *Chrysopa*, morphometric method, wing venation, key, Ukrainian Carpathians.

Introduction

The genus *Chrysopa* Leach & Brewster, 1815 belongs to the family Chrysopidae, which is one of the eight families of Neuroptera occurring in the Ukrainian Carpathians. Net-winged insects range in wing lengths from 0.18 cm to 8 cm. The hind wing is slightly smaller than the fore wing, and all species have transparent wing membranes with dark marks on some of them. The hind wing is reduced in some species of Hemerobiidae and Coniopterygidae or even their representatives are completely wingless. The membrane of the wings is more or less microtrichose and the wing edge often bears bristles forming dense fringes. The wings have a dense network of cross-veins, except the Coniopterygidae, which have a simplified venation. The anterior and posterior edges of wings sometimes have tiny inserted veins arranged between the terminal branches of longitudinal veins (*trz*). The fore wings in some neuropterans have a pterostigma (a cuticular darkened thickening in the distal part of the fore wing edge). Cross-veins in neuropterans can be scattered irregularly, but often they are arranged in rows, also called gradations of cross veins, or simply gradates (fig. 1) (Aspöck et al., 1980, 2001, 2007).

Most authors are focused on the morphology of wings when describing new species or conducting a revision. The following traits have been used: length and width of the fore wing and some cells of the costal, medial and radial fields; the ratio of wing length to width; shape of cells of radial and medial fields; the ratio of length to width of the radial, medial and intramedial cells; color of the membrane of the wing; the availability

of dark spots, their shape, size and location; the presence of a pterostigma; the number of cross-veins in inner and outer gradates of wing; the shape of *Psm* vein (Tauber & Sosa, 2015; Winterton & Garzón-Orduña, 2015; Breitkreuz et al., 2015; Zhao et al., 2015; Dong et al., 2016; Tauber et al., 2017). However, the ratios of measurements were not earlier used in the keys to Neuroptera.

The author suggests the new approach to identification of neuropteran taxa, based on the morphological structure of fore wing alone that has certain advantages. The morphometric method of identification gives the possibility to avoid the detailed examination of anatomical structure of insect body with preliminary preparation facilitating the process of identification making such keys useful for naturalists, students, agricultural entomologists and neuropterologists.

Material and methods

The study is based on author's own collections from the western part of Ukraine, and also specimens deposited in the entomological collections of the following institutions:

State Museum of Natural History of the National Academy of Sciences of Ukraine (Lviv); Museum of Nature of the Vasyl Karazyn Kharkiv National University; Department of Entomology and Biodiversity Conservation and Zoological Museum of the Uzhhorod National University; Zoological Museum of the Vasyl Stefanyk Precarpathian National University.

The terminology (including abbreviations, see also fig. 1) and nomenclature used here follow "Die Neuropteren Europas" (Aspöck et al., 1980).

Besides, the new keys have been supplemented by index ratios of some wing structures, introduced by the author.

As the aim was to compile the keys based on differences between the fore wing structures, it was necessary to reveal which structural traits would be useful for segregation of taxa with high level of reliability. The difference between structures of wings in representatives of different families is more obvious, whereas in genera it is less obvious, and in species of the same genus is the minimal. Thus, the utilization of the commonly used traits only, will not give the desirable result. It was found out, that in spite of visible variation in body size of insects, and correspondingly in size of wing structures, the ratios of length to width measurements in wing and its cells remain stable enough. Thus the index ratios were elaborated and introduced into keys based on the fore wing alone on the generic and specific levels.

To evaluate the statistical significance of the results the following parameters were calculated: the mean value for a sample (M), standard deviation (St. Dv.), value criterion of Student (t-value), number of degrees of freedom (df), confidence level (p). The results recognized reliable, when $p \leq 0.05$.

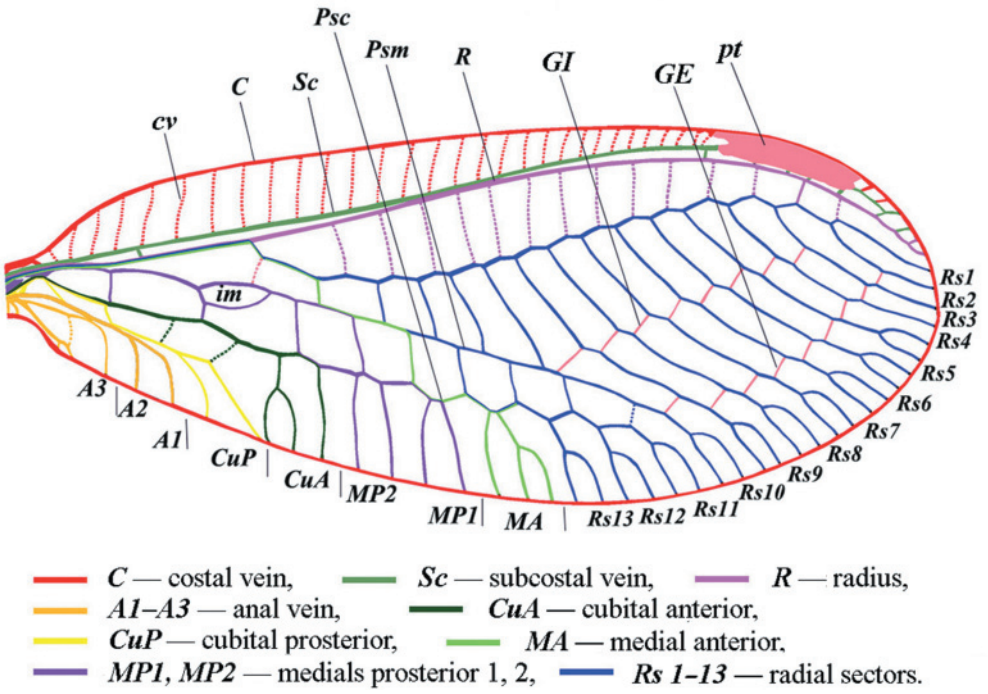


Fig. 1. General scheme for wing venation in Chrysopidae (legend on the figure): *Psm* — pseudomedian vein, *Psc* — pseudocubitus, *ini* — intramedian cell, *G1* — gradiformes internal, *GE* — gradiformes exstemal, *cv* — cross veins of costal sector, *pt* — pterostigma.

Results

1. Morphometric indices

The morphological characteristics and correlation of the ratio between lengths and widths of the structures of the fore wings are developed and applied as shown on table 1. For the average the median was used: the value of the measurement in the middle of the ranged sample series.

The resulting measurements were processed in Microsoft Excel 2007 and Statistica 10.0.

Table 1 contains the results of measurements for eleven species of the genus *Chrysopa*, which are keyed below.

Checking of the statistical indices (used in the keys to *Chrysopa* species) allowed to affirm that the indices *Iim, Ir2, Ir1* and *Im3* used for identification are reliable enough. The indices *Iw* and *Im2* are somewhat less reliable and should be used in separate cases only (table 2).

Not all indices are equally important for identification of species (fig. 2). For example, with the I_{im}*-index Chrysopa perla* can be separated from *C. formosa*. *C. hummeli* and *C. viridana*. At the same time the I_{m2}*-index* is suitable for differentiation between *C. pallens* and *C. walker*. The index ratio of length to width of the third median cell (I_{m3}) differentiates *C. dorsalis* and *C. hummeli* all others. The I_{r1}*-index* separate *C. hummeli* with high reliability. All species of the genus *Chrysopa* can be separated into two groups by means of the indices I_w and I_{r2}.

Since some of the indices have the same value for several species, it is not possible to use all of them simultaneously. However, most of the studied species are well distinguishable from others at least by one index that testifies to the effectiveness of using these indices for species identification (Serediuk, 2017).

