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Desmid algae (Charophyta: Conjugatophyceae) of Ekaterinburg, Middle Urals, Russia

Andrei S. Shakhmatov[1*], Evgeniy V. Pavlovskiy[1,2] & Alexander G. Paukov[1]

[1]Ural Federal University, Institute of Natural Sciences and Mathematics, Kuybysheva Street 48, 620000 Ekaterinburg, Russia. *E-mail: shahmatov1992@mail.ru

[2]Institute of Plant and Animal Ecology, Ural Division, Russian Academy of Sciences, 8 Marta Street 202/3, 620144 Ekaterinburg, Russia

Abstract: Species composition of desmid algae and their habitat preferences in water bodies of Ekaterinburg city were studied during the 2013–2017. Thirty-seven species and subspecific taxa which belong to 12 genera and 2 families were identified, of which 17 species are new for the eastern macroslope of the Middle Urals. Canonical correspondence analysis, which was performed to reveal habitat preferences, demonstrates that the majority of analyzed species prefer quarry lakes, ponds and overgrown lake shores, contrary to fens and rivers.

Keywords: Middle Urals, biodiversity, new findings, Desmidiales

INTRODUCTION

Ekaterinburg city is one of the most prominent industrial centers in the Urals that possesses extensive hydrographic network with numerous rivers, lakes, ponds, swamps and fens, where, considering the industrial impact in the studied region, a wide spectrum of environmental conditions has been created, providing a variety of habitats for algae. The territory attracted albeit little attention of algologists and there is a lack of available literature information on algal biodiversity in the region (Butakova & Stanislavskaya, 2004). The purpose of this work is to provide the results of the long-term biodiversity study of desmid algae and to analyze their habitat preferences.

MATERIAL AND METHODS

The city of Ekaterinburg is located on the eastern macroslope of the Middle Urals in the southern taiga subzone of the boreal forest zone (Fig. 1), which is characterized by a continental climate with clearly expressed cold and warm periods (average temperature -16°C in January and +18°C in July), and predominance of pine forests in the vegetation (Kulikov et al., 2013).

The samples were collected during the 2013–2017 by using 40 μm mesh-size planktonic net in 22 different-type water bodies, of which 16 are located in an urban area and 9 are in the suburban zone (Table 1). The majority of studied water bodies are exposed to a heavy metal emission, a man-made eutrophication process and a recreational load (Seleznev & Yarmoshenko, 2014).

The collected material was studied in the laboratory using Levenhuk 320, Micros MC-50, Biomed-5 light microscopes and Levenhuk C310 NG, ToupCam U3CMOS18000KPA digital cameras. Cell measurements were made using ToupView v.3.7.1047 and Digimizer v.4.6.1. Species identification was performed using special literature (Kosinskaya, 1960; Palamar-Mordvintseva, 1982; Coesel & Meesters, 2007, 2013). Validity of taxa was verified with Algaebase (Guiry & Guiry, 2018). The establishment of the habitat preferences was performed using Canoco 5.0 for Windows (ter Braak & Šmilauer, 2012).

LIST OF SPECIES

The annotated list contains 37 species and subspecific taxa, followed by the finding localities (Loc.), cell measurements (Dim.), and frequency of occurrence (s – single finding, r – rare, c – common, a – abundant, m – mass occurrence). Illustrations are given for every mentioned species. The taxa which are marked by an asterisk (*) are new to the eastern macroslope of the Middle Urals.

