Arthropoda Selecta 33(4): 480–492 © ARTHROPODA SELECTA, 2024

Fauna and local associations of water fleas (Crustacea: Branchiopoda: Cladocera) in small water bodies of Moscow City

Фауна и локальные ассоциации ветвистоусых ракообразных (Crustacea: Branchiopoda: Cladocera) малых водоемов города Москвы

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KEY WORDS: urban territories, ecology, anthropogenic factors, European Russia.

КЛЮЧЕВЫЕ СЛОВА: городские территории, экология, антропогенные факторы, европейская часть России.

ABSTRACT. In the frame of our work, a special large-scale study on diversity of the Cladocera (Crustacea: Branchiopoda) in small water bodies of Moscow city was carried out for the first time. Forty five species belonging to 23 genera were found in 112 water bodies. Eurythopic species, which are widely distributed in Russia and neighboring areas, predominate there. Scanning electron microscope images are provided for some taxa to confirm their accurate identification. The investigated water bodies are characterized by an oligodominant species complex, which includes only two taxa (*Chydorus sphaericus* and *Bosmina longirostris*). Our analysis of the mutual associations of the species at a significance level of p = 0.05 using the binomial distribution model revealed four major clusters. The cluster 1, containing many species of different mode of life and taxonomic position, is present in many water bodies. Its existence revealed a significant similarity between the species composition of most studied samples, independently of the water body type and size. Such uniformity seems to be a sign of the urban territories. The chydorid cluster 2 was confined to water bodies that can be characterized as mesotrophic, with a moderate anthropogenic pressure. Moreover, two daphniid-dominated clusters (3 and 4) were revealed. Presence of a local mutual association 3 containing *Daphnia curvirostris*, *D. magna*, *Ceriodaphnia laticaudata* and *C. quadrangula* indicates a high level of eutrophicationin a water body.

How to cite this paper: Mityaeva K.Yu., Neretina A.N., Garibian P.G., Kotov A.A., Petrovskiy A.B. 2024. Fauna and local associations of water fleas (Crustacea: Branchiopoda: Cladocera) in small water bodies of Moscow City // Arthropoda Selecta. Vol.33. No.4. P.480–492, Suppl. Tables. doi: 10.15298/arthsel.33.4.05

РЕЗЮМЕ. В рамках нашей работы впервые было проведено специальное масштабное исследование разнообразия ветвистоусых ракообразных (Crustacea: Branchiopoda: Cladocera) в малых водоемах Москвы. В 112 водоемах нами было обнаружено 45 видов кладоцер, принадлежащих к 23 родам. В этих водоемах преобладают эвритопные виды, широко распространенные в России и сопредельных территориях. Для некоторых таксонов приведены фотографии, полученные на растровом электронном микроскопе, подтверждающие их точную идентификацию. Для исследованных водоемов характерен олигодоминантный комплекс видов, включающий всего два таксона (*Chydorus sphaericus* и *Bosmina longirostris*). Анализ ассоциаций видов в водоемах при уровне значимости p = 0,05 с использованием биномиальной модели распределения выявил четыре основных кластера. Кластер 1 содержит множество видов, различающихся по образу жизни и таксономическому положению, и присутствует во многих водоемах. Его существование подчеркивает

значительное сходство между видовым составом большинства исследованных проб, независимо от типа и размера водоема. Такое единообразие является признаком городских территорий. Хидоридная ассоциация кластера 2 приурочена к водоемам, которые можно охарактеризовать как мезотрофные, с умеренной антропогенной нагрузкой. Кроме того, нами были выделены еще два кластера, 3 и 4, с преобладанием Daphniidae. Присутствие в водоеме ассоциации 3, содержащей *Daphnia curvirostris*, *D. magna*, *Ceriodaphnia laticaudata* и *C. quadrangula*, указывает на высокий уровень эвтрофикации в водоеме.

Introduction

The water fleas, or cladocerans (Crustacea: Branchiopoda: Cladocera), are among the most common microscopic invertebrates in inland water bodies of all continents, including waters subjected to high anthropogenic pressures. Cladocerans, along with copepods and rotifers, represent an important model group for ecological monitoring of the aquatic ecosystem state [Korovchinsky *et al*., 2021a, b]. Different cladoceran species are regarded as bioindicators of water quality, test-objects in toxicological test etc. [Smirnov, 2017] and models in paleolimnological studies [Smirnov, 2010].

Their taxonomy and local faunas are intensively studied. During recent decades, new taxa were described from the water bodies of Russia [Kotov, Sinev, 2011; Korovchinsky, 2020], some unfairly forgotten taxa were redescribed [Zuykova *et al*., 2018] and new records for the country were made [Kotov *et al*., 2011; Aksenova *et al*., 2023; Garibian, Aksenova, 2023]. In general, significant progress has been achieved in the inventory of cladocerans of Northern Eurasia [Kotov, 2016; Korovchinsky *et al*., 2021a, b]. Cladoceran fauna, species associations and their Holocene history are studied in great detail in some water bodies of European Russia, e.g., Lake Glubokoe located in the Ruza District of Moscow Area, which could be considered as the best studied water body in the world [Matveev, 1986; Kotov, 2013; Korovchinsky *et al*., 2021a, b].

Surprisingly, the cladocerans inhabiting natural and artificial water bodies of Moscow City (being a separate Metropolitan Area of the Russian Federation and the capital of a country with well-developed “cladocerology”) very rarely served as objects of special faunistic and even ecological investigations, they appear to have been studied inadequately. The first list of the cladocerans of Moscow city and its vicinities was published by Poggenpohl [1874] based on samples collected in 1870–1872. It included 20 species, but its interpretation is rather difficult now as some of them are considered as junior synonyms of previously established taxa, or *species inquirendae*. The next inventory was carried out by Matile [1890], where *Ceriodaphnia setosa* Matile, 1890 was described from Mytishchi. This is a very specific valid species requiring redescription to modern standard [Korovchinsky *et al*., 2021b]. Interesting new data were added in course of studies at Kosino lakes [Gal’tsov, 1914; Lukashina *et al*., 2016], e.g. during the activities of staff of Kosino Biological Station and Kosino Nature Reserve [Shirokova, Ozerova, 2019].

Unfortunately, data on cladoceran diversity from published ecological papers on the cladocerans from Moscow ponds (e.g. Bubunets *et al*. [2018]; Gerasimova *et al*. [2019, 2020]; Evgrafov *et al*. [2023]) were scarce and controversial. It is known that the cladoceran fauna of urban ponds is species-poor [Pawlikiewicz, Jurasz, 2017; Andreeva *et al*., 2023] as such water bodies are prone to eutrophication and siltation, but nobody has demonstrated adequately the same pattern for Moscow city. Moreover, public utilities clean many ponds during summer time [A.B. Petrovskiy, personal observations]. It could partly explain the low interest of cladocerologists to artificial water bodies located within the metropolitan area. But influence of such pond cleaning on cladoceran associations is unknown.

At the same time, few Moscow ponds have existed for more than 300 years and have a great historical and cultural value [Gerasimova *et al*., 2019]. With growth of human population and urban development, the anthropogenic press on aquatic ecosystems is constantly increasing. Inevitably, the risk of rare and vulnerable native species extinction and the probability of dangerous invasive species appearance increase [Korovchinsky *et al*., 2021a, b]. Under these conditions, faunistic and ecological studies are particularly relevant for the development of criteria to conserve biodiversity and protect ponds (and other small water bodies located within the city) as historical sites in the changing urban landscapes.

The aim of our work is to study the cladoceran fauna and local associations of the waters in Moscow City what could be regarded as the first step towards understanding of their changes under anthropogenic pressure.

Materials and methods

We studied 169 samples from 112 ponds, springs and lakes, located within so-called “Old Moscow” (not covering the area of “New Moscow” located outside of the Moscow Ring Road, but included in the Moscow Metropolitan Area in 2012) (Fig. 1A, see Supplementary Table 1). The material was collected by A.B. Petrovskiy and P.G. Garibian in autumn of 2021 and K.Yu. Mityaeva, A.N. Neretina and P.G. Garibian in summer of 2023 (Fig. 1A) out via small hand-made plankton nets (with mesh size less than 50 μm). In case of relatively large water bodies, littoral and open water zones were collected separately. In the case of small and shallow water bodies, a single total sample was taken via an entire water body without differentiation of the zones. Samples were fixed in 96% ethanol. Their preliminary analysis was conducted in the laboratory using the stereoscopic microscope Olympus SZX2-ZB10 (Olympus Corporation, Japan). Some specimens were transferred to slides with glycerol drops and dissected by electrogalvanically sharpened tungsten needles [Kotov, 2013]. Body parts important for taxon identification were transferred separately into new drops of glycerol, covered with cover slips using plasticine (=model clay) “legs” and investigated under an Olympus BX41 high-power microscope (Olympus Corporation, Japan).