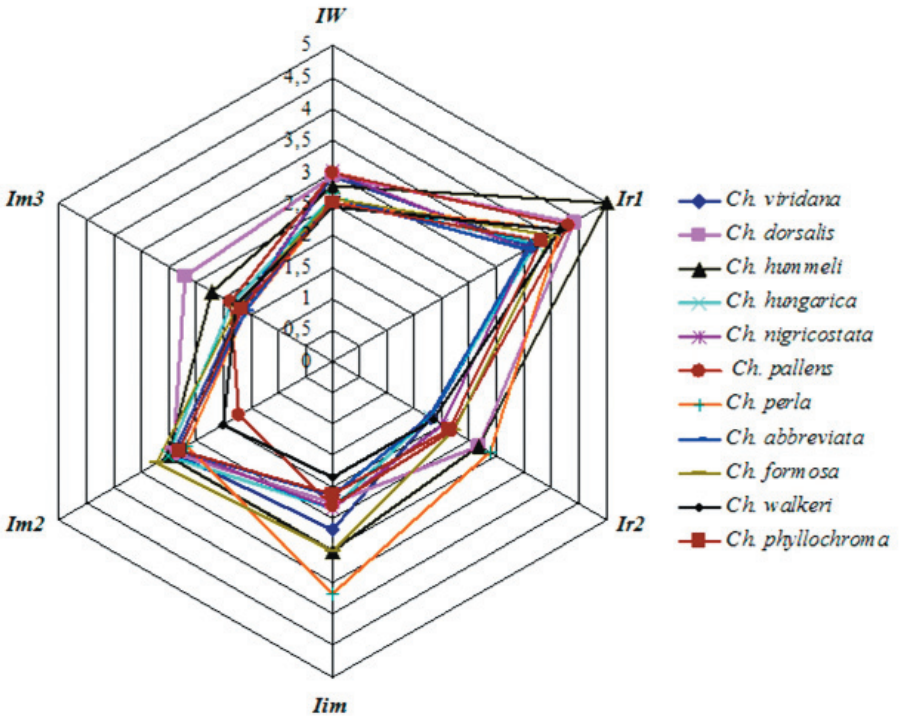


Fig. 2. Comparative diagram of the indices of the ratio of structures of the fore wing for the species of the genus *Chrysopa* from the Ukrainian Carpathians: *Chrysopa* from the Ukrainian Carpathians.

Table 1. The main morphometric indices of the fore wing structures in species of the genus *Chrysopa* from the Ukrainian Carpathians

Species	Results of measurements																		
		W			r1			r2			im			m2			m3		
	n	length, mm	width, mm	Iw	length, mm	width, mm	Ir1	length, mm	width, mm	Ir2	length, mm	width, mm	Iim	length, mm	width, mm	Im2	length, mm	width, mm	Im3
Ch. viridana	1	10.7	3.7	2.89	1.8	0.5	3.60	0.7	0.4	1.75	0.7	0.3	2.33	1.2	0.4	3.00	1.0	0.6	1.67
	2	10.9	3.7	2.95	1.9	0.5	3.80	0.7	0.4	1.75	0.7	0.3	2.33	1.2	0.4	3.00	1.0	0.6	1.67
	3	11.4	3.9	2.92	1.9	0.5	3.80	0.7	0.4	1.75	0.7	0.3	2.33	1.2	0.4	3.00	1.1	0.6	1.83
	4	12.1	4.1	2.95	2.1	0.6	3.50	0.8	0.4	2.00	0.8	0.3	2.67	1.3	0.5	2.60	1.1	0.6	1.83
	5	12.9	4.4	2.93	2.2	0.6	3.67	0.8	0.4	2.00	0.8	0.3	2.67	1.4	0.5	2.80	1.2	0.7	1.71
	6	13.2	4.5	2.93	2.3	0.6	3.83	0.8	0.4	2.00	0.8	0.3	2.67	1.4	0.5	2.80	1.2	0.7	1.71
	7	13.3	4.5	2.96	2.3	0.6	3.83	0.8	0.4	2.00	0.8	0.3	2.67	1.4	0.5	2.80	1.2	0.7	1.71
	8	13.8	4.7	2.94	2.4	0.7	3.43	0.9	0.5	1.80	0.9	0.3	3.00	1.5	0.5	3.00	1.3	0.8	1.63
	9	14.2	4.8	2.96	2.4	0.7	3.43	0.9	0.5	1.80	0.9	0.3	3.00	1.5	0.5	3.00	1.3	0.8	1.63
	10	14.4	4.9	2.94	2.5	0.7	3.57	0.9	0.5	1.80	0.9	0.3	3.00	1.6	0.6	2.67	1.3	0.8	1.63
	M	**12.69**	**4.32**	**2.94**	2.18	0.6	3.65	0.8	0.43	1.87	0.8	0.3	2.67	1.37	0.48	2.87	1.17	0.69	1.7
	σ	1.28	0.42	0.02	0.23	0.08	0.15	0.08	0.05	0.11	0.08	0	0.26	0.13	0.06	0.15	0.11	0.08	0.07
Ch. dorsalis	1	11.2	3.8	2.95	1.8	0.4	4.50	0.7	0.3	2.33	0.8	0.4	2.00	1.2	0.4	3.00	1.6	0.6	2.67
	2	11.2	3.8	2.95	1.8	0.4	4.50	0.7	0.3	2.33	0.8	0.4	2.00	1.2	0.4	3.00	1.6	0.6	2.67
	3	11.7	4.1	2.85	1.9	0.5	3.80	0.7	0.3	2.33	0.8	0.4	2.00	1.3	0.5	2.60	1.7	0.6	2.83
	4	12.5	4.3	2.91	2.0	0.5	4.00	0.8	0.3	2.67	0.9	0.4	2.25	1.4	0.5	2.80	1.8	0.7	2.57
	5	12.9	4.4	2.93	2.1	0.5	4.20	0.8	0.3	2.67	0.9	0.4	2.25	1.4	0.5	2.80	1.9	0.7	2.71
	6	13.5	4.6	2.93	2.2	0.5	4.40	0.8	0.3	2.67	0.9	0.4	2.25	1.5	0.5	3.00	2.0	0.7	2.88
	7	13.6	4.6	2.96	2.2	0.5	4.40	0.8	0.3	2.67	0.9	0.4	2.25	1.5	0.5	3.00	2.0	0.7	2.88
	8	14.0	4.8	2.92	2.3	0.5	4.60	0.9	0.3	3.00	1.0	0.4	2.50	1.5	0.5	3.00	2.1	0.8	2.63
	9	14.3	4.9	2.92	2.3	0.5	4.60	0.9	0.3	3.00	1.0	0.4	2.50	1.6	0.6	2.67	2.1	0.8	2.63
	10	14.7	5.0	2.94	2.4	0.6	4.00	0.9	0.3	3.00	1.0	0.4	2.50	1.6	0.6	2.67	2.2	0.8	2.75
	M	**12.96**	**4.43**	2.93	2.1	0.49	4.3	0.8	0.3	2.67	0.9	0.4	2.25	1.42	0.5	2.85	1.9	0.7	2.72
	σ	1.27	0.43	0.03	0.22	0.06	0.28	0.08	0	0.27	0.08	0	0.2	0.15	0.07	0.16	0.22	0.08	0.11
Ch. hummeli	1	11.0	3.9	2.82	2.3	0.4	5.75	0.7	0.3	2.33	0.8	0.3	2.67	1.3	0.4	3.25	1.0	0.5	2.00
	2	11.3	4.0	2.83	2.4	0.5	4.80	0.7	0.3	2.33	0.8	0.3	2.67	1.4	0.5	2.80	1.0	0.5	2.00
	3	11.4	4.1	2.78	2.4	0.5	4.80	0.7	0.3	2.33	0.8	0.3	2.67	1.4	0.5	2.80	1.0	0.5	2.00
	4	11.5	4.1	2.80	2.4	0.5	4.80	0.8	0.3	2.67	0.8	0.3	2.67	1.4	0.5	2.80	1.0	0.5	2.00
	5	11.6	4.2	2.76	2.5	0.5	5.00	0.8	0.3	2.67	0.9	0.3	3.00	1.5	0.5	3.00	1.1	0.5	2.20
	6	11.6	4.2	2.76	2.5	0.5	5.00	0.8	0.3	2.67	0.9	0.3	3.00	1.5	0.5	3.00	1.1	0.5	2.20
	7	11.9	4.3	2.77	2.5	0.5	5.00	0.8	0.3	2.67	0.9	0.3	3.00	1.5	0.5	3.00	1.1	0.5	2.20
	8	12.0	4.3	2.79	2.5	0.5	5.00	0.8	0.3	2.67	0.9	0.3	3.00	1.5	0.5	3.00	1.1	0.5	2.20
	9	12.1	4.3	2.81	2.6	0.5	5.20	0.8	0.3	2.67	0.9	0.3	3.00	1.5	0.5	3.00	1.1	0.5	2.20
	10	12.3	4.4	2.79	2.6	0.5	5.20	0.8	0.3	2.67	0.9	0.3	3.00	1.5	0.5	3.00	1.1	0.5	2.20
	M	**11.67**	4.18	2.79	2.47	0.49	5.06	0.77	0.3	2.57	0.86	0.3	2.87	1.45	0.49	2.97	1.06	0.5	2.12
	σ	0.4	0.15	0.02	0.09	0.03	0.29	0.05	0	0.16	0.05	0	0.17	0.07	0.03	0.14	0.05	0	0.1
Ch. hungarica	1	9.1	3.5	2.60	1.6	0.4	4.00	0.6	0.3	2.00	0.6	0.3	2.00	1.1	0.4	2.75	1.0	0.5	2.00
	2	9.3	3.6	2.58	1.7	0.5	3.40	0.6	0.3	2.00	0.6	0.3	2.00	1.1	0.4	2.75	1.0	0.5	2.00
	3	9.4	3.6	2.61	1.7	0.5	3.40	0.7	0.4	1.75	0.7	0.3	2.33	1.1	0.4	2.75	1.0	0.5	2.00
	4	9.8	3.8	2.58	1.8	0.5	3.60	0.7	0.4	1.75	0.7	0.3	2.33	1.2	0.4	3.00	1.1	0.6	1.83
	5	10.1	3.9	2.59	1.8	0.5	3.60	0.7	0.4	1.75	0.7	0.3	2.33	1.2	0.4	3.00	1.1	0.6	1.83
	6	10.1	3.9	2.59	1.8	0.5	3.60	0.7	0.4	1.75	0.7	0.3	2.33	1.2	0.4	3.00	1.1	0.6	1.83
	7	10.5	4.1	2.56	1.9	0.5	3.80	0.7	0.4	1.75	0.7	0.3	2.33	1.3	0.4	3.25	1.1	0.6	1.83
	8	10.6	4.1	2.59	1.9	0.5	3.80	0.7	0.4	1.75	0.7	0.3	2.33	1.3	0.4	3.25	1.2	0.7	1.71
	9	10.7	4.1	2.61	1.9	0.5	3.80	0.7	0.4	1.75	0.7	0.3	2.33	1.3	0.4	3.25	1.2	0.7	1.71
	10	10.8	4.2	2.57	1.9	0.5	3.80	0.7	0.4	1.75	0.7	0.3	2.33	1.3	0.4	3.25	1.2	0.7	1.71
	M	10.04	3.88	2.59	1.8	0.49	3.68	0.68	0.38	1.8	0.68	0.3	2.26	1.21	0.4	3.03	1.1	0.6	1.85
	σ	0.62	0.25	0.02	0.11	0.03	0.19	0.04	0.04	0.11	0.04	0	0.14	0.09	0	0.22	0.08	0.08	0.12