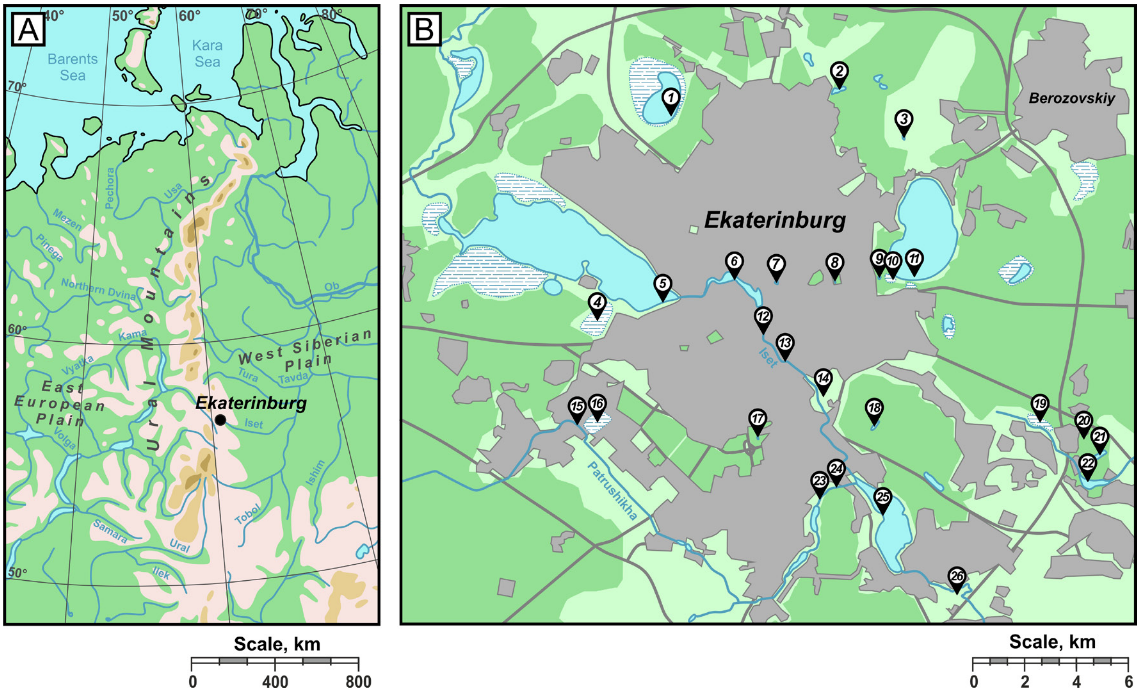

Fig. 1. Location of Ekaterinburg in the Ural Mountains (A) and sampling sites on its territory (B).

Table 1. Characteristics of the sampling sites. The numbering of a site corresponds to the Figure 1, B. Used abbreviations: Lk – lakes, Fn – fens, Ql – quarry lakes, Pd – ponds, Rv – rivers.

No	Coordinates	Water body type	Description
1	56.903689°N 60.550000°E	Fn	Shuvakish lake. Large natural lake-type water body, undergoing the last stages of transformation into a fen.
2	56.913213°N 60.655570°E	Ql	Kalinovka pond. Artificial pond with clean sandy banks in the mined-out quarry.
3	56.896776°N 60.695343°E	Ql	Kalinovskiye Razrezy pond. Artificial pond with a pinewood along the banks, located on the mined-out gold quarry.
4	56.835418°N 60.511745°E	Fn	Nameless meliorated fen on a bank of the Verkh-Isetskiy pond .
5	56.858773°N 60.479504°E	Rv	Verkh-Isetskiy pond. Large artificial water body on the Iset river.
6	56.847187°N 60.589237°E	Rv	Central city pond. Artificial water body on the Iset river.
7	56.846750°N 60.613881°E	Pd	Nameless artificial pond in the center of Rastorguyev-Kharitonov mansion park with clean banks and sedge clumps in the water.
8	56.847218°N 60.649955°E	Pd	Nameless artificial pond in the Ekaterinburg Dendrological park.
9	56.848604°N 60.678205°E	Pd	Stariye Karasiki pond. Small water body with sedge hummocks along the banks.
10	56.849586°N 60.683843°E	Ql	Karasiki pond. Shallow artificial water body in an abandoned granite quarry.
11	56.848176°N 60.697736°E	Lk	Shartash lake. Large natural water body with banks partially covered by pine forests.