All specimens were identified to species, species group or genus level (in case of their belonging to groups with confused

Table 1. Taxonomic structure of Cladocera found in the small water bodies of Moscow.
Таблица 1. Таксономический спектр ветвистоусых ракообразных в малых водоемах Москвы.

Order, Family		**The number of taxa**	
		Genera	**Species**
Order Anomopoda Sars, 1865	Family Bosminidae Baird, 1845 emend. Sars, 1865	1	1
	Family Chydoridae Dybowski et Grohowski, 1894	12	20
	Family Daphniidae Straus, 1820	4	18
	Family Ilyocryptidae Smirnov, 1992	1	1
	Family Macrothricidae Norman et Brady, 1867 emend. Smirnov, 1976	1	1
	Family Moinidae Goulden, 1968	1	3
Order Ctenopoda Sars, 1865	Family Sididae Baird, 1850	2	2
Order Onychopoda Sars, 1865	Family Polyphemidae Baird, 1845	1	1
Totally:		**23**	**45**

taxonomy or presenting in the dormant stage (ephippia) only according to Korovchinsky *et al*. [2021b]. For confirmation of our identification accurateness, some specimens were dehydrated in an increasing standard ethanol series and 100% acetone (40 minutes in each series), then transferred to hexamethyldisilazane (for 40 minutes), air-dried overnight [Laforsch, Tollrian, 2000], attached to stubs under a stereoscopic microscope Leica S9D (Leica Microsystems, Germany), covered by gold in S150A Sputter Coater (Edwards, UK) and examined under a TESCAN MIRA 3 LMH (Tescan, Czech Republic) scanning electron microscope.

Visualization of sampling localities was carried out in QGIS 3.32.2 packet based on their geographical coordinates. Data processing was carried out in Microsoft Excel 2013. Completeness of the cladoceran diversity study was evaluated using non-parametric methods for extrapolation of species richness [Colwell, Elsensohn, 2014], implemented in the EstimateS 9.1 software package. Both taxa identified up to the species level and those identified only to the genus level were included in the analysis. The matrix of species occurrence in each sample was prepared via special module developed by A.V. Omelchenko. Based on this matrix, the species accumulation curves as a function of sampling effort (number of samples analysed) were constructed using five different algorithms: Chao 1, Chao 2, Jacknife 1, Jacknife 2 and Bootstrap. The best model was recognised by the smallest variance of the predicted values for each step (the step differed by one trial). Simultaneously, a randomised empirical curve was plotted in the same program.

A special package using binomial and hypergeometric distribution function (within the framework of R-programming) developed by D.G. Seleznev (http://apps.ibiw.ru/coobs/) [see Prokin *et al*., 2021; Kotov *et al*., 2022; Andreeva *et al*., 2023] was used to identify the mutual species associations at $p = 0.01$ and 0.05. The ecological preferences of each taxon were interpreted according to earlier published data on the crustaceans of Northern Eurasia [Fryer, 1993; Korovchinsky *et al*., 2021b], as well as more detailed special reviews on Ctenopoda [Korovchinsky, 2004], benthic Anomopoda [Kotov, 2006], families Chydoridae [Fryer, 1968; Korovchinsky *et al*., 2021b] and Macrothricidae [Fryer, 1974; Smirnov, 1976].

Unfortunately, 30 species (i.e., more than half of the identified taxa) belonged to non-revised widespread taxa [Kotov, 2016] which made possible analysis of their geographic preferences useless.

Results

Totally, we obtained 870 identifications belonging to 45 species (Tables 1–3). The largest species diversity (16 species) was recorded in the Middle Kirovograd Pond (Supplementary Table 2); 15 species were recorded from two ponds; 10–14 species — from 18 ponds, 9 or less species — from 91 ponds.

Neither empirical nor model curve of the species accumulation reached the plateau, but both were close to such a state. Therefore, we did not have a full list of the cladocerans, but we believe that only few species were not recorded by us. Chao1 model, the best among five models applied (Fig. 1B), has estimated the species richness as 50 species (vs. 45 actually found). It was assumed that the total number of species in the region corresponded to the former value.

Our taxa belonged to three orders, 8 families and 23 genera. The families Chydoridae (20 species) and Daphniidae (18 species) were the richest in species number, while other families were represented by three or less species (Table 1). *Ceriodaphnia*, *Daphnia* (7 species in each genus), *Pleuroxus* (5 species), *Moina, Simocephalus* (3 species in each genus) were the most diverse genera making 55.6% of the total number of identified cladocerans (Table 2, Fig. 1C).

Benthic-phytophilous cladocerans inhabiting the surface of aquatic macrophytes and the bottom sediments are represented by 25 species; planktonic crustaceans, inhabiting the water column of deep and relatively shallow water bodies, includes 19 species; neustonic cladocerans, attaching to the surface water film, are represented by a single species, *Scapholeberis mucronata* (Fig. 1E, Table 3).

Eurythopic species predominated among the identified taxa (Fig. 1E, Table 3), they represented 80% of all studied species. Eurythermal oligosaprobic and thermophilic eurytopic cladocerans each made 4.4%, while thermophilic oligosaprobic cladocerans made 2.2%. Another 8.9% of studies species were identified only to genus level, their preferences were unclear.

Table 2. Genus structure of Cladocera found in the small water bodies of Moscow.
Таблица 2. Родовой спектр ветвистоусых ракообразных в малых водоемах Москвы.

No.	**Genus**	**Species number**
1	*Ceriodaphnia* Dana, 1853	7
2	*Daphnia* O.F. Müller, 1785	7
3	*Pleuroxus* Baird, 1843	5
4	*Moina* Baird, 1850	3
5	*Simocephalus* Schoedler, 1858	3
6	*Acroperus* Baird, 1843	2
7	*Alonella* Sars, 1862	2
8	*Alona* Baird, 1843	1
9	*Biapertura* Smirnov, 1971	1
10	*Bosmina* Baird, 1845	1
11	*Camptocercus* Baird, 1843	1
12	*Chydorus* Leach, 1816	1
13	*Coronatella* Dybowski et Grochowski, 1894	1
14	*Diaphanosoma* Fischer, 1850	1
15	*Disparalona* Fryer, 1968	1
16	*Graptoleberis* Sars, 1862	1
17	*Ilyocryptus* Sars, 1862	1
18	*Macrothrix* Baird, 1843	1
19	*Oxyurella* Dybowski et Grochowski, 1894	1
20	*Polyphemus* O.F. Müller, 1785	1
21	*Pseudochydorus* Fryer, 1968	1
22	*Scapholeberis* Schoedler, 1858	1
23	*Sida* Straus, 1820	1
Totally:		**45**

Table 3. Ecological and geographical preferences of Cladocera found in small water bodies of Moscow.
Таблица 3. Эколого-географическая приуроченность ветвистоусых ракообразных из малых водоемов Москвы.

No.	**Species**	**Mode of life**	**Ecology**
1	*Acroperus angustatus* Sars, 1863	BF	eurythermal, eurytopic
2	*Acroperus harpae* (Baird, 1834)	BF	eurythermal, eurytopic
3	*Alona guttata* Sars, 1862	BF	eurythermal, eurytopic
4	*Alonella excisa* (Fischer, 1854)	BF	eurythermal, eurytopic
5	*Alonella exigua* (Lilljeborg, 1853)	BF	eurythermal, eurytopic
6	*Biapertura affinis* (Leydig, 1860)	BF	eurythermal, eurytopic
7	*Bosmina* (*Bosmina*) *longirostris* (O.F. Müller, 1776)	PL	eurythermal, eurytopic
8	*Camptocercus rectirostris* Schödler, 1862	BF	eurythermal, eurytopic
9	*Ceriodaphnia dubia* Richard, 1894	PL	eurythermal, eurytopic
10	*Ceriodaphnia laticaudata* P.E. Müller, 1867	PL	eurythermal, eurytopic
11	*Ceriodaphnia pulchella* Sars, 1862	PL	eurythermal, eurytopic
12	*Ceriodaphnia quadrangula* (O.F. Müller, 1785)	PL	eurythermal, eurytopic
13	*Ceriodaphnia reticulata* (Jurine, 1820)	PL	eurythermal, eurytopic

Table 3 (continued).
Таблица 3 (продолжение).