Ch. nigricostata	1	8.9	3.0	2.97	1.3	0.4	3.25	0.6	0.3	2.00	0.5	0.2	2.50	1.0	0.4	2.50	1.0	0.6	1.67
	2	9.6	3.2	3.00	1.4	0.4	3.50	0.6	0.3	2.00	0.6	0.3	2.00	1.1	0.4	2.75	1.0	0.6	1.67
	3	10.2	3.4	3.00	1.5	0.4	3.75	0.7	0.3	2.00	0.6	0.3	2.00	1.2	0.4	3.00	1.1	0.7	1.57
	4	11.5	3.8	3.03	1.7	0.5	3.40	0.8	0.4	2.00	0.7	0.3	2.33	1.3	0.5	2.60	1.3	0.8	1.63
	5	12.0	4.0	3.00	1.8	0.5	3.60	0.8	0.4	2.00	0.7	0.3	2.33	1.4	0.5	2.80	1.3	0.8	1.63
	6	12.3	4.1	3.00	1.9	0.5	3.80	0.8	0.4	2.00	0.7	0.3	2.33	1.4	0.5	2.80	1.3	0.8	1.63
	7	12.9	4.3	3.00	1.9	0.5	3.80	0.9	0.5	1.80	0.8	0.3	2.67	1.5	0.5	3.00	1.4	0.9	1.56
	8	13.5	4.5	3.00	2.0	0.6	3.33	0.9	0.5	1.80	0.8	0.3	2.67	1.6	0.6	2.67	1.5	0.9	1.67
	9	14.7	4.9	3.00	2.2	0.6	3.67	1.0	0.5	2.00	0.9	0.4	2.25	1.7	0.6	2.83	1.6	1.0	1.60
	10	15.8	5.3	2.98	2.4	0.7	3.43	1.1	0.6	1.83	0.9	0.4	2.25	1.8	0.6	3.00	1.7	1.1	1.55
	M	12.14	4.05	3	1.81	0.51	3.55	0.82	0.42	1.94	0.72	0.31	2.33	1.4	0.5	2.8	1.32	0.82	1.62
	σ	2.2	0.74	0.02	0.35	0.1	0.2	0.16	0.1	0.09	0.13	0.06	0.23	0.26	0.08	0.17	0.24	0.16	0.05
Ch. pallens	1	14.6	4.9	2.98	2.5	0.6	4.17	0.9	0.4	2.25	0.8	0.3	2.67	1.0	0.6	1.67	1.4	0.7	2.00
	2	15.2	5.1	2.98	2.6	0.6	4.33	0.9	0.4	2.25	0.9	0.4	2.25	1.0	0.6	1.67	1.4	0.7	2.00
	3	16.8	5.6	3.00	2.9	0.7	4.14	1.0	0.5	2.00	0.9	0.4	2.25	1.1	0.6	1.83	1.6	0.8	2.00
	4	17.4	5.8	3.00	3.0	0.7	4.29	1.1	0.5	2.20	1.0	0.4	2.28	1.2	0.7	1.71	1.6	0.9	1.78
	5	18.2	6.1	2.98	3.1	0.7	4.43	1.1	0.5	2.20	1.0	0.4	2.28	1.2	0.7	1.71	1.7	0.9	1.78
	6	19.3	6.5	2.97	3.3	0.8	4.13	1.2	0.6	2.00	1.1	0.4	2.75	1.3	0.8	1.63	1.8	1.0	1.80
	7	19.9	6.7	2.97	3.4	0.8	4.25	1.2	0.6	2.00	1.1	0.4	2.75	1.3	0.8	1.63	1.9	1.0	1.90
	8	20.6	6.7	3.07	3.5	0.8	4.38	1.3	0.6	2.17	1.1	0.4	2.75	1.4	0.8	1.75	1.9	1.0	1.90
	9	21.2	7.1	2.99	3.5	0.8	4.38	1.3	0.6	2.17	1.2	0.5	2.22	1.4	0.8	1.75	2.0	1.1	1.82
	10	21.7	7.3	2.97	3.6	0.8	4.50	1.3	0.6	2.17	1.2	0.5	2.22	1.4	0.8	1.75	2.0	1.1	1.82
	M	18.49	6.18	2.99	3.14	0.73	4.3	1.13	0.53	2.14	1.03	0.41	2.44	1.23	0.72	1.71	1.73	0.92	1.88
	σ	2.47	0.82	0.03	0.39	0.08	0.13	0.16	0.08	0.1	0.13	0.06	0.25	0.16	0.09	0.06	0.23	0.15	0.09
Ch. perla	1	11.0	4.4	2.50	2.2	0.5	4.40	0.9	0.3	3.00	0.9	0.3	3.00	1.3	0.5	2.60	1.1	0.7	1.57
	2	11.8	4.7	2.51	2.3	0.5	3.83	1.0	0.4	2.50	1.0	0.3	3.33	1.4	0.5	2.80	1.2	0.7	1.71
	3	12.4	4.9	2.53	2.4	0.6	4.00	1.0	0.4	2.50	1.0	0.3	3.33	1.5	0.6	2.50	1.2	0.7	1.71
	4	12.9	5.1	2.53	2.5	0.6	4.17	1.1	0.4	2.75	1.1	0.3	3.67	1.6	0.6	2.67	1.3	0.8	1.63
	5	13.3	5.3	2.51	2.6	0.6	4.33	1.1	0.4	2.75	1.1	0.3	3.67	1.6	0.6	2.67	1.3	0.8	1.63
	6	13.7	5.5	2.49	2.6	0.6	4.50	1.1	0.4	2.75	1.1	0.3	3.67	1.7	0.6	2.83	1.4	0.9	1.56
	7	14.2	5.7	2.49	2.8	0.6	4.00	1.2	0.4	3.00	1.2	0.3	4.00	1.7	0.6	2.83	1.4	0.9	1.56
	8	14.3	5.7	2.51	2.8	0.7	4.00	1.2	0.4	3.00	1.2	0.3	4.00	1.7	0.6	2.83	1.4	0.9	1.56
	9	14.6	5.8	2.52	2.9	0.7	4.14	1.2	0.4	3.00	1.2	0.3	4.00	1.8	0.7	2.57	1.4	0.9	1.56
	10	14.8	5.9	2.51	2.9	0.7	4.14	1.2	0.4	3.00	1.2	0.3	4.00	1.8	0.7	2.57	1.5	0.9	1.67
	M	**13.3**	**5.3**	**2.51**	**2.6**	**0.61**	**4.15**	**1.1**	**0.39**	**2.83**	**1.1**	**0.3**	**3.67**	**1.61**	**0.6**	**2.69**	**1.32**	**0.82**	1.62
	σ	1.27	0.51	0.01	0.25	0.07	0.21	0.11	0.03	0.21	0.11	0	0.35	0.17	0.07	0.13	0.12	0.09	0.06
Ch. abbreviata	1	8.4	3.2	2.63	1.4	0.4	3.50	0.6	0.3	2.00	0.6	0.2	2.00	1.1	0.4	3.00	0.9	0.5	1.80
	2	8.8	3.4	2.59	1.5	0.4	3.75	0.6	0.3	2.00	0.7	0.3	2.33	1.2	0.4	3.00	0.9	0.5	1.80
	3	9.4	3.6	2.61	1.6	0.4	4.00	0.6	0.3	2.00	0.7	0.3	2.33	1.2	0.4	3.00	1.0	0.6	1.67
	4	10.1	3.9	2.59	1.7	0.5	3.40	0.7	0.4	1.75	0.8	0.4	2.00	1.3	0.5	2.60	1.1	0.7	1.57
	5	10.6	4.1	2.59	1.8	0.5	3.60	0.7	0.4	1.75	0.8	0.4	2.00	1.4	0.5	2.80	1.1	0.7	1.57
	6	10.9	4.2	2.60	1.9	0.5	3.80	0.7	0.4	1.75	0.8	0.4	2.00	1.4	0.5	2.80	1.1	0.7	1.57
	7	11.2	4.3	2.60	1.9	0.5	3.80	0.7	0.4	1.75	0.9	0.4	2.25	1.5	0.5	3.00	1.2	0.8	1.50
	8	11.7	4.5	2.60	2.0	0.6	3.33	0.8	0.5	1.60	0.9	0.4	2.25	1.6	0.6	2.67	1.2	0.8	1.50
	9	12.2	4.7	2.60	2.1	0.6	3.50	0.8	0.5	1.60	0.9	0.4	2.25	1.6	0.6	2.67	1.3	0.8	1.63
	10	12.6	4.9	2.57	2.1	0.6	3.50	0.8	0.5	1.60	1.0	0.5	2.00	1.7	0.6	2.83	1.3	0.8	1.63
	M	**10.59**	**4.08**	**2.6**	**1.8**	**0.5**	**3.62**	**0.7**	**0.4**	**1.78**	**0.81**	**0.37**	**2.14**	**1.4**	**0.5**	**2.84**	**1.11**	0.69	1.62
	σ	1.41	0.56	0.02	0.24	0.08	0.21	0.08	0.08	0.17	0.12	0.08	0.15	0.2	0.08	0.16	0.14	0.12	0.11
Ch. formosa	1	11.3	4.4	2.57	1.7	0.4	4.25	0.8	0.4	2.00	0.9	0.3	3.00	1.6	0.5	3.20	1.2	0.7	1.71
	2	11.6	4.5	2.58	1.8	0.5	3.60	0.8	0.4	2.00	0.9	0.3	3.00	1.7	0.5	3.40	1.2	0.7	1.71
	3	11.9	4.6	2.59	1.8	0.5	3.60	0.8	0.4	2.00	0.9	0.3	3.00	1.7	0.5	3.40	1.3	0.7	1.86
	4	12.8	5.0	2.56	2.0	0.5	4.00	0.9	0.4	2.25	1.0	0.4	2.50	1.9	0.6	3.20	1.4	0.8	1.75
	5	13.1	5.1	2.58	2.0	0.5	4.00	0.9	0.4	2.25	1.0	0.4	2.50	1.9	0.6	3.20	1.4	0.8	1.75
	6	13.7	5.3	2.58	2.1	0.5	4.20	0.9	0.4	2.25	1.1	0.4	2.75	2.0	0.6	3.33	1.5	0.9	1.67
	7	14.2	5.5	2.58	2.2	0.6	3.67	1.1	0.5	2.20	1.1	0.4	2.75	2.1	0.7	3.00	1.5	0.9	1.67
	8	14.8	5.8	2.55	2.3	0.6	3.83	1.1	0.5	2.20	1.1	0.4	2.75	2.2	0.7	3.10	1.6	0.9	1.78
	9	15.3	6.0	2.55	2.4	0.6	4.00	1.1	0.5	2.20	1.2	0.4	3.00	2.2	0.7	3.10	1.6	0.9	1.78
	10	15.4	6.0	2.57	2.4	0.6	4.00	1.1	0.5	2.20	1.2	0.4	3.00	2.2	0.7	3.10	1.7	1.0	1.70
	M	**13.41**	**5.22**	**2.57**	**2.07**	**0.53**	**3.92**	**0.95**	**0.44**	**2.16**	**1.04**	**0.37**	**2.83**	**1.95**	**0.61**	**3.2**	1.44	0.83	1.74
	σ	1.51	0.6	0.01	0.25	0.07	0.23	0.14	0.05	0.11	0.12	0.05	0.21	0.23	0.09	0.14	0.17	0.11	0.06