Table 1 (continued)

No	Coordinates	Water body type	Description
12	56.828166°N 60.605597°E	Rv	Iset river bank near Kuybisheva street.
13	56.820555°N 60.619748°E	Rv	Iset river bank near Belinskogo street.
14	56.808208°N 60.642415°E	Pd	Nameless pond in the “Mayakovsky Central Park”.
15	56.797907°N 60.492862°E	Rv	Patrushikha river in the Shirokaya Rechka district.
16	56.799464°N 60.508968°E	Fn	Nameless meliorated fen on the Patrushikha river bank.
17	56.797499°N 60.603020°E	Pd	Nameless pond in the Russian Academy of sciences (RAS) botanical garden.
18	56.798902°N 60.676659°E	Pd	Trekhozerka pond in the “Park lesovodov Rossii” Forest Park.
19	56.799993°N 60.776108°E	Fn	Nameless turfy fen in the Bukhara-Ural station area.
20	56.796158°N 60.807511°E	Pd	Nameless polluted pond inside the “Lastochka” gardening cooperative.
21	56.789788°N 60.817146°E	Pd	Nameless pond near Maliy Istok water reservoir.
22	56.778731°N 60.811339°E	Rv	Maliy Istok water reservoir located on the Istok river.
23	56.775016°N 60.639665°E	Pd	Patrushikhinskiy pond. Artificial water body on the Patrushikha river.
24	56.777978°N 60.647491°E	Rv	Patrushikha river near the confluence with Iset river.
25	56.766939°N 60.681233°E	Rv	Nizhne-Isetskiy water reservoir located on the Iset river.
26	56.740866°N 60.726048°E	Pd	Artificial pond left after an attempt of straightening of a canal of Iset river.

Family: Closteriaceae Bessey, 1907

Closterium acerosum Ehrenberg ex Ralfs, 1848 (Fig. 2, 1–2) – Loc.: 7a, 11r, 19c. Dim.: 471.5–502.8 µm length and 50.1–71.2 mm wide.

Closterium limneticum Lemmermann, 1899 (Fig. 2, 3–4) – Loc.: 2s, 13s, 16s. Dim.: 166.2–270.1 µm length and 6.9–10.3 µm wide.

Closterium moniliferum Ehrenberg ex Ralfs, 1848 (Fig. 2, 5) – Loc.: 4a, 6a, 8r, 15a, 19a. Dim.: 250.7–305.1 µm length and 33.8–52.6 µm wide.

Closterium parvulum Nägeli, 1849 (Fig. 2, 6) – Loc.: 4c, 9r, 10a. Dim.: 113.8–136.9 µm length and 10–16.8 µm wide.

Closterium turgidum Ehrenberg ex Ralfs, 1848 (Fig. 2, 7–8) – Loc.: 9c, 10c. Dim.: 574.6–624.3 µm length and 51.9–52.2 µm wide.

Closterium venus Kützing ex Ralfs, 1848 (Fig. 2, 9) – Loc.: 10s. Dim.: 88.8–99.2 µm length and 10.6–11.5 µm wide.

Family: Desmidiaceae Ralfs, 1848

Cosmarium contractum O.Kirchner, 1878 (Fig. 3, 10) – Loc.: 13c. Dim.: 21.8–28.4 µm length and 17.3–20.4 µm wide. Isthmus 6.6–8.2 µm wide.

Cosmarium depressum (Nägeli) P.Lundell, 1871 (Fig. 3, 11) – Loc.: 10c. Dim.: 36,9–41,9 µm length and 36,9–44,4 µm wide. Isthmus 10.3–11.6 µm wide.

*Cosmarium fontigenum Nordstedt, 1878 (Fig. 3, 12) – Loc.: 10s. Dim.: 25.9 µm length and 26.6 µm wide. Isthmus 8.4 µm wide.

Fig. 2. 1–2 – *Closterium acerosum*, 3–4 – *Closterium limneticum*, 5 – *Closterium moniliferum*, 6 – *Closterium parvulum*, 7–8 – *Closterium turgidum*, 9 – *Closterium venus*.

Cosmarium formosulum Hoff, 1888 (Fig. 3, 13) – Loc.: 10c. Dim.: 54.7–67.9 µm length and 52.6–55.9 µm wide. Isthmus 16.5–19.4 µm wide.

Cosmarium granatum Brébisson ex Ralfs, 1848 (Fig. 3, 14) – Loc.: 2s. Dim.: 42.8 µm length and 29.3 µm wide. Isthmus 11.1 µm wide.