No.	Species	Mode of life	Ecology
14	*Ceriodaphnia rotunda* (Straus, 1820)	PL	eurythermal, eurytopic
15	*Ceriodaphnia* sp.	PL	no data
16	*Chydorus sphaericus* (O.F. Müller, 1776)	BF	eurythermal, eurytopic
17	*Coronatella rectangula* (Sars, 1862)	BF	eurythermal, eurytopic
18	*Daphnia* (*Ctenodaphnia*) *magna* Straus, 1820	PL	eurythermal, eurytopic
19	*Daphnia* (*Daphnia*) *cucullata* Sars, 1862	PL	eurythermal, eurytopic
20	*Daphnia* (*Daphnia*) *curvirostris* Eylmann, 1887	PL	eurythermal, eurytopic
21	*Daphnia* (*Daphnia*) *galeata* Sars, 1864	PL	eurythermal, eurytopic
22	*Daphnia* (*Daphnia*) *longispina* (O.F. Müller, 1776)	PL	eurythermal, eurytopic
23	*Daphnia* (*Daphnia*) *pulex* Leydig, 1860	PL	eurythermal, eurytopic
24	*Daphnia* (*Daphnia*) sp.	PL	no data
25	*Diaphanosoma brachyurum* (Liévin, 1848)	PL	thermophilic oligosaprobic
26	*Disparalona rostrata* (Koch, 1841)	BF	eurythermal, eurytopic
27	*Graptoleberis testudinaria* (Fischer, 1851)	BF	eurythermal, eurytopic
28	*Ilyocryptus agilis* Kurz, 1878	BF	eurythermal, eurytopic
29	*Macrothrix laticornis* (Jurine, 1820)	BF	eurythermal, eurytopic
30	*Moina* cf. *brachiata* (Jurine, 1820)	PL	thermophilic eurytopic
31	*Moina macrocopa* (Straus, 1820)	PL	thermophilic eurytopic
32	*Moina* sp.	PL	no data
33	*Oxyurella tenuicaudis* (Sars, 1862)	BF	eurythermal, eurytopic
34	*Pleuroxus aduncus* (Jurine, 1820)	BF	eurythermal, eurytopic
35	*Pleuroxus laevis* (Sars, 1862)	BF	eurythermal oligosaprobic
36	*Pleuroxus trigonellus* (O.F. Müller, 1776)	BF	eurythermal, eurytopic
37	*Pleuroxus truncatus* (O.F. Müller, 1785)	BF	eurythermal, eurytopic
38	*Pleuroxus uncinatus* (Baird, 1850)	BF	eurythermal, eurytopic
39	*Polyphemus pediculus* (Linnaeus, 1761)	BF	eurythermal, eurytopic
40	*Pseudochydorus globosus* (Baird, 1843)	BF	eurythermal, eurytopic
41	*Scapholeberis mucronata* (O.F. Müller, 1776)	NE	eurythermal, eurytopic
42	*Sida crystallina* (O.F. Müller, 1776)	BF	eurythermal oligosaprobic
43	*Simocephalus serrulatus* (Koch, 1841)	BF	eurythermal, eurytopic
44	*Simocephalus vetulus* (O.F. Müller, 1776)	BF	eurythermal, eurytopic
45	*Simocephalus* sp.	BF	no data

BF — benthic-phytophilous; NE — neustonic; PL — planktonic.

Some of the encountered taxa are illustrated in Figs 3–6.

Two eurythopic species, *Chydorus sphaericus* and *Bosmina longirostris*, were the most widely distributed taxa in the investigated water bodies: the former was found in 93, the latter — in 76 water bodies (among 112 studied) (Fig. 2A, Supplementary Table 2). Therefore the investigated water bodies were characterized by an oligodominant species complex. The remaining species were found in 48 water bodies or fewer. Seven species (*Acroperus angustatus, Ceriodaphnia reticulata*, *C. rotunda*, *Moina macrocopa*, *Oxyurella tenuicaudis*, *Pleuroxus laevis*, *Simocephalus serrulatus*) were recorded only in a sole water body each.

An analysis of the mutual associations of species in the water bodies at a significance level of p = 0.05 using the binomial distribution model revealed four major clusters = local mutual associations (1–4). The cluster 1 contained numerous planktonic and benthic-phytophylous taxa from different genera and families from the water bodies of different types; the chydorid cluster 2 shares four benthic-phytophylous taxa, the predominantly daphniid cluster 3 represented shallow eutrophic pools, the daphniid cluster 4 was present in several ponds.

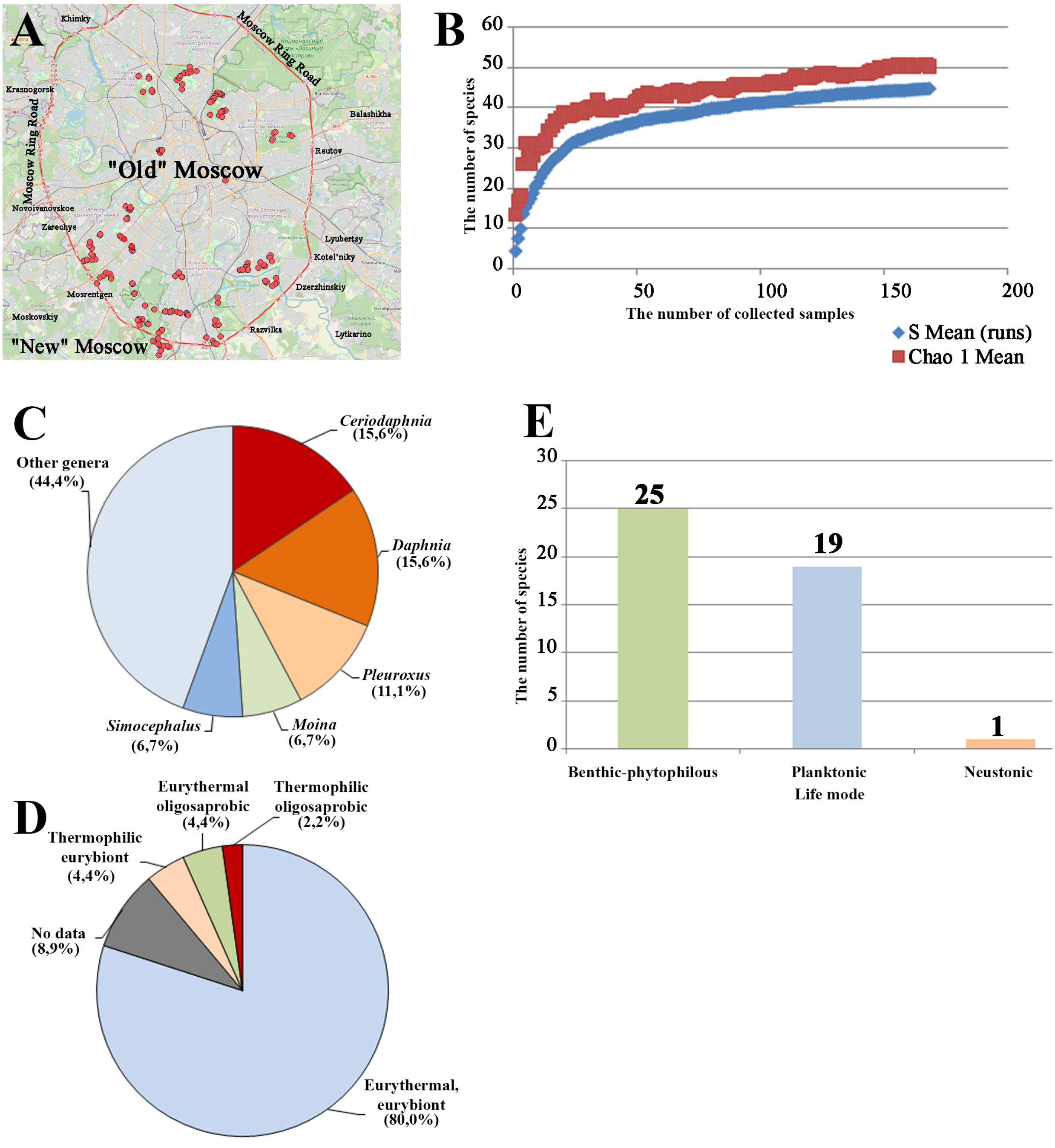

Fig. 1. A — a map with sampling sites; B — randomized assembler curve and taxa accumulation curve as the number of samples increases, plotted from the best model (Chao 1) for the studied water bodies; C — distribution of revealed species between different genera; D — distribution of cladocerans by their life mode; E — distribution cladocerans by their ecological preferences.

Рис. 1. A — карта с местами отбора проб; B — рандомизированная кривая сборщика и кривая накопления таксонов по мере увеличения числа проб, построенная по результатам применения лучшей модели (Chao 1) для исследованных водоемов; C — распределение выявленных видов по родам; D — распределение ветвистоусых ракообразных по образу жизни; E — распределение ветвистоусых ракообразных по экологической приуроченности.

The same analysis at p = 0.01 revealed four major clusters representing the cores of local mutual associations 1, 2 and 3 (Fig. 2C: 1, 2, 3a, 3b). As in the previous case, cluster 1 shared many animals with different modes of life and belonging to different families (plus *Ceriodaphnia dubia*, *Daphnia longispina*, *D. pulex*, *Disparalona rostrata*, *Moina macrocopa* from clusters 2, 3, 4 at p = 0.05), cluster 2 again includes chydorids only; two daphniid clusters, 3a and 3b corresponded to parts of cluster 3 p = 0.05). Cluster 4 is collapsed at p = 0.01.

