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Desmid flora (Chlorophyta, Zygnematophyceae) of the river Tisa in the Province of Vojvodina (Northern Serbia)

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ABSTRACT Results of a detailed investigation into the qualitative composition of the desmid flora of the river Tisa, performed from April 2002 to May 2003, are presentet in this paper. A total of 33 desmid taxa belonging to genera *Closterium*, *Cosmarium* and *Staurastrum* were recorded from which 12 taxa are new to the Vojvodina stretch of the river Tisa, whereas *Cosmarium subcostatum* var *beckii* and *C. vexatum* var. *rotundatum* are new to the algal flora of Serbia. Qualitative dominance of desmid taxa, typical of alkaline and eutrophic ecosystems, was observed. The qualitative and partly relative quantitative composition of planktonic taxa were analysed dependent on the physico-chemical characteristics of the water. Basised on the presence of desmids, which are bioindicators, water quality was analyzed. Despite the inconvenient environmental conditions, special ecological remarks regarding partly unexpected presence of *Cosmarium subcostatum* and C. *subcostatum* var *beckii* as inhabitants of oligotrophic lakes and pools from a boreal part of Northwestern Europe were also recorded. An almost regular seasonal dynamics of the desmid community of the river Tisa was observed during one-year study.

Key words: Desmids, the river Tisa, Vojvodina, Serbia

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INTRODUCTION

The river Tisa (hung. Tisa) is the largest tributary of the river Danube, considering its total length (966 km) and the total basin area (157 220 km^2). It extends 164 km through the Province of Vojvodina (Northern Serbia) to its confluence into the Danube, near the Slankamen village. the river Tisa is a typical lowland river flowing through the Vojvodina with low velocity, high flow rate, seasonal variations of water level and numerous connections with irrigation/drainage canals (Ržaničanin 2004).

Due to geological base and human impact, the river Tisa water in Vojvodina is moderately alkaline, enriched with mineral salts and various organic, biodegradable compounds and with a high degree of total hardness (Rajković *et al.* 1995). Situated in a moderate continental climate and rich in natural resources, the Province of Vojvodina is an important agricultural and industrial region. Therefore, there are many pollutants in the river Tisa, because of which it is not a sutable site for the development of a rich desmid flora.

During the previous algological studies of the Serbian stretch of the river Tisa, desmids have been rarely found and frequently they have not been determined to the species level.

The occurrence of small number of the representatives of the desmids have been previously reported, but withouth illustrations and any descriptions of desmid taxa (Szabados 1966; Kalafatić *et al.* 1982; Kojčić *et al.* 1988; Đukić *et al.* 1994; Rajković *et al.* 1995;

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Pujin *et al.* 1999; Subakov 2001; Ržaničanin 2004; Ržaničanin *et al.* 2005). The present paper reports the results of a detailed one-year study of the desmid flora from the Serbian stretch of the river Tisa. In the present study, desmids of the river Tisa have been for the first time extensively researched and the many of them depicted and briefly annotated. Excepcitons are the taxa which were also recorded in the Danube (Stamenković & Cvijan 2008), and if the differences between the taxa from both rivers are not expressed.

MATHERIAL AND METHODS

A detailed investigation into the desmid community was carried out from April 2002 to May 2003. In all, 30 samples of water for the qualitative phytoplankton and physico-chemical analyses were collected from three localities along the river Tisa: Martonoš (1), Padej (2) and Titel (3) (Figure 1.).

Martonoš site is situated at 148 km of the river Tisa; 76.00 m height above sea level. Padej site is situated at 105.4 km of the river Tisa; 72.62 m height above sea level. Titel site is situated at 9.5 km of the river Tisa, downstream the confluence of the river Begej; 69.70 m height above sea level.

Phytoplankton samples were collected by towing a plankton net (mesh size 25 μm) through the open water. The taxonomical analysis of the sampled material was performed in the Institute of Botany and Botanical Garden „Jevremovac", Faculty of Biology, University of Belgrade. Material was studied using the Reichart Diastar™ microscope equipped with a Canon Power Shot S40 digital camera. The drawings of desmids were made with the aid of a drawing tube.

Physico-chemical analyses were performed in a laboratory of the Republic Hydrometeorologic Service of Serbia, Belgrade (RHMSS) and presented in its Annual Reports (RHMSS 2002, 2003).