*Cosmarium impressulum Elfving, 1881 (Fig. 1, 15) – Loc.: 7c, 9s, 17r. Dim.: 27.7–29.1 µm length and 19.1–21.7 µm wide. Isthmus 6.7–7.1 µm wide.

*Cosmarium pachydermum P.Lundell, 1871 (Fig. 3, 16) – Loc.: 4c, 21c. Dim.: 71.4–79.6 µm length and 67.5–73.2 µm wide. Isthmus 36–44.9 µm wide.

*Cosmarium regnellii Wille, 1884 (Fig. 3, 17) – Loc.: 10c, 11r. Dim.: 14.6–15.6 µm length and 12.8–14.7 µm wide. Isthmus 5.2–5.8 µm wide.

Cosmarium subprotumidum var. septentrionale (Croasdale) Coesel, 1989 (Fig. 3, 18) – Loc.: 7r, 10r, 11r. Dim.: 24.1–29.8 µm length and 21.7–26.9 µm wide. Isthmus 8.8–9.3 µm wide.

*Desmidium aptogonum Brébisson ex Kützing, 1849 (Fig. 3, 19) – Loc.: 10r, 11s. Dim.: 16.8–17.6 µm length and 31.7–31.9 µm wide. Isthmus 25.8–26.1 µm wide.

*Euastrum coeselii Kouwets, 1987 (Fig. 3, 20) – Loc.: 10s. Dim.: 18.2 µm length and 15.1 µm wide. Isthmus 5.4 µm wide.

Euastrum pulchellum Brébisson, 1856 (Fig. 3, 21) – Loc.: 10c, 11s. Dim.: 24.3–28.8 µm length and 19–22.8 µm wide. Isthmus 7.4–7.9 µm wide.

Hyalotheca dissiliens Brébisson ex Ralfs, 1848 (Fig. 3, 22) – Loc.: 9r, 10c. Dim.: 27.8–30.1 µm length and 13.3–18.3 µm wide.

Micrasterias crux-melitensis (Ehrenberg) Trevisan, 1842 (Fig. 3, 23) – Loc.: 9r, 10r. Dim.: 119.4–125.3 µm length and 113.1–121.3 µm wide. Isthmus 16.6–21.1 µm wide.

*Onychonema filiforme (Ralfs) J.Roy et Bisset, 1886 (Fig. 3, 24) – Loc.: 9s. Dim.: 14.7–14.9 µm length and 16.4–17.6 µm wide. Isthmus 4.9–5.2 µm wide.

Pleurotaenium trabecula Nägeli, 1849 (Fig. 4, 25) – Loc.: 9c, 10c, 21r. Dim.: 451.6–612.5 µm length and 31.1–42.5 µm wide. Isthmus 3.5–3.7 µm wide.

*Staurastrum acutum Brébisson, 1856 (Fig. 4, 26) – Loc.: 10s. Dim.: 41.4 µm length and 41.5 µm wide. Isthmus 19.2 µm wide.

Staurastrum avicula Brébisson, 1848 (Fig. 4, 27) – Loc.: 13s. Dim.: 28.9 µm length and 24.6 µm wide without spines (with spines 29.7 µm length and 36.1 µm wide). Isthmus 9.2 µm wide.