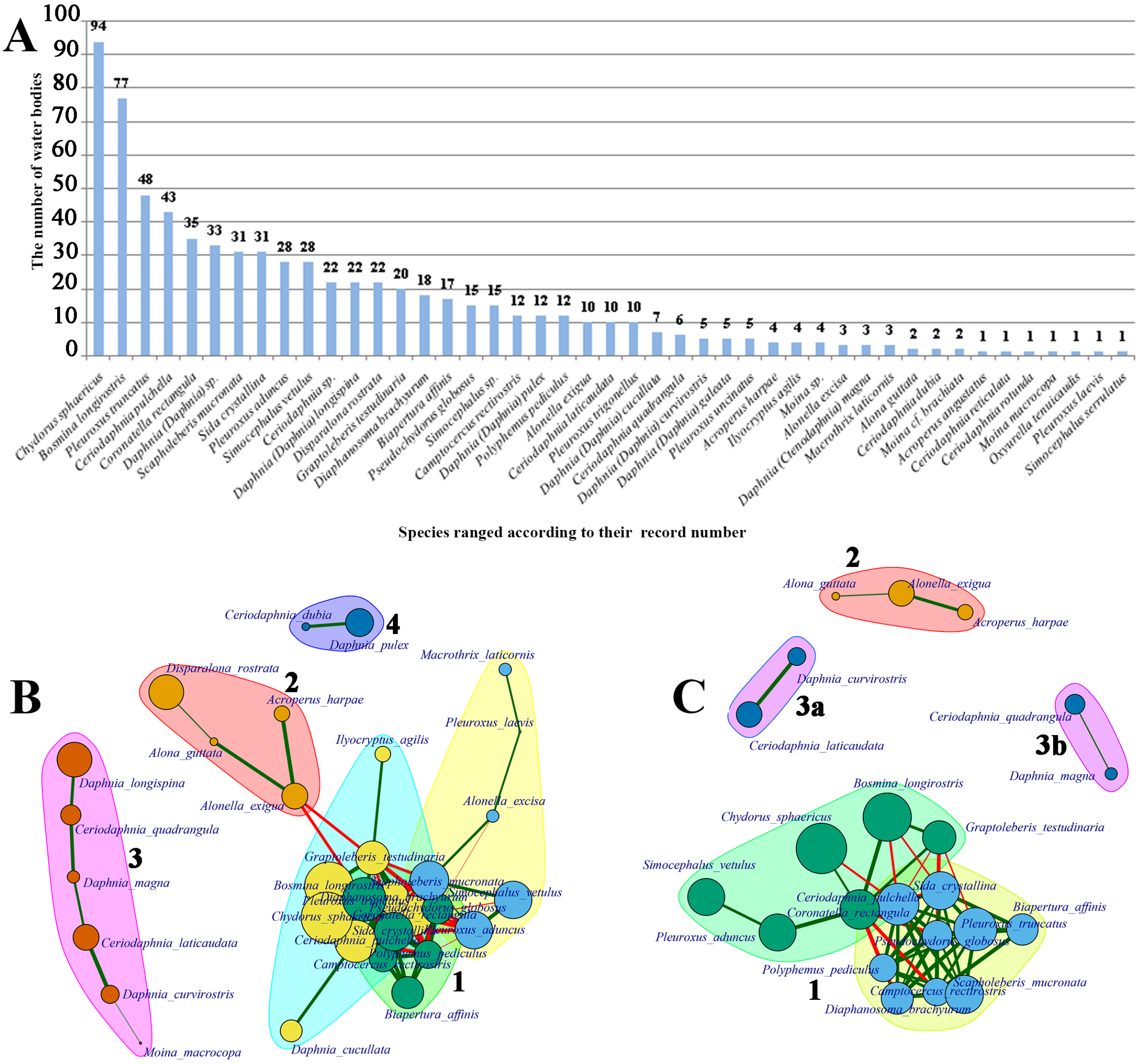

Fig. 2. A — occurrence of identified cladocerans in the small water bodies of Moscow (ordinate axis — the number of water bodies where the species was found); B — graphs of mutual association of cladocerans in the investigated water bodies at significance level p=0.05, calculated on the basis of binomial distribution; C — the same at p=0.01. Marker size is logarithmically proportional to the frequency of species detection in water bodies; edge thickness reflects the strength of species association and is inversely proportional to the significance level of association.

Рис. 2. A — встречаемость выявленных видов ветвистоусых ракообразных в малых водоемах Москвы (по оси ординат — число водоемов, в которых был найден вид); B — графы взаимной ассоциированности видов ветвистоусых ракообразных в исследованных водоемах при уровне значимости p=0,05, рассчитанные на основе биномиального распределения; C — то же при уровне p=0,01. Размер маркера логарифмически пропорционален частоте обнаружения вида в водоемах; толщина ребра отражает силу связи видов и обратно пропорциональна уровню значимости связи.

Discussion

Ironically, the most comprehensive previous study of the cladoceran fauna of Moscow City waters was carried out by Poggenpohl [1874] 150 years ago. From his species list (author's spelling is kept by us), *Daphnella Brandtiana* Sars most likely corresponds to *Diaphanosoma brachyurum* (Liévin, 1848) s.str. (see Korovchinsky *et al*. [2021b]); *Lynceus griseus* Fischer — to *Disparalona rostrata* (Koch, 1841); *Alona minuta* Poggenpol, 1874 — to *A. guttata* Sars, 1862; *Camptocercus biserratus* Schd. — to *C. rectirostris* Schödler, 1862 [Kotov *et al*., 2013]; *Pleuroxus personatus* (Leyd.) — to *P. uncinatus* (Baird, 1850). Few taxa, described in this paper, *Chydorus alexandrovi* Poggenpol, 1874, *C. ciliatus* Poggenpol, 1874, *C. tuberculatus* Poggenpol, 1874 and *Pleuroxus convexus* (Poggenpol, 1874), now are considered as *species inquirendae* [Kotov *et al*., 2013]. Other taxa marked by Poggenpohl [1874] represented widespread species found also by us: *Daphnia magna*, *D. pulex*, *D. longispina*, *Scapholeberis mucronata*, *Ceriodaphnia rotunda*, *C. reticulata*, *Simocephalus vetulus*, *Chydorus sphaericus*, *Pleuroxus truncatus* and *Polyphemus pediculus.* Among 16 valid taxa reported by Poggenpohl [1874],