Ch. walkeri	1	12.2	5.0	2.44	2.4	0.6	4.00	0.8	0.4	2.00	0.8	0.4	2.00	1.2	0.6	2.00	1.4	0.8	1.75
	2	12.3	5.0	2.46	2.5	0.6	4.17	0.9	0.5	1.80	0.9	0.5	1.80	1.2	0.6	2.00	1.4	0.8	1.75
	3	13.1	5.3	2.47	2.6	0.6	4.33	0.9	0.5	1.80	0.9	0.5	1.80	1.3	0.7	1.86	1.4	0.8	1.75
	4	13.7	5.6	2.45	2.7	0.7	3.86	0.9	0.5	1.80	0.9	0.5	1.80	1.3	0.7	1.86	1.5	0.8	1.20
	5	14.5	5.9	2.46	2.9	0.7	4.14	1.0	0.5	2.00	1.0	0.5	2.00	1.4	0.7	2.00	1.6	0.9	1.78
	6	14.6	5.9	2.47	2.9	0.7	4.14	1.0	0.5	2.00	1.0	0.5	2.00	1.4	0.7	2.00	1.6	0.9	1.78
	7	14.9	6.1	2.44	3.0	0.7	4.29	1.0	0.5	2.00	1.0	0.5	2.00	1.4	0.7	2.00	1.6	0.9	1.78
	8	15.4	6.3	2.44	3.2	0.8	4.00	1.1	0.6	1.83	1.1	0.6	1.83	1.5	0.8	1.86	1.7	1.0	1.70
	9	16.2	6.6	2.45	3.2	0.8	4.00	1.1	0.6	1.83	1.1	0.6	1.83	1.6	0.8	2.00	1.8	1.0	1.80
	10	16.6	6.8	2.44	3.3	0.8	4.13	1.1	0.6	1.83	1.1	0.6	1.83	1.6	0.8	2.00	1.8	1.0	1.80
	M	**14.35**	**5.85**	**2.45**	**2.87**	**0.7**	**4.11**	**0.98**	**0.52**	**1.89**	**0.98**	**0.52**	**1.89**	**1.39**	**0.71**	1.96	1.58	0.89	1.71
	σ	1.52	0.63	0.01	0.31	0.08	0.14	0.1	0.06	0.1	0.1	0.06	0.1	0.14	0.07	0.07	0.15	0.09	0.18
Ch. phyllochroma	1	9.8	3.9	2.51	1.9	0.5	3.80	0.7	0.3	2.33	0.8	0.4	2.00	1.2	0.4	3.00	1.1	0.7	1.57
	2	10.2	4.0	2.55	2.0	0.5	4.00	0.7	0.4	2.33	0.8	0.4	2.00	1.2	0.4	3.00	1.2	0.7	1.71
	3	10.6	4.2	2.52	2.0	0.5	4.00	0.7	0.4	2.33	0.8	0.4	2.00	1.3	0.5	2.60	1.2	0.7	1.71
	4	11.1	4.4	2.52	2.1	0.6	3.50	0.8	0.4	2.00	0.9	0.4	2.25	1.4	0.5	2.80	1.3	0.8	1.63
	5	11.5	4.6	2.50	2.2	0.6	3.67	0.8	0.4	2.00	0.9	0.4	2.25	1.4	0.5	2.80	1.3	0.8	1.63
	6	11.9	4.8	2.48	2.3	0.6	3.83	0.8	0.4	2.00	0.9	0.4	2.25	1.4	0.5	2.80	1.4	0.8	1.75
	7	12.3	4.9	2.51	2.4	0.6	4.00	0.9	0.4	2.25	1.0	0.5	2.00	1.5	0.5	3.00	1.4	0.9	1.56
	8	12.8	5.1	2.50	2.5	0.7	3.57	0.9	0.4	2.25	1.0	0.5	2.00	1.6	0.6	2.67	1.5	0.9	1.67
	9	13.5	5.4	2.50	2.6	0.7	3.71	0.9	0.5	1.80	1.1	0.5	2.20	1.6	0.6	2.67	1.5	0.9	1.67
	10	13.9	5.6	2.48	2.7	0.7	3.86	1.0	0.5	2.00	1.1	0.5	2.20	1.7	0.6	2.83	1.6	1.0	1.60
	M	**11.76**	**4.69**	**2.51**	**2.27**	**0.6**	**3.79**	**0.82**	**0.41**	**2.13**	**0.93**	**0.44**	**2.12**	**1.43**	0.51	2.82	1.35	0.82	1.65
	σ	1.38	0.58	0.02	0.28	0.08	0.18	0.1	0.06	0.19	0.12	0.05	0.12	0.17	0.07	0.15	0.16	0.1	0.06