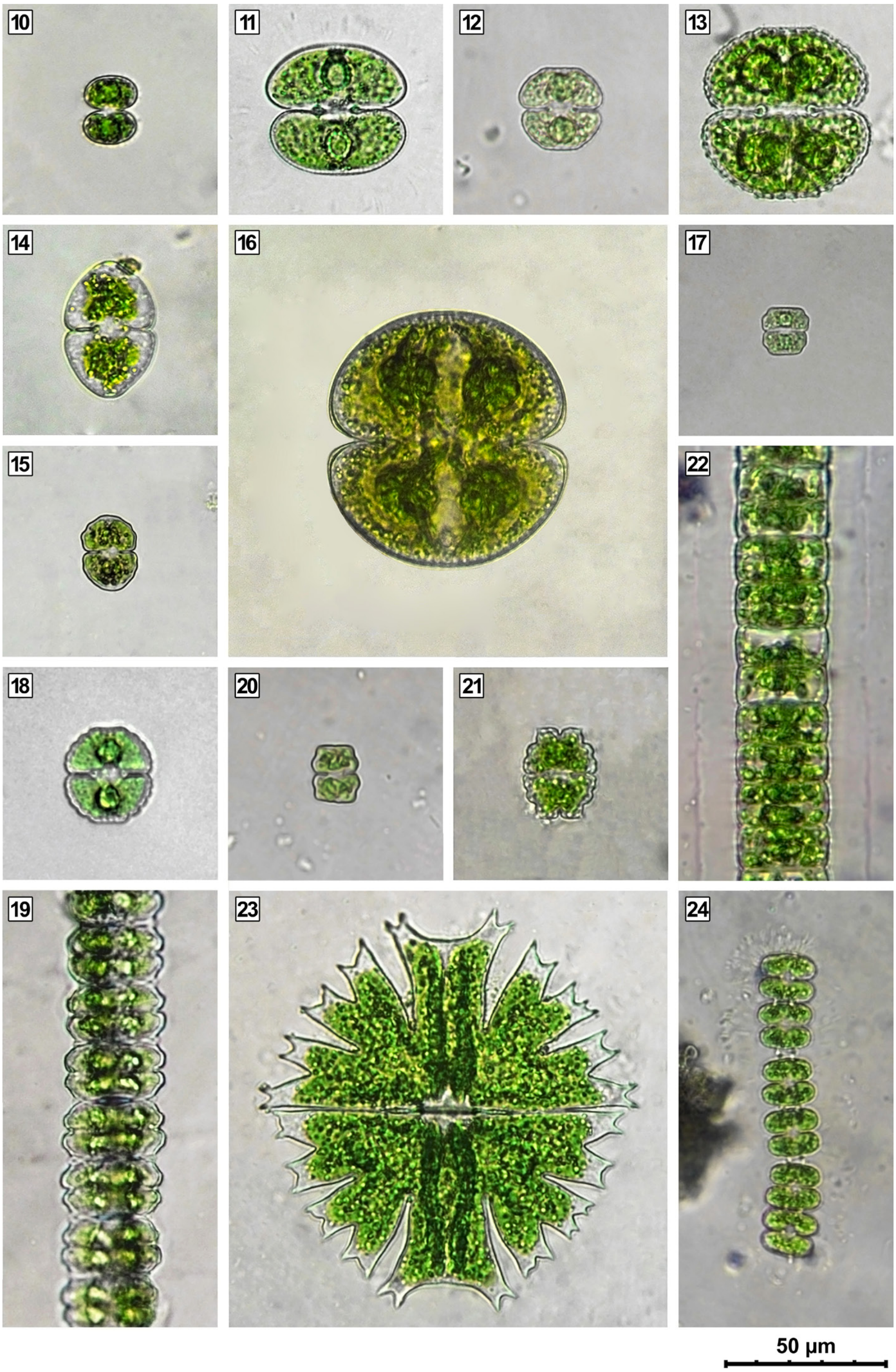

Fig. 3. 10 – *Cosmarium contractum*, 11 – *Cosmarium depressum*, 12 – *Cosmarium fontigenum*, 13 – *Cosmarium formosulum*, 14 – *Cosmarium granatum*, 15 – *Cosmarium impressulum*, 16 – *Cosmarium pachydermum*, 17 – *Cosmarium regnellii*, 18 – *Cosmarium subprotumidum* var. *septentrionale*, 19 – *Desmidium aptogonum*, 20 – *Euastrum coeselii*, 21 – *Euastrum pulchellum*, 22 – *Hyalotheca dissiliens*, 23 – *Micrasterias crux-melitensis*, 24 – *Onychonema filiforme*.