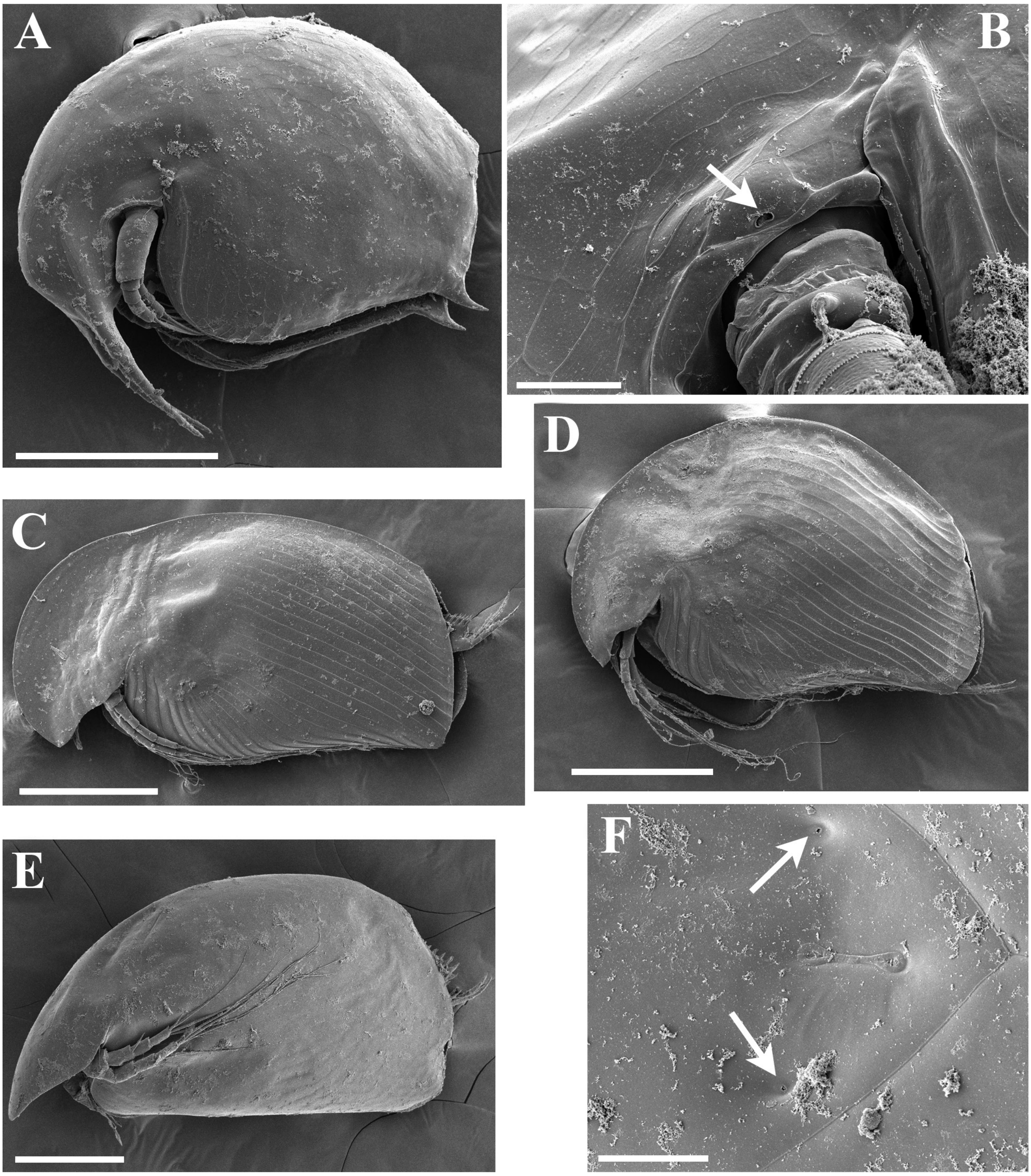

Fig. 3. A–B — general view and lateral pore of parthenogenetic female of *Bosmina* (*Bosmina*) *longirostris* (O.F. Müller, 1776) from Big Garden Pond, R.I. Schroeder Dendrological Garden; C — general view of parthenogenetic female of *Acroperus angustatus* Sars, 1863 from Big Garden Pond, R.I. Schroeder Dendrological Garden; D — general view of parthenogenetic female of *Acroperus harpae* (Baird, 1834) from First Putyaevsky Pond, Sokolniki N-HP, Sokolniki Forest Park; E–F — general view and head pores of parthenogenetic female of *Biapertura affinis* (Leydig, 1860) from Lower Biryulevsky pond, around Mikhnevsky proezd. Scale bars: A, C–E — 0.2 mm; B — 0.02 mm; F — 0.01 mm.

Рис. 3. A–B — общий вид и латеральная пора *Bosmina* (*Bosmina*) *longirostris* (O.F. Müller, 1776) из Большого Садового пруда, Дендрологический Сад имени Р.И. Шредера; C — общий вид партеногенетической самки *Acroperus angustatus* Sars, 1863 из Большого Садового пруда, Дендрологический Сад имени Р.И. Шредера; D — общий вид партеногенетической самки *Acroperus harpae* (Baird, 1834) из Первого Путяевского пруда, П-ИП «Сокольники», лесопарк Сокольники; E–F — общий вид и головные поры партеногенетической самки *Biapertura affinis* (Leydig, 1860) из Нижнего Бирюлевского пруда, окрестности. Михневского проезда. Масштабные отрезки: A, C–E — 0,2 мм; B — 0,02 мм; F — 0,01 мм.

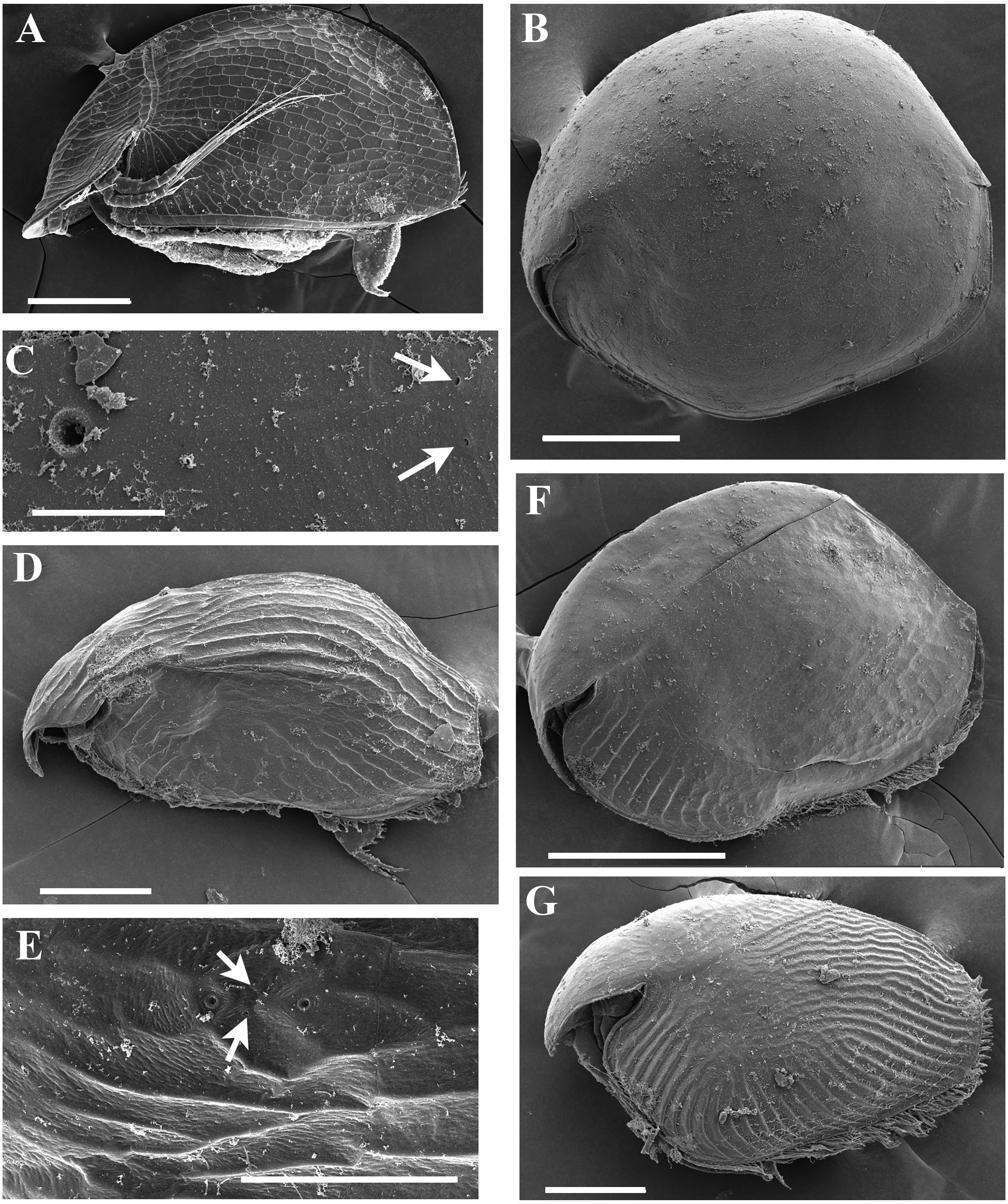

Fig. 4. A — general view of parthenogenetic female of *Graptoleberis testudinaria* (Fischer, 1851) from Kalitnikovsky Pond, public garden at Kalitnikovsky Pond; B–C — general view and head pores of parthenogenetic female of *Chydorus sphaericus* (O.F. Müller, 1776) from Kalitnikovsky Pond, public garden at Kalitnikovsky Pond; D–E — general view and head pores of parthenogenetic female of *Disparalona rostrata* (Koch, 1841) from Lower Biryulevsky pond, around Mikhnevsky proezd; F — general view of parthenogenetic female of *Pleuroxus aduncus* (Jurine, 1820) from the unnamed pond, LZ "Tyoply Stan", Teplostansky forest park; G — general view of parthenogenetic female of *Pleuroxus truncatus* (O.F. Müller, 1785) from Big Garden Pond, R.I. Schroeder Dendrological Garden. Scale bars: F — 0.2 mm; B, D, G — 0.1 mm; E — 0.05 mm; A, C — 0.01 mm.

Рис. 4. A — общий вид партеногенетической самки *Graptoleberis testudinaria* (Fischer, 1851) из Калитниковского пруда, сквер у Калитниковского пруда; B–C — общий вид и головные поры партеногенетической самки *Chydorus sphaericus* (O.F. Müller, 1776) из Калитниковского пруда, сквер у Калитниковского пруда; D–E — общий вид и головные поры партеногенетической самки *Disparalona rostrata* (Koch, 1841) из Нижнего Бирюлевского пруда, окрестности Михневского проезда; F — общий вид партеногенетической самки *Pleuroxus aduncus* (Jurine, 1820) из пруда без названия, ЛЗ «Тёплый стан», Теплостанский лесопарк; G — общий вид партеногенетической самки *Pleuroxus truncatus* (O.F. Müller, 1785) из Большого Садового пруда, Дендрологический Сад имени Р.И. Шредера. Масштабные отрезки: F — 0,2 мм; B, D, G — 0,1 мм; E — 0,05 мм; A, C — 0,01 мм.