The arithmetic weighted index of water quality, WQI (Scottish Development Department 1976), was calculated. Since that data on a number of fecal coliform bacteria for the investigated samples were not available, the calculated WQI values were corrected by the multiplication with 1/x; where x represents the sum of the observed parameter weightings. In this instance the WQI values were multiplied with 1/0.88.

In this paper the classification of the phylum Chlorophyta according to Brook and Johnson (2003) is accepted. A modification concerning the Peniaceae (Kouwets & Coesel 1984) is also taken into consideration. New taxa to the algal flora of Serbia are designated with two asterisks (**), new taxa only to the Vojvodina with one asterisk (*) and taxonomically doubtful taxa with a symbol (#). A relative abundance of desmids in the samples was estimated according to the following scale: very frequent, frequent, common, rare, very rare. Abbreviations: Ref. – references; Dim. – dimensions (in μm): L.-length of cell, Bc.-breadth of cell, Ba.- breadth of apex; L.:B.-ratio length of cell/breadth of cell, I-breadth of isthmus, Th.-thickness; P.r. – previous records; Loc. – locality along the Tisa; Com. – comment.

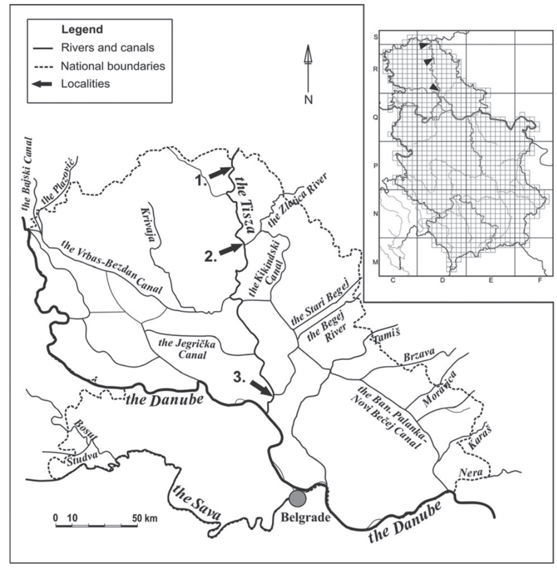

Figure 1. Map of the Province of Vojvodina (Northern Serbia) with the location of the investigated sites (1–3).

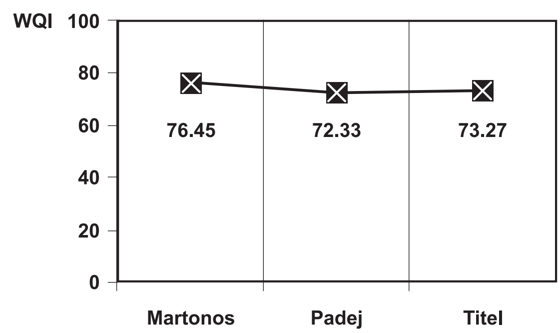

Fig. 2. Average WQI values for the investigated localities along the River Tisa.

RESULTS AND DISCUSSION

Physical and chemical analyses The results of detailed physico-chemical analyses are presented in Table 1.

The river Tisa water was slightly to moderately alkaline with relatively high values of total hardness. The unexpectedly high temperature values were recorded during summer months (29°C) and exceeded the maximum for the Vojvodina section of this river (RHMSS 2002, 2003).

High conductivity pointed to a moderately amount of mineral salts in water. HCO_3^-, was a dominant anion and Ca^{2+} dominant cation. The river Tisa water was characterized by relatively high concentrations of Cl^-, SO_4^-, Na^+ and K^+. It is noteworthy that the concentrations of Ca^{2+} and Mg^{2+} were slightly lower than those on investigated sites of the Danube (Stamenković & Cvijan 2008). Exceedingly high amounts of suspended solids, were recorded on Martonoš and Padej sites. According to the relatively high values of β-radioactivity measured, the river Tisa showed relatively high radioactivity degree.