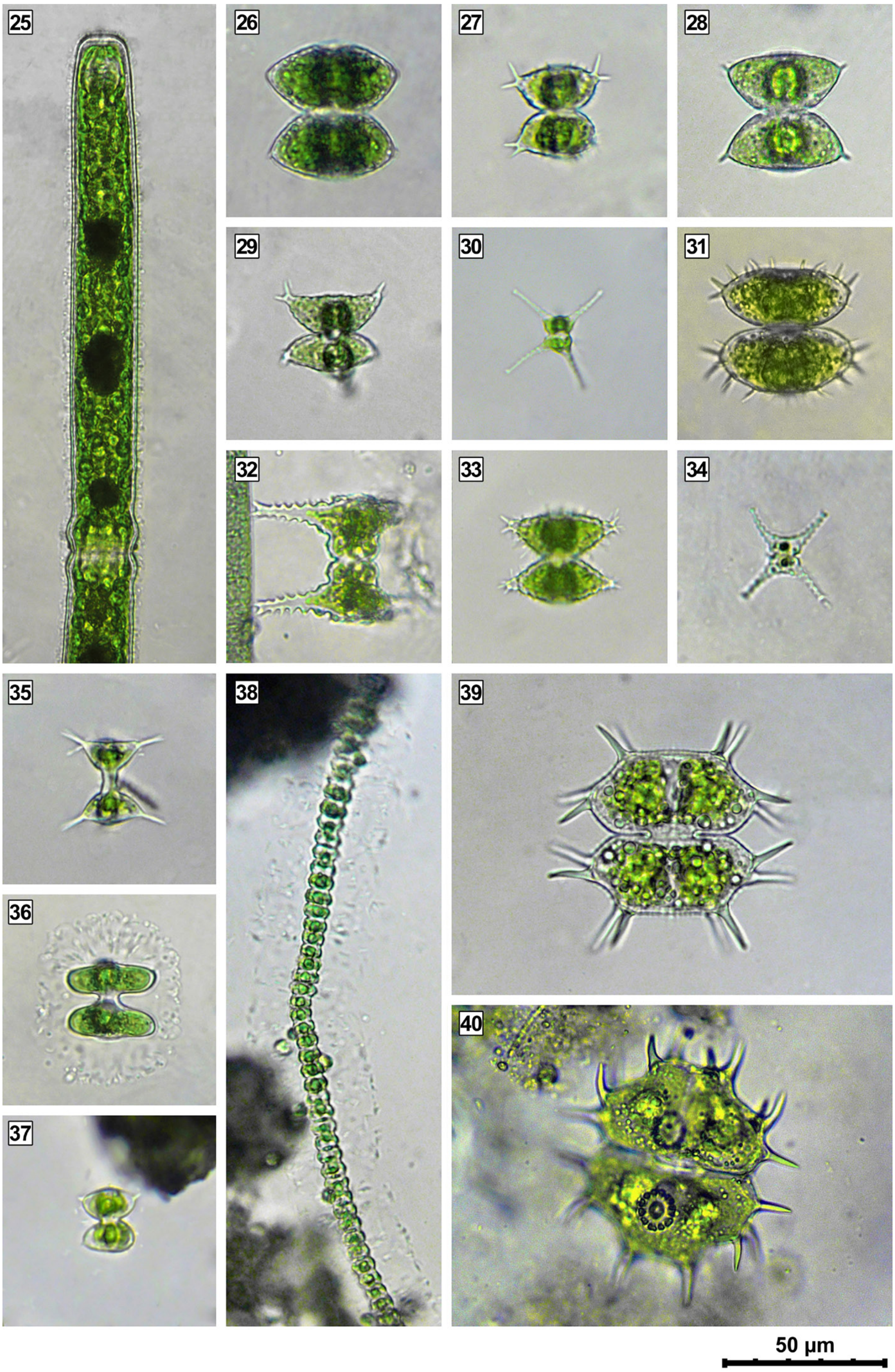

Fig. 4. 25 – *Pleurotaenium trabecula*, 26 – *Staurastrum acutum*, 27 – *Staurastrum avicula*, 28 – *Staurastrum avicula* var. *lunatum*, 29 – *Staurastrum avicula* var. *subarcuatum*, 30 – *Staurastrum chaetoceras*, 31 – *Staurastrum gladiosum*, 32 – *Staurastrum manfeldtii*, 33 – *Staurastrum polymorphum*, 34 – *Staurastrum tetracerum*, 35 – *Staurodesmus cuspidatus*, 36 – *Staurodesmus dejectus* var. *apiculatus*, 37 – *Staurodesmus patens*, 38 – *Teilingia excavata*, 39 – *Xanthidium antilopaeum*, 40 – *Xanthidium uncinatum*.