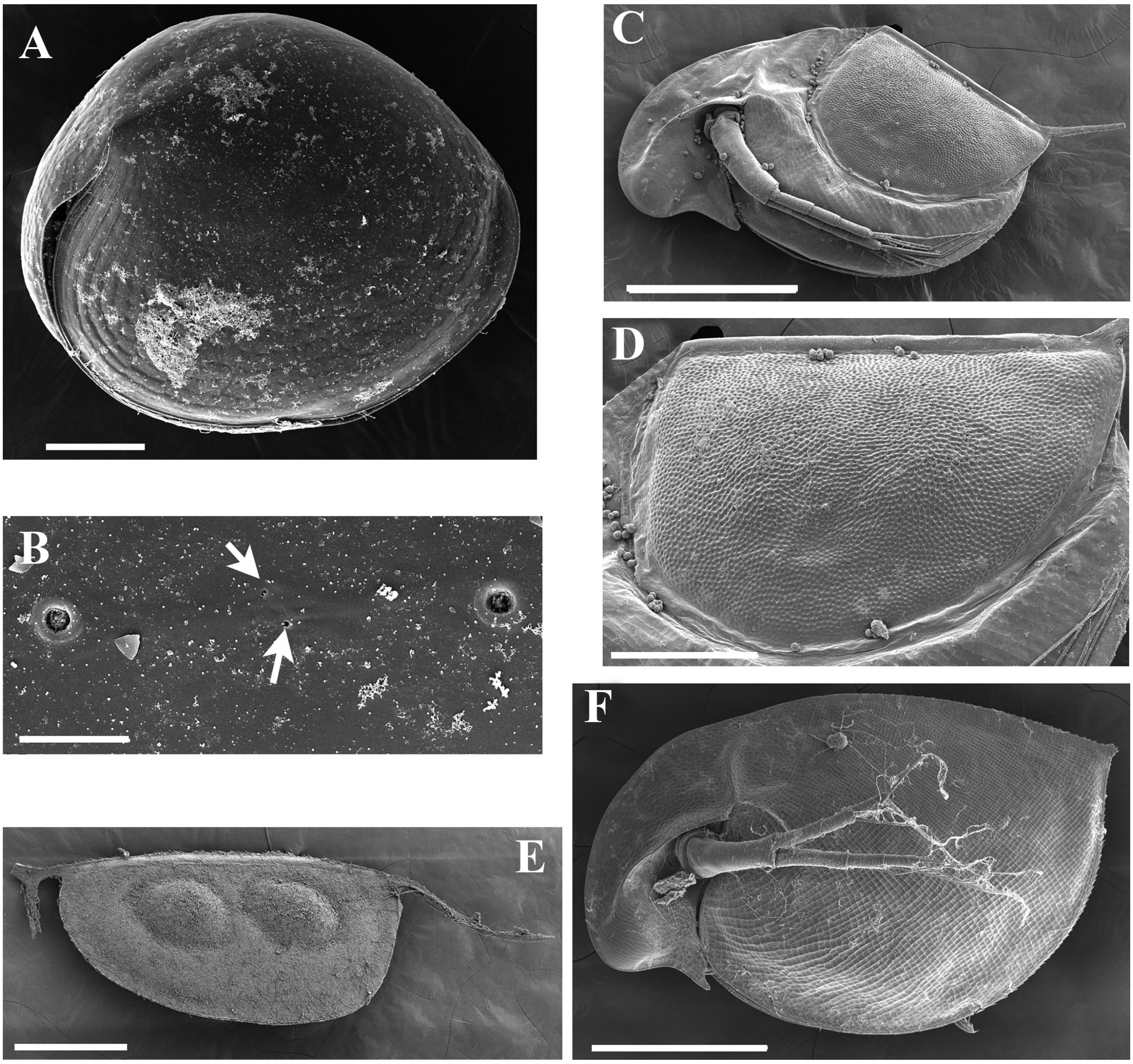

Fig. 5. A–B — general view and head pores of parthenogenetic female of *Pseudochydorus globosus* (Baird, 1843) from Iziutinsky pond; C–D — general view of ephippial female and ephippium of *Daphnia* (*Daphnia*) *longispina* (O.F. Müller, 1776) from Fourth Putyaevsky Pond, Sokolniki N-HP, Sokolniki Forest Park; E — an ephippium of *Daphnia* (*Ctenodaphnia*) *magna* Straus, 1820 from 3rd Vorontsovsky Pond, Vorontsovsky Park; F — a parthenogenetic female of *Daphnia* (*Daphnia*) *pulex* Leydig, 1860 from unnamed, N-HP "Bittsevsky les", Bittsevsky lesopark. Scale bars: C, E–F — 0.5 mm; D — 0.2 mm; A — 0.1 mm; B — 0.001 mm.

Рис. 5. A–B — общий вид и головные поры партеногенетической самки *Pseudochydorus globosus* (Baird, 1843) из Изютинского пруда; C–D — общий вид эфиппиальной самки и эфиппиум *Daphnia* (*Daphnia*) *longispina* (O.F. Müller, 1776) из Четвертого Путяевского пруда, П-ИП «Сокольники», лесопарк Сокольники; E — эфиппиум *Daphnia* (*Ctenodaphnia*) *magna* Straus, 1820 из 3-го Воронцовского пруда, Воронцовский парк; F — партеногенетическая самка *Daphnia* (*Daphnia*) *pulex* Leydig, 1860 из пруда без названия, П-ИП «Битцевский лес», Битцевский лесопарк. Масштабные отрезки: C, E–F — 0,5 мм; D — 0,2 мм; A — 0,1 мм; B — 0,001 мм.

we did not find only *Alona quadrangularis* (O.F. Müller, 1776). Probably, the cladoceran fauna did not change a lot since Poggenpohl's [1874] time. Note that *D. magna* still inhabits the ponds in Moscow Zoo as a century ago [Matile, 1890]!

In ecological publications of the 21st century, the number of identified cladoceran species in the ponds of Moscow varied from 10 [Pogozhev, Gerasimova, 2005] to 13 [Gerasimova, Pogozhev, 2002], but, unfortunately, the authors did not publish full lists of species. Here, we investigate the cladoceran diversity relatively adequately (according to the pattern of species accumulation curves). Missing taxa may be found in the future due to analysis of new samples i.e. collected in certain water bodies throughout the full vegetation season, from spring to autumn.

The revealed taxonomic structure with predominance of Chydoridae and Daphniidae and eurythopic species is typical of the small water bodies located within cities and subjected to high anthropogenic pressure [Sukop, 2008, 2014a, b; Frolova, 2015; Pawlikiewicz, Jurasz, 2017; Gerasimova *et al*., 2019; Andreeva *et al*., 2023].