High values of dissolved O_2 as well as relatively low BOD, COD and concentrations of nutrients pointed to a moderately amount of biodegradable compounds in the water. Relatively high concentrations of PO_4^{3-} and total phosphorus pointed to the intensive eutrophication. High NH_4^+ concentrations, recorded in almost all the investigated months, appeared as a consequence of the decomposition of fresh nitrogen-containing organic compounds in water. However, the concentrations of NO_3^- and NO_2^- were relatively low and balanced during the investigated months. The presence of free CO_2 and low O_2 saturation in Titel site pointed to the decomposition of organic compounds and, therefore, the process of the gradual organic pollution of the river Tisa along its flow through the Vojvodina.

According to the average WQI values, water quality of the river Tisa was designated as good in all the investigated localities (Figure 2). It slightly decreased along the flow of the river through the Province of Vojvodina. The average WQI values for the river Tisa localities were lower as compared to the average values along the river Danube (see: Stamenković 2006), pointing to a poorer water quality of this river in the Vojvodina. The concentrations of evaporable phenols gradually increased downstream the border site, up to 5 μg L^{-1} before the confluence into the Danube. During the previous studies of the river Tisa considerably high conductivity and total hardness have been recorded as well as periodically high concentrations of nitrate, Fe, Hg, Cd, Cu, Ni and Cr (Subakov 2001). The water quality improvement of the river Tisa was observed as the above-mentioned parameters were measured in relatively small values during this study.

In general, the river Tisa, do not provide favorable physico-chemical conditions for the development of a rich desmid flora.

Table 1. Physico-chemical characteristics of the River Tisa water.

Locality	1. Martonoš	2. Padej	3. Titel
Period of sampling	22.05.02 – 16.04.03	13.06.02 – 10.04.03	13.05.02 – 03.04.03
Parameters	Ranges of the parameter values		
T (°C)	0.6 - 29.4	8.4 - 22.8	5.4 - 27.6
pH	7.4 - 8.3	7.5 - 8.2	7.4 - 7.9
Conductivity (μS cm^{-1})	340 - 486	326 - 383	269 - 537
Free CO_2(mg l^{-1})	0 - 3.2	0 - 3.0	1.4 - 5.6
CO_3^{2-} (mg l^{-1})	0 - 3.6	0	0
HCO_3^- (mg l^{-1})	140 - 159	135 - 140	186 - 205
Total hardness (mg l^{-1})	141 - 195	135 - 151	119 - 189
Dissolved O_2 (mg l^{-1})	3.9 - 11.9	6.1 - 10.4	5.5 - 10.5
Saturation O_2(%)	52 - 118	70 - 121	64 - 91
BOD (mg l^{-1})	1.2 - 3.8	2.3 - 3.7	1.4 - 2.4
COD / $KMnO_4$ / (mg l^{-1})	3.4 - 9.2	6.0 - 7.9	3.2 - 6.0
Suspended solids (mg l^{-1})	6 - 202	20 - 211	9 - 86
NH_4^+ (mg l^{-1})	0.09 - 0.53	0.10 - 0.54	0.21 - 0.45
NO_3^- (mg l^{-1})	0.3 - 2.0	0.7 - 1.8	0.6 - 2.0
NO_2^- (mg l^{-1})	0.015 - 0.077	0.018 - 0.080	0.012 - 0.046
SO_4^{2-} (mg l^{-1})	38 - 70	36 - 50	26 - 67
Cl^- (mg l^{-1})	28 - 67	27 - 41	18 - 54
PO_4^{3-} (mg l^{-1})	0.008 - 0.096	0.038 - 0.058	0.040 - 0.139
Total phosphorus (mg l^{-1})	0.070 - 0.168	0.132 - 0.172	0.100 - 0.273
Ca^{2+} (mg l^{-1})	43 - 55	41 - 45	36 - 55
Mg^{2+} (mg l^{-1})	9 - 17	8 - 10	7 - 13
Na^+ (mg l^{-1})	24.0 - 37.3	22.7 - 33.2	14.9 - 37.4
K^+ (mg l^{-1})	2.6 - 4.4	2.3 - 3.8	2.4 - 4.4
Pb (μg l^{-1})	0 - 2	1 - 2	0 - 7
Cu (μg l^{-1})	14 - 86	10 - 29	7 - 19
Fe (μg l^{-1})	82 - 295	77 - 212	75 - 155
Mn (μg l^{-1})	11 - 104	13 - 43	26 - 57
Evaporable phenols (μg l^{-1})	1 - 3	1 - 2	1 - 5
β–radioactivity (Bq l^{-1})	0.12 - 0.59	0.20 - 0.32	0.13 - 0.34