*Staurastrum avicula var. lunatum (Ralfs) Coesel et Meesters, 2013 (Fig. 4, 28) – Loc.: 10r. Dim.: 36.1–38.8 µm length and 33.8–35.1 µm wide without spines (with spines 40–41.9 µm wide). Isthmus 13.1–13.6 µm wide.

*Staurastrum avicula var. subarcuatum (Wolle) West et G.S.West 1894 (Fig. 4, 29) – Loc.: 10s. Dim.: 23.3 µm length and 29.9 µm wide without processes. Isthmus 9.9 µm wide.

*Staurastrum chaetoceras (Schröder) G.M.Smith, 1924 (Fig. 4, 30) – Loc.: 5r, 11a, 13r. Dim.: 12.9 µm–21.6 length and 10.1 –13.7 µm wide without processes (with processes 27.5–39.3 µm length and 38.4–48.3 µm wide). Isthmus 6.9–8.3 µm wide.

*Staurastrum gladiosum W.B.Turner, 1885 (Fig. 4, 31) – Loc.: 21s. Dim.: 38.8 µm length and 41.5 µm wide without spines (with spines 43.2 µm length and 50.1 µm wide). Isthmus 15.5 µm wide.

Staurastrum manfeldtii Delponte, 1878 (Fig. 4, 32) – Loc.: 7r, 9c, 11r. Dim.: 39.2–52.4 µm length and 24,9–26.4 µm wide without processes (with processes 63.1–70.1 µm wide). Isthmus 10.3–13.6 µm wide.

Staurastrum polymorphum Brébisson, 1848 (Fig. 4, 33) – Loc.: 13r. Dim.: 26.1–27.3 µm length and 32.2–32.5 µm wide. Isthmus 9.8–10.1 µm wide.

*Staurastrum tetracerum Ralfs ex Ralfs, 1848 (Fig. 4, 34) – Loc.: 9r. Dim.: 12 µm length and 12.1 µm wide without processes (with processes 29.3 µm length and 27.5 µm wide). Isthmus 6.1 µm wide.

Staurodesmus cuspidatus (Brébisson) Teiling, 1967 (Fig. 4, 35) – Loc.: 13r. Dim.: 25.3–26.3 µm length and 18.9–19.1 µm wide without spines (with spines 26.9–29.7 µm length and 32.9–33.3 µm wide). Isthmus 4.5–5.5 µm wide.

*Staurodesmus dejectus var. apiculatus (Brébisson) Croasdale, 1957 (Fig. 4, 36) – Loc.: 9c, 21r. Dim.: 20.3–23.9 µm length and 22.7–27.7 µm wide. Isthmus 5.6–6 µm wide.

*Staurodesmus patens (Nordstedt) Croasdale, 1957 (Fig. 4, 37) – Loc.: 13s. Dim.: 20.4 µm length and 16.4 µm wide without spines (with spines 20.3 µm wide). Isthmus 6.6 µm wide.

*Teilingia excavata (Ralfs ex Ralfs) Bourrelly, 1964 (Fig. 4, 38) – Loc.: 10s. Dim.: 7.8–9.8 µm length and 6.8–8.8 µm wide. Isthmus 5.2–5.4 µm wide.

Xanthidium antilopaeum Kützing, 1849 (Fig. 4, 39) – Loc.: 10c. Dim.: 50.9–52.5 µm length and 51.4–53.8 µm wide without spines (with spines 65.9–70.6 µm length and 70.9–75.2 µm wide). Isthmus 14.9–17 µm wide.