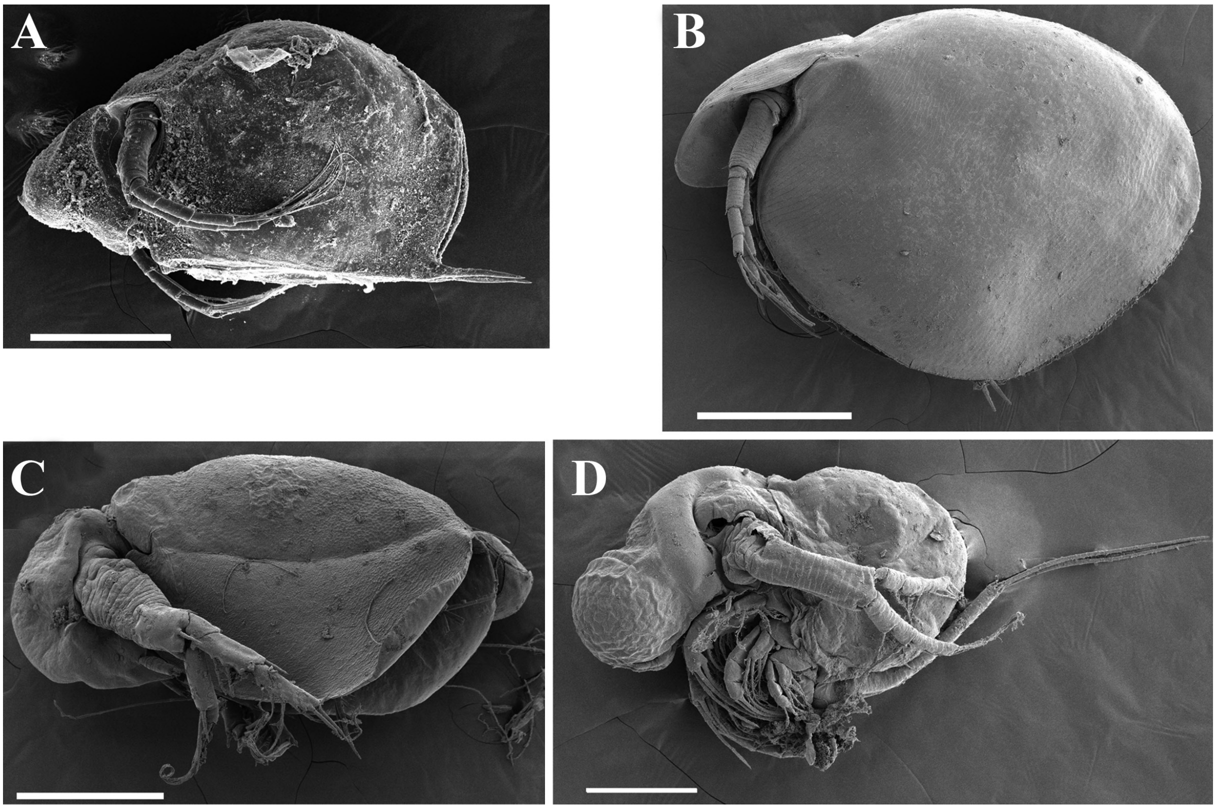

Fig. 6. A — general view of parthenogenetic female of *Scapholeberis mucronata* (O.F. Müller, 1776) from Iziutinsky pond; B — general view of parthenogenetic female of *Simocephalus vetulus* (O.F. Müller, 1776) from the unnamed pond, MSU Botanical Garden; C — general view of parthenogenetic female of *Sida crystallina* (O.F. Müller, 1776) from Middle Kirovogradskiy Pond, Kirovogradskiy Ponds Cascade Park; D — general view of parthenogenetic female of *Polyphemus pediculus* (Linnaeus, 1761) from First Putyaevsky Pond, Sokolniki N-HP, Sokolniki Forest Park. Scale bars: B–F — 0.5 mm; A, D — 0.2 mm.

Рис. 6. A — общий вид партеногенетической самки *Scapholeberis mucronata* (O.F. Müller, 1776) из Изютинского пруда; B — общий вид партеногенетической самки *Simocephalus vetulus* (O.F. Müller, 1776) из пруда без названия, Ботсад МГУ; C — общий вид партеногенетической самки *Sida crystallina* (O.F. Müller, 1776) из Среднего Кировоградского пруда, Парк Каскад Кировоградских прудов; D — общий вид партеногенетической самки *Polyphemus pediculus* (Linnaeus, 1761) из Первого Путяевского пруда, П-ИП «Сокольники», лесопарк Сокольники. Масштабные отрезки: B–F — 0,5 мм; A, D — 0,2 мм.

The small number of thermophilic species in the studied material may be related to the predominance of samples taken in the autumn period. In particular, our results underestimated the diversity of the genus *Moina*. Species of this genus are predominantly thermophilic cladocerans inhabiting eutrophic water bodies [Smirnov, 1976]. For example, *Moina micrura* Kurz, 1875 is one of the common species in the eutrophic water bodies of the middle zone of the European part of Russia. Thus, thermophilic cladocerans in the water bodies of Moscow need further research.

Cluster 1, containing many species with different modes of life and taxonomic position, is present in many water bodies. Its existence is a sign of a significant similarity between the species composition of most studied samples, independently of the water body type and size. Such uniformity seems to be a sign of any urban territories [Pickett *et al*., 2001; Vilisics, Hornung, 2009]. At $p = 0.01$, *Ceriodaphnia dubia*, *Daphnia longispina*, *D. pulex*, *Disparalona rostrata*, *Moina macrocopa* from clusters 2, 3, 4 are added to cluster 1. It happens due to the low strength of connectivity between these taxa within the original clusters at $p = 0.05$. Despite the change in the cluster 1 composition from $p = 0.05$ to $p = 0.01$, it is a unified cluster, as evidenced by the fact that the number of links within each "provisionary sub-cluster" that the program identifies (black lines) differs significantly from the number of links between "provisionary sub-clusters" (red lines). Unlike cluster 2, that connected with cluster 1 by two links, but through a sole taxon. That is, links in cluster 2 have a single input. The links within "provisionary sub-clusters" are reconstructed by an algorithm with lower reliability, and the correspondence of sub-clusters at $p = 0.001$ and 0.05 is not unambiguous, so their color does not matter. On the contrary, in the case of clusters 2 and 3, the colors emphasize the clear homology of these clusters, although cluster 3 has split into two separate clusters at $p = 0.01$.

Chydorid cluster 2 at $p = 0.01$, according to Fryer's [1993] terminology with three species in its core (*Alona guttata*, *Alonella exigua*, *Acroperus harpae*), occurred in the macrophyte thickets of relatively large ponds. Apparently, this local association was confined to water bodies that can be characterized as mesotrophic, with moderate anthropogenic pressure. At $p = 0.01$ *Disparalona rostrata* moves from this cluster to cluster 1 due to the low level of connectivity between *D. rostrata* and *A. guttata*, *A. exigua*, *A. harpae*. In fact, *D. rostrata* is characterized for the open littoral zone, while *A. guttata*, *A. exigua*, *A. harpae* inhabit macrophyte thickets.

In our analysis at p = 0.05, two daphniid-dominated clusters were revealed according to Fryer's [1993] terminology; cluster 3 was separated into two cores at p = 0.01: 3a with *Daphnia curvirostris* and *Ceriodaphnia laticaudata*, and 3b with *Daphnia magna* and *Ceriodaphnia quadrangula*. All these species occur in shallow, lentic water bodies, mainly ponds experiencing high eutrophication and visible littering. These local faunistic associations are characteristic only of the hypereutrophic ponds located in the territory of the Moscow Zoo (Small and Big ponds, Gibbon Pond, Pelican Pond), Upper and Lower Biryulevsky Ponds, Gertsensky Pond, Upper Saltykovsky Pond, Leonovsky Pond, 5th Vorontsovsky Pond, as well as unnamed ponds in Troparevsky Forest Park, Losiniy Ostrov, Bittsevsky Forest Park, respectively. Note that our data corresponded well to observationsby previous authors. For example, Gerasimova & Pogozhev [2002] mentioned earlier *Ceriodaphnia quadrangula* and *Daphnia magna* in hypereutrophic Chistye Prudy Pond.

Remarkably, the daphniid-dominated cluster, similar to our cluster 3, was previously revealed in the urban eutrophic ponds of the City of Yakutsk, located at a distance of ca. 5000 km east from Moscow. The daphniid-dominated association in Yakutsk ponds contains *D. magna*, *D. curvirostris*, *D. longispina*, *Simocephalus exspinosus*, *Ceriodaphnia dubia* and *Pleuroxus aduncus*. It is characteristic of shallow ponds with an almost completely absent zone of macrophytes; in natural conditions such situation is rare in the forest zone, but more characteristic of the "steppe" type pools and the Arid belt located far south of Yakutsk [Andreeva *et al*., 2023] and Moscow. At least, all three species of *Daphnia* are identical in two urban regions. Here we confirmed the idea that the daphniid-dominated association containing *D. magna*, *D. curvirostris* and *D. longispina* could be regarded as characteristic of hypereutrophic urban ponds in cities of the forest zone.

Supplementary data. The following Excel-tables are available online.

Supplementary Table 1. The studied water bodies names and their code used in the analysis.

Supplementary Table 2. Distribution of cladocerans in the studied water bodies (1–species was present in the sample; 0–species was absent in the sample). See the water bodies codes in the Supplementary Table 1.

Compliance with ethical standards

CONFLICT OF INTEREST: The authors declare that they have no conflict of interest.

Ethical approval: No ethical issues were raised during our research.

Acknowledgements. Many thanks to R.J. Shiel for linguistic comments on earlier draft. Our research was supported by the Russian Science Foundation (grant no. 23-14-00128). SEM investigations were carried out at the Joint Usage Center "Instrumental methods in ecology" at the A.N. Severtsov Institute of Ecology and Evolution of Russian Academy of Sciences.

References

Andreeva L.V., Seleznev D.G., Garibian P.G., Kotov A.A. 2023. [Local faunistic association of water fleas (Crustacea: Cladocera) in the water bodies of left bank of the Lena River (Yakutia, Russia)] // Biologiya vnutrennikh vod. Vol.16. No.5. P.793–804 [in Russian].

Aksenova M.D., Krolenko I.I., Kotov A.A, 2023. Cladocera (Crustacea: Branchiopoda) in lowlands of the Ciscaucasian Region, European Russia // Arthropoda Selecta. Vol.32. No.4. P.365–378. https://doi.org/10.15298/arthsel.32.4.01

Bubunets S.O., Zhigin A.V., Bubunets E.V. 2018. [Biological characterization of small reservoirs located in park zones of Moscow] // Vestnik AGTU, Ser. Rybnoe hozyaistvo. No.1. P.14–26 [in Russian].

Colwell R.K., Elsensohn J.E. 2014. EstimateS turns 20: Statistical estimation of species richness and shared species from samples, with non-parametric extrapolation // Ecography. Vol.37. P.609–613.

Evgrafov A.V., Kosov N.S., Tsvetkova A.V. 2023. [Effect on environmental conditions on the composition of zooplankton in the middle stream of the Likhoborka River] // Timiryazevskiy biologicheskiy zhurnal. Vol.1. P.73–79 [in Russian].