Annotated list of desmid species

Order: Zygnematales
Suborder: Closteriineae
Family: Closteriaceae Ehr. ex Pritch.
***Closterium* Nitzsch ex Ralfs**

1. *C. acerosum* (Schrank) Ehrenb. ex Ralfs var. *minus* Hantzsch (Plate 1.1; Plate 2.1)
Ref: Ružička (1977), p. 158, pl. 18: 8–9

Dim: L.: 220–280; B.: 20–27.5; Ba.: 4–5; L.:B. = 7.7–12.5.
P.r.: Guelmino (1973); Ržaničanin (2004); Ržaničanin *et al.* (2005).
Loc.: 1 and 2, common.

2. *C. acutum* Bréb.
Ref.: Ružička (1977), p. 95, pl. 6: 16–22
Dim: L.: 107.5–109.5; B.: 5–5.5; Ba.: 1; L.:B. = 19.9–21.9.
P.r.: Guelmino (1973); Kojčić *et al.* (1988); Đukić *et al.* (1994).
Loc.: 1 and 3, rare.

3. *C. acutum* var. *variabile* (Lemm.) W. Krieger
Ref.: Ružička (1977), p. 95, pl. 6: 32–37
Dim.: L.: 135–140.5; B.: 4–4.5; L.:B. = 28.1–30.2.
P.r.: Guelmino (1973).
Loc.: 1, rare.

*4. *C. ehrenbergii* Menegh. ex Ralfs (Plate 1.3)
Ref.: Ružička (1977), p. 141, pl. 15: 1–3
Dim.: L.: 350–370; B.: 60–80; Ba.: 11–11.5; L.:B. = 5.8–6.2.
P.r.: No exist.
Loc.: 1, very rare.

5. *C. gracile* Bréb. ex Ralfs
Ref.: Ružička (1977), p. 168, pl. 21: 1–4
Dim.: L.: 182.5–200; B.: 5–7.5; Ba.: 2.5–3; L.:B. = 25.7–36.5.
P.r.: Szabados (1966); Guelmino (1973); Kalafatić *et al.* (1982); Đukić *et al.* (1994); Ržaničanin (2004); Ržaničanin *et al.* (2005).
Loc.: 1 and 3, common.

6. *C. limneticum* Lemm.
Ref.: Ružička (1977), p. 171, pl. 21: 9–11
Dim.: L.: 157.5–275; B.: 5–7.5; Ba.: 1–1.5; L.:B. = 22.7–48.8.
P.r.: Guelmino (1973); Kojčić *et al.* (1988); Đukić *et al.* (1994); Pujin *et al.* (1999); Subakov (2001).
Loc.: 1, 3, very frequent; 2, frequent.

*7. *C. limneticum* var. *fallax* Růžička
Ref.: Ružička (1977), p. 171, pl. 21: 15–17
Dim.: L.: 205–210; B.: 9.5–10.5; Ba.: 1.5–2; L.:B. = 25.6–26.7.
P.r.: No exist.
Loc.: 1 and 2, rare.
*8. *C. limneticum* var. *tenue* Lemm.
Ref.: Ružička (1977), p. 171, pl. 21: 12–14.
Dim.: L.: 152.5–205; B.: 3.5–4; Ba.: 0.7–0.9; L.:B. = 38.1–51.3.
P.r.: No exist.
Loc.: 1, 2, rare; 3, very rare.

9. *C. littorale* Gay (Plate 2.3)
Ref.: Ružička (1977), p. 150, pl. 17: 1–7
Dim.: L.: 142.5–150; B.: 16–18; Ba.: 3.5–4.5; L.:B. = 9–10.1.
P.r.: Guelmino (1973).
Loc.: 1, very rare.

10. *C. macilentum* Bréb. (Plate 2.2)
Ref.: Ružička (1977), p. 212, pl. 31: 9–13.
Dim.: L.: 305–315; B.: 15–17; Ba.: 5–5.5; L.:B. = 21–22.3.
P.r.: Guelmino (1973).
Loc.: 1, very rare.