Note. W — wings; im — intramedian cell; r1 — 1st radial cell; r2 — 2nd radial cell; m2 — 2nd median cell; m3 — 3rd median cell; M — aerage value; σ — standard deviation; Iw — index ratio between the length of wing and its width; Ir1 — index ratio between the length of the 2nd radial cell and its width; Ir2 — index ratio between the length of the 2nd radial cell and its width; Iim — index ratio between the length of intramedian cell and its width; Im2 — index ratio between the length of the 2nd median cell and its width; Im3 — index ratio between the length of the 3rd median cell and its width.

Table 2. Checking of the statistical indexes, that were used in the keys to determine the species of the genus *Chrysopa*

Grouping: Group 1 (Species of the genus *Chrysopa*) Group 2 (Indexes)							
Index	M1	M 2	t-value	df	p	St.Dv. 1	St.Dv.2
Iw	2.937	2.926	0.928	18	0.365771	0.021	0.031
Ir1	3.646	4.300	–6.338	18	0.000006	0.163	0.283
Ir2	1.865	2.667	–8.514	18	0.000000	0.118	0.274
Iim	2.667	2.250	3.864	18	0.001138	0.274	0.204
Im2	2.867	2.854	0.184	18	0.857227	0.153	0.165
Im3	1.702	2.722	–24.304	18	0.000000	0.075	0.109

2. Keys to Neuroptera from the Ukrainian Carpathians based on ratios of fore wing and cell sizes

Key to families of Neuroptera occurring in Ukraine (modified from Aspök et al., 1980)

1. Length of fore wing is more than 3 cm. 2
— Length of fore wing less than 2 cm. 3
2. Width of cubital sector more than 0.2 (c. 0.25) of fore wing width. Veins *Sc* and *R* fused into smooth curve towards the wing tip; distal cell between *R* and *Rs* is elongated, being 4–7 times as long as wide (fig. 3a). Antenna gradually thickening towards the tip or clavate. ..... Myrmeleontidae

— Width of cubital sector less than 0.15 (usually 0.1) of fore wing width. The vein *Sc+R* right after fusing steeply bent backwards; distal cell (fig. 3b) between *R* and *Rs* short, quadrangular or nearly square, being 1.5 times as long as wide. Antenna clavate, long. ..... Ascalaphidae

3. Radial sector always includes three cells; *R* vein forming *Rt* (radial triangular) in front of the first *Rs* (fig. 3f). Fore leg raptorial. ..... Mantispidae

— Radial sector always includes more than three cells; *R* vein not forming *Rt* (radial triangular). Fore leg walking. 3

4. Fore wing longer than 1.2 cm. 6

— Fore wing shorter than 1 cm. 11

5. Wing membrane transparent with many dark spots, main veins brownish. Veins *Sc* and *R* fused gradually towards wing tip (fig. 3c). Head with three simple ocelli. ..... Osmylidae

— Wing membrane transparent without spots, main veins greenish (yellowish in dry specimens). Veins *Sc* and *R* fused at the wing tip, or joined by cross veins, if not fused (fig. 3d). Head without simple ocelli. .... Chrysopidae

6. Fore wing longer than 0.6 cm. 7

— Fore wing shorter than 0.5 cm. 13

7. Wing membrane transparent, often with dark spots or characteristic drawings. Fore wing with two or more branches *Rs*; *Sc* and *R* terminate separately. Radial sector with many cross veins. Numerous *trz* are clearly visible on wing edges (fig. 3h). ..... Hemerobiidae

— Wing membrane transparent, uniformly brownish colored, lacking spots and pattern. Fore wing with only one branch *Rs; Sc* and *R* are fused near wing tip, vein *Sc* is steeply curved before fusion with *R* (fig. 3e). Radial sector includes few cross veins. Wing edges lacking *trz.* ..... Sisyridae

6. Body and wings covered with white wax-like coating. Wings lack setae and spots. Venation simple: few cross veins, not more than 5; costal sector lacking cross veins; longitudinal veins without branching (fig. 3g). Female ovipositor lacking. ..... Coniopterygidae