Frolova V.D. 2015. [Planktonic crustaceans of the pond in the park "Rodnichok Nadezhdy" of Samara City] // Vestnik molodykh uchenykh i specialistov Samarskogo universiteta. Vol.1. No.6. P.26–33 [in Russian].

Fryer G. 1968. Evolution and adaptive radiation in the Chydoridae (Crustacea: Cladocera): a study in comparative functional morphology and ecology // Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences. Vol.254. P.221–385.

Fryer G. 1974. Evolution and adaptive radiation in the Macrothricidae (Crustacea, Cladocera): a study in comparative functional morphology and ecology // Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences. Vol.269. P.137–274.

Fryer G. 1993. The freshwater Crustacea of Yorkshire. A faunistic and ecological survey. UK: Yorkshire Naturalists' Union and Leeds Philosophical and Literary Society. 312 pp.

Gal'tsov P.S. 1914. [Study of Kosino Lakes] // Dnevnik Zoologicheskogo Otdeleniya Imperatorskogo Obschestva Liubiteley Estestvozhaniya, Antropologii i Etnografii. Vol.12. P.1–107 [in Russian].

Garibian P.G., Aksenova M.D. 2023. *Ovalona cambouei* (Guerne et Richard, 1893) (Cladocera: Anomopoda: Aloninae): the first record for Russia // Invertebrate Zoology. Vol.20. No.4. P.411–416.

Gerasimova T.N., Pogozhev P.I. 2002. Reduction of the trophic status of a water body with the use of large-size zooplankton // Water Resources. Vol.29. P.412–421.

Gerasimova T.N., Pogozhev P.I., Sadchikov A.P. 2019. [Zooplankton of Patriarshie and Chistye Prudy ponds (Moscow) Moscow Society of Naturalists]. Available from: https://viperson.ru/articles/zooplankton-patriarshih-i-chistyh-prudov-moskva?ysclid=lsbhea93gn634872831 (accessed 10 May 2024) [in Russian]

Gerasimova T.N., Pogozhev P.I., Sadchikov A.P. 2020. Changes in Zooplankton Structure in an Experimental System at the Isolation of Plankton-Eating Fish // Russian Journal of General Chemistry. Vol.90. P.2681–2686.

Korovchinsky N.M. 2004. [The Cladocera order Ctenopoda of the world (morphology, systematics, ecology, zoogeography)]. Moscow: KMK Sci. Press. 410 p. [In Russian]

Korovchinsky N.M. 2020. Description of a new species in the genus *Bythotrephes* Leydig, 1860 (Crustacea: Cladocera: Onychopoda), supplements to selected species, and concluding remarks on the genus // Zootaxa. Vol.4789. No.2. P.441–465.

Korovchinsky N.M., Kotov A.A., Boikova O.S., Smirnov N.N. 2021a. [The water fleas (Crustacea: Cladocera) of Northern Eurasia. Vol.1. General Part]. Moscow: KMK Sci. Press. 481 p. [In Russian]

Korovchinsky N.M., Kotov A.A., Sinev A.Yu., Neretina A.N., Garibian P.G. 2021b. [The water fleas (Crustacea: Cladocera) of Northern Eurasia. Vol.2. Taxonomic Part]. Moscow: KMK Sci. Press. 544 p. [In Russian]

Kotov A.A. 2006. [Adaptations of Anomopoda crustaceans (Cladocera) to the benthic mode of life] // Zoologicheskiy Zhurnal. Vol.85. No.9.

P.1043–1059 [in Russian]
Kotov A.A. 2013. [Morphology and phylogeny of Anomopoda (Crustacea: Cladocera)]. Moscow: KMK Sci. Press. 638 p. [In Russian]
Kotov A.A. 2016. [Faunistic complexes of the Cladocera (Crustacea, Branchiopoda) of Eastern Siberia and Far East of Russia] // Zoologicheskiy Zhurnal. Vol.95. No.7. P.748–768 [in Russian].
Kotov A.A., Forró L., Korovchinsky N.M., Petrusek A. 2013. World checklist of freshwater Cladocera species. World Wide Web electronic publication. Available from: http://fada.biodiversity.be/group/show/17 (accessed 30 May 2024)
Kotov A.A., Korovchinsky N.M., Sinev A.Yu., Smirnov N.N. 2011. Cladocera (Crustacea, Branchiopoda) of the Zeya basin (Amurskaya Area, Russian Federation). 3. Systematic-faunistic and zoogeographic analysis // Zoologichesky Zhurnal. Vol.90. P.402–411.
Kotov A.A., Sinev A.Yu. 2011. Cladocera (Crustacea, Branchiopoda) of the Zeya basin (Amurskaya Area, Russian Federation). 2. Descriptions of new taxa // Zoologichesky Zhurnal. Vol.90. P.272–284.
Kotov A.A., Seleznev D.G., Garibian P.G., Korovchinsky N.M., Neretina A.N., Sinev A.Yu., Jeong H.-J., Yand H.-M., Lee W. 2022. History of colonization of Jeju Island (Republic of Korea) by the water fleas (Crustacea: Cladocera) is reflected by the seasonal changes in their fauna and species associations // Water. Vol.14. Art.3394.
Laforsch C., Tollrian R. 2000. A new preparation technique of daphnids for scanning electron microscopy using hexamethyldisilazane // Archiv fuer Hydrobiologie. Vol.149. P.587–596.
Lukashina L.S., Gaponenko A.V., Rozanov V.B., 2016. [The study of freshwater zooplankton of three Kosino lakes] // Servetnik G.E. et al. (eds.). Integrirovanniye tekhnologii akvakul'tury v fermeskikh khoziaystvakh. Trudy Mezhdunarodnoy naunchno-prakticheskoy konferentsii, Moskva, 9 dekabrya 2016. Moscow: Pero. P.75–79 [in Russian].
Matile P. 1890. Die Cladocera der Umgegend von Moscou // Bulletin de la Société Impériale des naturalistes de Moscou. Vol.1 (for 1890). S.1–67.
Matveev V.F. 1986. History of the community of planktonic Cladocera in Lake Glubokoe (Moscow Region) // Hydrobiologia. Vol.141. P.145–152.
Pawlikiewicz P., Jurasz W. 2017. Ecological drivers of cladoceran diversity in the central European city (Łódź, Poland): effects of urbanisation and size of the water body // Annales Zoologici Fennici. Vol.54. No.5–6. P.315–333.
Pickett S.T., Cadenasso M.L., Grove J.M., Nilon C.H., Pouyat R.V., Zipperer W.C., Costanza R. 2001. Urban ecological systems: linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas // Annual Review of Ecology and Systematics. Vol.32. No.1. P.127–157.
Pogozhev P.I., Gerasimova T.N. 2005. The role of filtering zooplankton in de-eutrophication of water bodies // Water Resources. Vol.32. P.337–345.
Poggenpohl M. 1874. [A list of copepods, cladocerans and ostracods of Moscow and its nearest vicinities] // Trudy Imperatorskogo Obschestva Liubiteley Estestvozhaniya, Antropologii i Etnografii. Vol.10. No.2. P. 69–77 [in Russian].
Prokin A.A., Seleznev D.G., Tsvetkov A.I. 2021. Influence of environmental factors on the interannual variability of macrozoobenthos of the floodplain lakes // Ecosystem Transformation. Vol.4. No.2. P.3–15.
Shirokova V.A., Ozerova N.A. 2019. [Kosino lakes as a cradle of Russian limnology: the history of the Kosino Biological Station Nature Reserve] // Voprosy istorii estestvoznaniia i tekhniki. Vol.40. No.2. P.233–253 [in Russian].
Smirnov N.N. 1976. [Macrothricidae and Moinidae of the World fauna] // Fauna SSSR, novaya seriya. Rakoobraznye. Vol.1. No.3. 237 p. [In Russian]
Smirnov N.N. 2010. [Historical biocenology of freshwater zoocenoses]. Moscow: KMK Sci. Press. 225 p. [In Russian]
Smirnov N.N. 2017. Physiology of the Cladocera. 2nd Edition. London etc.: Academic Press. 418 p.
Sukop I. 2008. Zooplankton Zámeckého rybníku // Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. Vol.56. No.1. P.189–199.
Sukop I. 2014a. Aquatic invertebrate of mikulovské rybníky ponds // Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. Vol. 55. No.2. P.77–84.
Sukop I. 2014b. Zooplankton and zoobenthos of the ponds in the Žďár region // Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. Vol.55. No.5. P.171–180.
Vilisics F., Hornung E. 2009. Urban areas as hot-spots for introduced and shelters for native isopod species // Urban Ecosystems. Vol.12. P. 333–345.
Zuykova E.I., Simonov E.P., Bochkarev N.A., Taylor D.J., Kotov A.A. 2018. Resolution of the *Daphnia umbra* problem (Crustacea: Cladocera) using an integrated taxonomic approach // Zoological Journal of the Linnean Society. Vo.184. No.4. P.969–998.

Responsible editor K.G. Mikhailov