11. *C. moniliferum* (Bory) Ehrenb. ex Ralfs
Ref.: Ružička (1977), p. 137, pl. 14: 3–6.
Dim.: L.: 214–230; B.: 37–40; Ba.: 8.5–9; L.:B. = 5.8–7.
P.r.: Guelmino (1973); Đukić *et al.* (1994); Pujin *et al.* (1999); Ržaničanin (2004); Ržaničanin *et al.* (2005).
Loc.: 3, rare.

12. *C. pronum* Bréb. (Plate 1.2)
Ref.: Ružička (1977), p. 102, pl. 7: 23–26.
Dim.: L.: 190–250; B.: 7.5–9; Ba.: 2–2.5; L.:B. = 25.3–35.7.
P.r.: Guelmino (1973); Ržaničanin (2004); Ržaničanin *et al.* (2005).
Loc.: 1, common; 3, rare.

*13. *C. pseudolunula* Borge (Plate 2.4)
Ref.: Ružička (1977), p. 148, pl. 16: 7–15.
Dim.: L.: 235.5–240; B.: 33–34.5; Ba.: 6–9; L.:B. = 6.8–7.3.
P.r.: No exist.
Loc.: 3, very rare.
Com.: Cells elongate and slightly curved, gradually attenuated toward apices, dorsal part of cells convex, ventral part straight or very slightly concave. Apices slightly recurved; cell wall without girdle bands, brownish, with dense-arranged and delicate striae. Chloroplasts with 4–6 longitudinal ridges visible, containing an axile series of pyrenoids.

14. *Closterium* sp. (Plate 2.5)
Dim.: L.: 105; B.: 13.5; Ba.: 2; L.:B. = 7.7.
P.r.: No exist.
Loc.: 1, very rare.
Com.: Insufficient data for determination - only one empty cell wall of some *Closterium* species was recorded. This specimen morphologically resembled *Closterium parvulum* Näg.
15. *C. strigosum* Bréb.
Ref.: Ružička (1977), p. 173, pl. 21: 18–26.
Dim: L.: 177.5–300; B.: 12.5–18; Ba.: 2–2.5; L.:B. = 11.5–18.9.
P.r.: Guelmino (1973); Pujin *et al.* (1999).
Loc.: 1 and 2, frequent.

16. *C. strigosum* var. *elegans* (G. S. West) W. Krieger
Ref.: Ružička (1977), p. 173, pl. 22: 1–11.
Dim.: L.: 165–170; B.: 13–15; Ba.: 2.5–3; L.:B. = 12.7–15.
P.r.: Subakov (2001).
Loc.: 1, rare.

17. *C. subulatum* (Kütz.) Bréb.
Ref.: Ružička (1977), p. 109, pl. 9: 23–26.
Dim.: L.: 172.5–180; B.: 13–13.5; Ba.: 2–2.5; L.:B. = 13.3–14.
P.r.: Guelmino (1973).
Loc.: 1, rare.

*18. *C. tumidulum* Gay (Plate 2.6)
Ref.: Ružička (1977), p. 124, pl. 12: 1–10.
Dim.: L.: 120–130; B.: 16–17.5; Ba.: 1.5–2; L.:B. = 7.4–8.3.
P.r.: No exist.
Loc.: 1, very rare.

Suborder: Desmidiineae
Family: Desmidiaceae Ralfs
***Cosmarium* Corda ex Ralfs**

*19. *C. depressum* (Näg.) Lund. var. *planctonicum* Reverd. (Plate 1.10; Plate 2.7)
[= *C. subtumidum* Nordst. var. *minus* Ström]
Ref.: Lenzenweger (1999), p. 46, pl. 49: 18.
Dim.: L.: 23–23.5; B.: 25–25.5; I.: 7–7.5; Th.:12.5–13.5.
P.r.: No exist.
Loc.: 3, rare.
Com.: Cells slightly wider than long, apex broadly truncate. In apical view semicells oval. Cells wrapped in mucilaginous sheaths. Taxon is a typical euplankter (Lenzenweger 1999).

20. *C. granatum* Bréb. in Ralfs (Plate 1.9)
Ref.: Prescott *et al.* (1981), p. 146, pl. 185: 1–3; Lenzenweger (2001), p. 255, pl. 1: 13–15.
Dim.: L.: 43.5–45; B.: 28–30; I.: 7.5–9; Th.:16.5–17.
P.r.: Szabados (1966); Guelmino (1973); Kojčić *et al.* (1988); Đukić *et al.* (1994); Pujin *et al.* (1999).
Loc.: 3, common.