— White wax-like coating lacking. Wings covered with long dense setae, usually with characteristic drawings, including numerous brown spots and stripes. Venation is dense and complex: many cross veins. Female has a long saber-like ovipositor. ..... Dilaridae

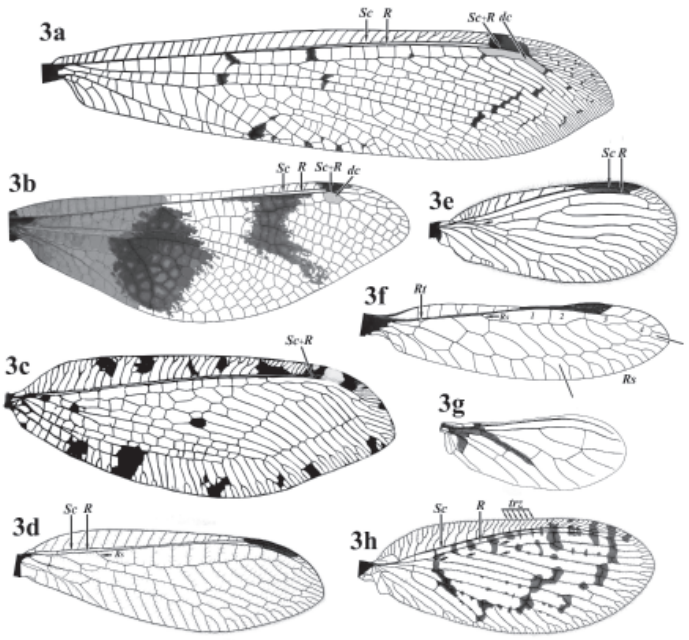
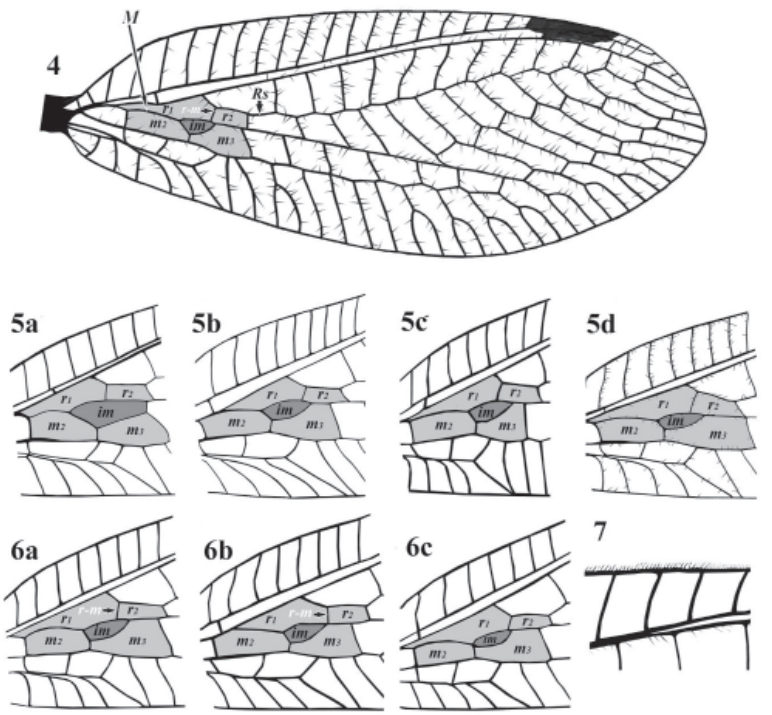


Fig. 3. Fore wing venation: 3a — Myrmeleontidae (*Distoleon* Banks, 1810); 3b — Ascalaphidae (*Libelloides* Schaffer, 1763); 3c — Osmylidae (*Osmylus* Latreille, 1802); 3d — Chrysopidae (*Chrysopa* Leach, 1815); 3e — Sisyridae (*Sisyra* Burmeister, 1839); 3f — Mantispidae (*Mantispa* Illiger in Kugelann, 1798); 3g — Coniopterigidae (*Conwentzia* Enderlein 1905); 3h — Hemerobiidae (*Hemerobius* Linnaeus, 1758); *R* — radius, *Rs* — radial sector, *Rt* — radial triangular, *dc* — distal cell between *R* and *Rs, Sc* — subcostal vein; *trz* — tiny inserted veins. arranged between the terminal branches of longitudinal veins.

Family CHRYSOPIDAE Schneider, 1851

Diagnosis. Green lacewings (Chrysopidae) are one of the largest families among Neuroptera. There are about 1,300 currently recognized species in the world, included in 87 genera and 3 subfamilies. The adults are mostly predators, but a few species feed on pollen. The adults have symmetrical mandibles and long setaceous antennae, which may exceed the length of the wing two times. The wings are large (hind wings slightly smaller than fore wings), semi-transparent, iridescent; veins mainly greenish or brownish. In contrast to other neuropterans, the chrysopids' wing membrane is without microtrichia and *trz*. The pterostigma is not always visible. Wing veins are covered with setae on both sides, forming a dense fringe in some members of the family. The jugulum lobe of the wing is present only in the most primitive species of the family. Wings have a characteristic venation, which is of great value for identifying the taxa (fig. 1) (e. g., Aspöck & Aspöck, 2007; Zakharenko, 1993 and many others).

The family Chrysopidae includes three subfamilies: Apochrysinae, Chrysopinae, and Nothochrysinae. The distribution ranges of most members of Apochrysinae are restricted to the Southern Hemisphere: seven species of two genera are known from Central and South America; two genera with three species occur in South Africa; five genera with 14 species live in the Australian Region. In the Northern Hemisphere, the subfamily is represented by a single species — *Nacaura matsumurae* Okamoto, 1912 from Japan (Brooks, 1997; Hölzel, 1984; Toschi, 1965; Winterton et al., 2015).



Figs 4–7. Fore wing venation of Chrysopidae: 4 — *Chrysotropia* Navás, 1911; 5 — base of fore wing: 5a — *Italochrysa* Principi. 1946, 5b — *Nineta* Navas, 1912, 5c — *Chrysopa* Leach in Brewster, 1815, 5d — *Peyerimhoffina* Lacroix, 1920; 6 — base of fore wing: 6a —*Pseudomallada* Tsukaguchi, 1995, 6b— *Chrysoperla* Steinmann, 1964, 6c — *Cunctochrysa* Hölzel, 1970; 7 — fragment of fore wing of *Chrysopa* Leach, 1815 with setae fringe; *M* — median vein, *im* — intramedian cell, m_2 — 2nd median cell, m_3 — 3rd median cell, r_1 — 1st radial cell, r_2 — 2nd radial cell, *r-m* — radial-median vein, *Rs* — radial sector.

Key to Ukrainian subfamilies of Chrysopidae

1. *Psm* vein of fore wing is zigzag in shape, fusing into inner gradates of cross veins. ....Nothochrysinae
— *Psm* vein of fore wing is strait, fusing into outer gradates of cross veins. ..... Chrysopinae

Subfamily Nothochrysinae

Species of the subfamily Nothochrysinae are represented in all continents (excluding Antarctica) by seven genera (17 species). Only three species (*Hypochrysa elegans* Burgmeister, 1839; *Nothochrysa capitata* Fabricius, 1793; and *Notochrysa fulvipes* Stephens, 1836) occur in Europe, including Ukraine (Aspöck et al., 1993).

Subfamily Chrysopinae

The subfamily Chrysopinae includes the largest number of species, which occur in all continents (excluding Antarctica). About 65 species of 12 genera are known from Europe (Canard, 2004), including 23 species of eight genera (*Italochrysa, Chrysopa, Chrysoperla, Chrysotropia, Cunctochrysa, Nineta, Peyerimhoffina, Pseudomallada*) from Ukraine (Serediuk, 2015).