Xanthidium uncinatum (Ralfs) Stastny, Skaloud et Neustupa, 2013 (Fig. 4, 40) – Loc.: 10c. Dim.: 61.4–64.3 µm length and 55.5–61.1 µm wide without spines (with spines 82.1–85.4 µm length and 77–83.1 µm wide). Isthmus 16.9–19.7 µm wide.

DISCUSSION

Thirty-seven species and infraspecific taxa which belong to 12 genera and 2 families were identified. The majority of species belong to genera *Cosmarium* (24.3%), *Staurastrum* (24.3%) and *Closterium* (16.2%), whereas others constitute 35% of the total species diversity.

Despite the relative poverty of the species composition, 17 species identified are new to the eastern macroslope of the Middle Urals. Nevertheless, this fact rather points to gaps in the knowledge of the studied area, given that most of the studied species are common in other areas of the Ural ridge (Briškaitė et al., 2016; Snitko & Sergeeva, 2003; Patova & Demina, 2008; Sterlyagova, 2008; Snitko, 2009; Voronikhin, 1930; Yarushina et al, 2004). However, particular attention deserves a finding of *Euastrum coeselii*, a rare species for the territory of Russia, which has been recorded only once in the Moscow region (Anissimova, 2015).

Canonical correspondence analysis, which based on species composition of water bodies as a dependent variable and types of water bodies as an explanatory variable, was performed to reveal habitat preferences of algal species as it has been previously made by Kaštovsky et al (2011). Ordination diagram (pseudo-F = 1.6, p = 0.01) (Fig. 5) demonstrates that the majority of species (89%) were associated with ponds and quarry lakes, i.e. typically mesotrophic water bodies with submerged aquatic vegetation, which agrees with the previous data (Kosinskaya, 1960; Coesel & Meesters, 2007). Small group of mesotrophic (*Staurastrum polymorphum*) and oligo-mesotrophic species (eg. *Cosmarium contractum*, *Staurodesmus cuspidatus*), however, were found in a phytoplankton of rivers, but

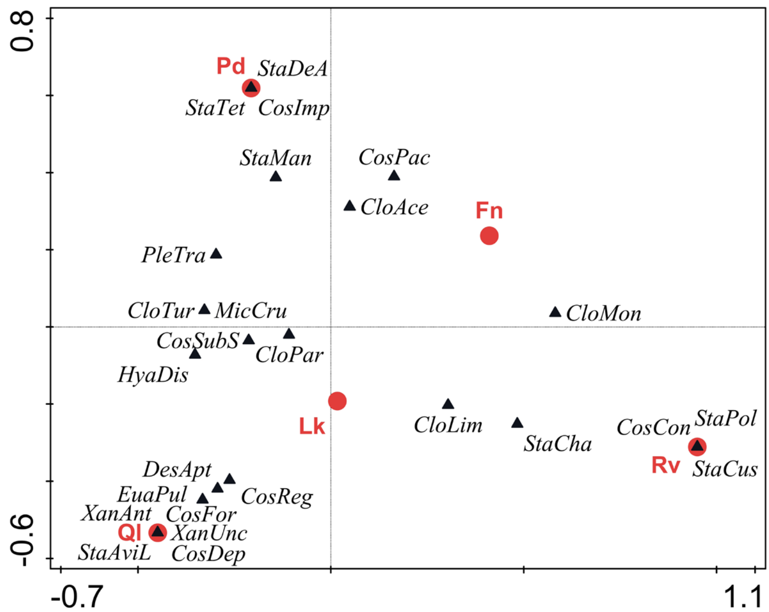

Fig. 5. CCA ordination plot showing the preferences of the most common desmid species to the water body type (Lk–lakes, Fn–fens, Ql–quarry lakes, Pd–ponds, Rv–rivers). Abbreviations of species names include the first three letters of a genus and a species names, and one letter of a variation name.

they could be overlooked because of their low abundance. On the contrary to them, eutrophic species (e.g. *Closterium acerosum, C. limneticum, Staurastrum chaetoceras*) that constitute together with the oligo-eutrophic *Staurastrum tetracerum* a minority (11%), do not show particular preferences, since they were found in all types of water bodies. This fact can be explained by a high local anthropogenic eutrophication.

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