Key to Ukrainian genera of Chrysopidae

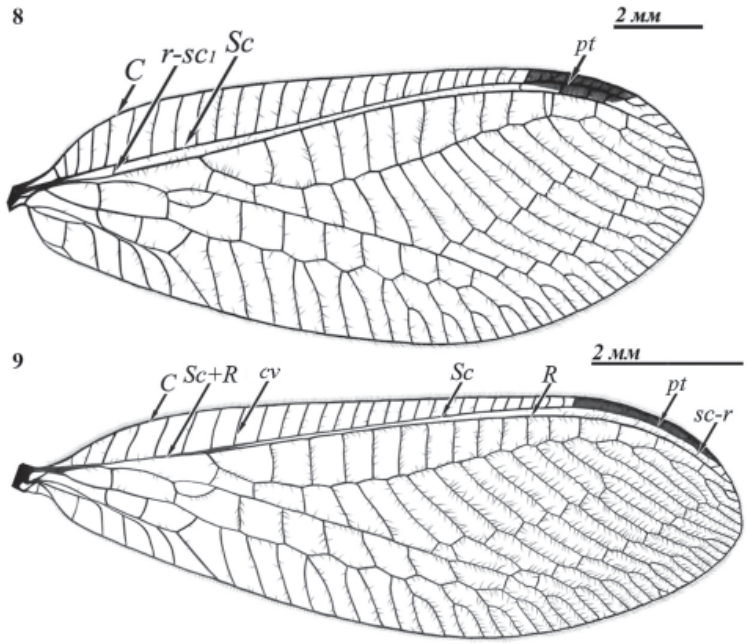
1. Intramedian cell *(im)* of fore wing is nearly trapeziform (fig. 5a). ..... *Italochrysa*
— Intramedian cell *(im)* of fore wing is nearly oval-triangular (fig. 5a–6c).....2
2. Fore wing longer than 16 mm and more.....3
— Fore wing shorter than 15 mm. 5
3. Setae in costal sector short and arranged at an acute angle (30–45°) to the costal vein (C). ..... *Nineta*
— Setae in costal sector are long and arranged at an angle from 60° to almost 90° to the costal vein (C). 4
4. Long setae along the costal vein *(C)* of fore wing arranged almost at right angle. ..... *Chrysotropia*
— Setae along the costal vein *(C)* of fore wing at an angle of not more than 60° (fig. 7). 9
5. Index of length to width ratio in the second cell of radial sector (r_2) is 1.6 or less. 6
— Index of length to width ratio in the second cell of radial sector (r_2) exceeds 1.8. 7
6. The cell m_2 nearly pentagonal, less than 2.5 (usually 2 times) as long as wide; cell m_3 nearly triangular in shape, almost as long as wide (fig. 5c). Head and sometimes body with dark spots. ..... *Chrysopa*
— The cell m_2 nearly quadrangular, more than 2.5 (usually 3 times) as long as wide; cell m_3 twice as long as wide (fig. 6c). Head and body are without dark spots. ..... *Cunctochrysa*
7. First cross vein between R_s and $M_{(r\text{-}m)}$ meets vein *M* at some distance from the apex of intramedian cell (*im*) (fig. 6a). Cross veins of the costal sector dark colored at their ends. Thorax and abdomen without longitudinal dorsal pale band. ..... *Pseudomallada*
— First cross vein between R_s and $M_{(r\text{-}m)}$ meets vein *M* slightly beyond the limits of the intramedian cell (*im*) (fig. 6b). Cross veins of the costal sector uniformly greenish. Thorax and abdomen with longitudinal dorsal pale band. ..... *Chrysoperla*

Genus *Chrysopa* Leach in Brewster, 1815

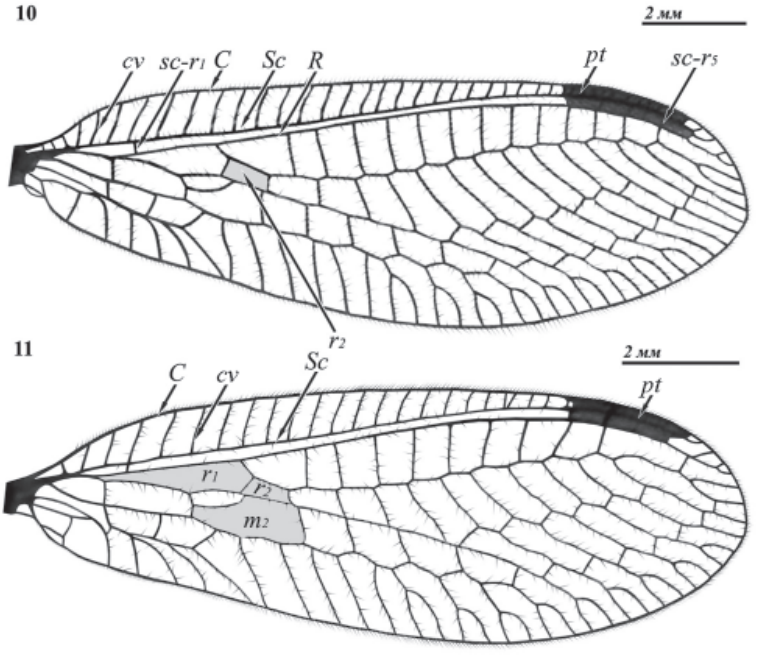
The genus *Chrysopa* includes 50 species, occurring in the Holarctic Region (Hölzel, 1984), with 18 of them recorded in Europe (Letardi, 2017). Twelve species are distributed in the Ukrainian Carpathians (Serediuk, 2016).

Key to the identification of species of the genus *Chrysopa*

1. Index ratio of length to width in m2 cell 2:1. 2
— Index ratio of length to width in m_2 cell 3:1. 3
2. *Sc* and *R* of fore wing not fused. Pterostigma covers 6–7 cells of costal field (*C*) and part of Sc field. Costal field includes 32–33 cells. Inner and outer gradates of the fore wing are black colored (fig. 8). .... *C. walkeri* McLachlan, 1893



Figs 8–9. Fore wings of species of Chrysopidae: 8 — fore wing of *Chrysopa walkeri* (McLachlan, 1893); 9 — fore wing of *Chrysopa pallens* (Rambur, 1838).

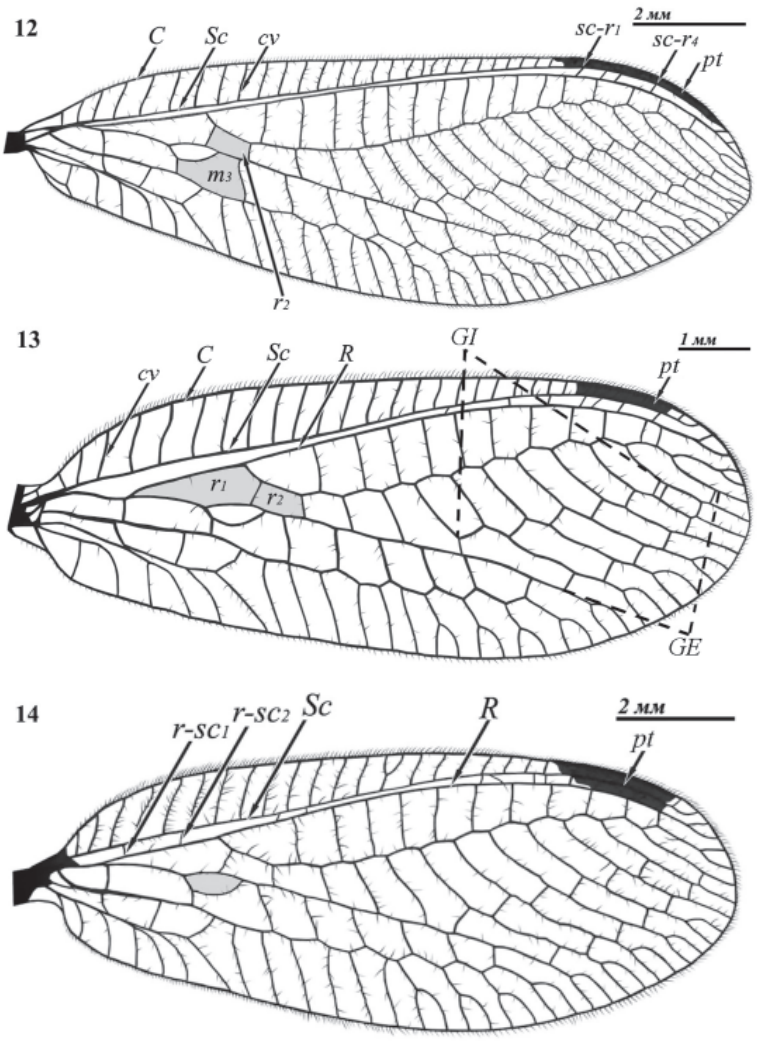


Figs 10–11. Fore wings of species of Chrysopidae: 10 — fore wing of *Chrysopa dorsalis* (Burmeister, 1839); 11 — fore wing of *Chrysopa hummeli* Tjeder, 1936.

— Sc and R of fore wing fused in the proximal part of fore wing. Pterostigma covers 10–12 cells of costal field (*C*). Costal field includes 41–42 cells. Inner and outer gradates of the fore wing are green colored (fig. 9) ..... *C. pallens* Rambur, 1838

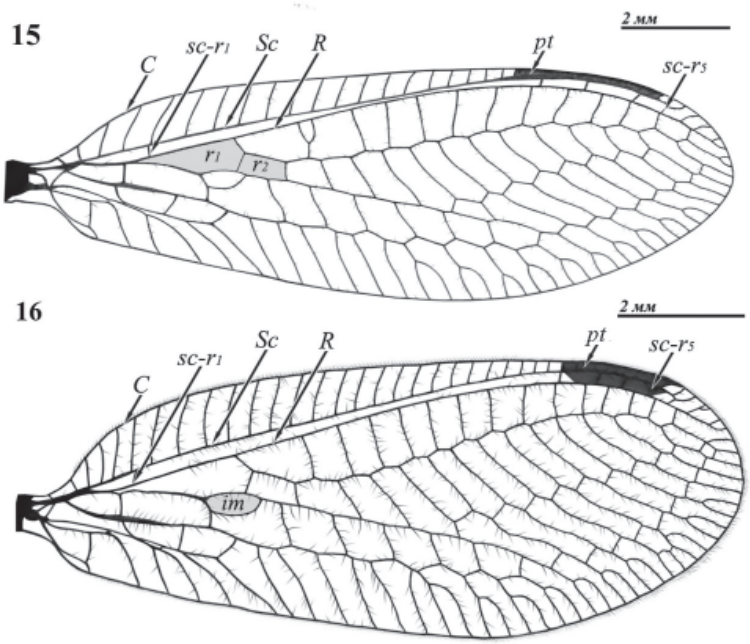
3. Ratio of length to width in m_3 cell 2:1 or slightly more. 4

— Ratio of length to width in m_3 cell 1.5:1 or slightly less. 5

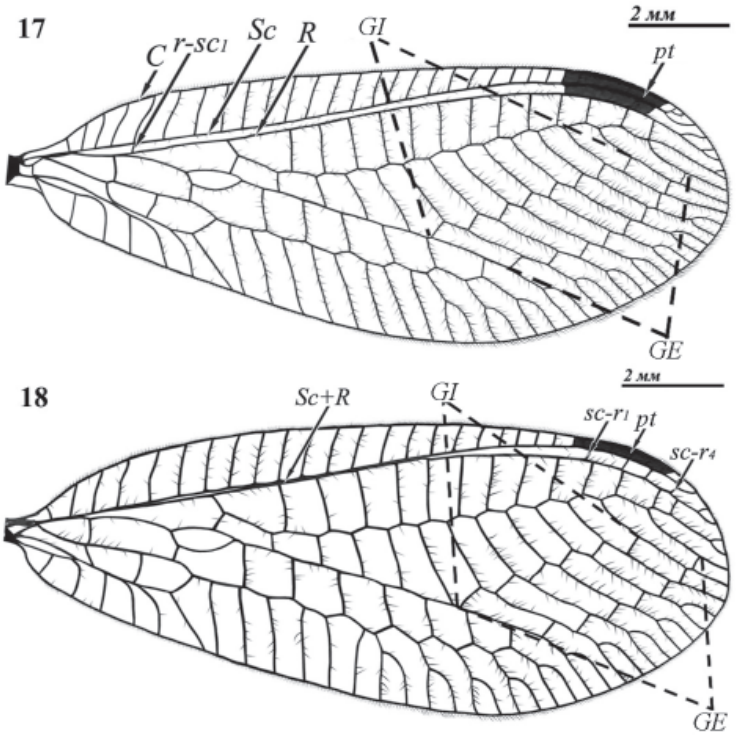


Figs 12–14. Fore wings of species of Chrysopidae: 12 — fore wing of *Chrysopa viridana* (Schneider, 1845); 13— fore wing of *Chrysopa hungarica* Klapalek, 1899; 14 — fore wing of *Chrysopa phyllochroma* (Wesmael, 1841).

4. Ratio of length to width in r_1 cell is 4:1. Costal field (*C*) has 36–37 cells. Pterostigma covers 8–9 cells of costal field and 4–5 cells of *Sc* field (fig. 10). ..... *C. dorsalis* Burmeister, 1839
— Ratio of length to width in r_1 cell 3:1. Costal field (*C*) has 28–32 cells. Pterostigma covers 5–6 cells of costal field and part of *Sc* field (fig. 11). ..... *C. hummeli* Tjeder, 1936
5. Ratio of length to width in *im* cell 3:1 or less. Not all cross veins of the fore wing are black. 6
— Ratio of length to width in *im* cell 3.3:1 or above. All cross veins of the fore wing are black (fig. 18). .... *C. perla* Linnaeus, 1758
6. In the basal part of *Sc* field cross veins are absent. 8
— In the basal part of *Sc* field cross veins are present. 7
7. Basal part of *Sc* field has 2 cross veins (fig. 14). ..... *C. phyllochroma* Wesmael, 1841
— Basal part of *Sc* field has 1 cross vein. 10
8. Cross veins of costal field are black. Pterostigma covers 8–9 cells of costal field. *Sc* vein is dark-green. Basal part of *Sc* field not widened (fig. 12). ..... *C. viridana* Schneider, 1845
— Cross veins of costal field are green. Pterostigma covers 4–5 cells of costal field and part of *Sc* field. Basal part of *Sc* field widened (fig. 13). ..... *C. hungarica* Klapalek, 1899
10. *Sc* field grows narrower in its middle part (fig. 15). ..... *C. nigricostata* Brauer, 1850



Figs 15–16. Fore wings of species of Chrysopidae: 15 — fore wing of *Chrysopa nigricostata* (Brauer, 1850); 16 — fore wing of *Chrysopa abbreviata* (Curtis, 1834).



Figs 17–18. Fore wings of species of Chrysopidae: 17 — fore wing of *Chrysopa formosa* (Brauer, 1850); 18 — fore wing of *Chrysopa perla* (Linnaeus, 1758).

— *Sc* field does not grow narrower in its middle part. 11
11. Costal field has 32–33 cells, rarely more. All veins are green. Index ratio of length to width in *im* cell is 2:1, it is egg-shaped. Fore wing has 10 inner and 10 outer gradates. ..... *C. abbreviata* Curtis, 1834
— Costal field has 28–30 cells. All cross veins are black. Index ratio of length to width in *im* cell is 3:1, it is oval-triangular in shape. Fore wing has 8–9 inner gradates and 9 outer gradates (fig. 17). .... *C. formosa* Brauer. 1850

Conclusions

The proposed morphometric parameters and indices for the identification of Neuroptera on the level of families, genera, and species are quite stable. This gives the possibility to use them for identification of *Chrysopa* species in particural. In this paper the indices $Ir_{1,}$ $Ir_{2,}$ *Iim,* $Im_{2,}$ Im_{3} have been used.

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