*21. *C. laeve* Rabenh. (Plate 1.11)
Ref.: West and West (1908), p. 99, pl. 73: 8–19; Lenzenweger (1999), p. 91, pl. 52: 24.
Dim.: L.: 27.5–29; B.: 17.5–18.5; I.: 5–6; Th.: 11.5–12.
P.r.: No exist.
Loc.: 2, rare.
*22. *C. punctulatum* Bréb. (Plate 1.6)
Ref.: Prescott *et al.* (1981), p. 253, pl. 235: 5, 6.
Dim.: L.: 30.5–31; B.: 28–29; I.: 8–9; Th.: 18–19.
P.r.: No exist.
Loc.: 1, very rare.

23. *Cosmarium* sp.
Dim.: L.: 15.5; B.: 13.5; I.: 5; Th.: 8.
Loc.: 1, very rare.
Com.: A single specimen of the genus was not enough for a reliable determination to the species. It somewhat resembled to *C. humile* (Gay) Nordst. in De Toni.

*24. *C. subcostatum* Nordst. in Nordst. & Wittrock (Plate 1.5; Plate 2.10)
Ref.: Prescott *et al.* (1981), p. 299, pl. 238: 6, 8.
Dim.: L.: 30–31; B.: 25–26.5; I.: 10–10.5; Th.: 15.5–16.
P.r.: No exist.
Loc.: 1 and 2, rare.
Com.: Cells approximately 1.2 times longer than broad; sinus narrow, closed and slightly dilated at the apex; semicells subtrapeziform, lateral margins convex with 6 emarginate crenulations. Apex truncate with 4 small crenations along the apical margin. Semicell face with 4 concentric intramarginal rows of granules. Prominent central protrusion furnished with 4–5 vertical series of small granules. In lateral view semicells oval but distinctly inflated in the basal region. Chloroplasts with two pyrenoids.

**25. *C. subcostatum* var. *beckii* (Gutwinski) W. & G. S. West (Plate 1.7; Plate 2.11)
Ref.: Prescott *et al.* (1981), p. 299, pl. 238: 3.
Dim.: L.: 27.5–30; B.: 24–25.5; I.: 5.5–6; Th.: 14.5–15.
P.r.: No exist.
Loc.: 1, frequent.
Com.: In contrast to the nominal variety semicells more elevated and subpyramidal. Granules on the facial protrusion clearly arranged in concentric rows. Chloroplasts with one pyrenoid. Intermediate forms were not observed in the river Tisa.

*26. *C. subprotumidum* Nordst. (Plate 1.4)
Ref.: Prescott *et al.* (1981), p. 309, pl. 275: 4.
Dim.: L.: 26.5–27; B.: 26–26.5; I.: 7.5–8; Th.: 17.5–18.
P.r.: No exist.
Loc.: 2, very rare.

**27. *C. vexatum* W. West var. *rotundatum* Messikommer (Plate 1.13; Plate 2.8)
Ref.: Prescott *et al.* (1981), p. 348, pl. 277: 7.
Dim.: L.: 46–46.5; B.: 43–44.5; I.: 13; Th.: 24–24.5.
P.r.: No exist.
Loc.: 3, very rare.
Com.: Cells slightly longer than broad; sinus more outwardly open than in the nominal variety. Semicells pyramidal-truncate, the lower angles of semicells widely rounded. Lateral margins convex and undulate, with 6 undulations gradually increasing in size from the lower angles to the upper angles. Apex truncate; intramarginal granules subacute rather than round, subconcentrically arranged, gradually diminishing in size toward a central area. In lateral view semicells subcircular, in vertical view oblong-elliptic, with a swolen midregion on either side. 2 irregular series of granules placed immediately above the isthmus.

*28. *C. wembaerense* Schmidle [= *C. laeve* Rabh. var. *tumidum* Grönbl.] (Plate 1.8)
Ref.: Prescott *et al.* (1981), p. 350, pl. 186: 14–16; Fehér (2003), p. 680, fig. 49.
Dim.: L.: 20.5–22; B.: 16.5–17; I.: 5–6; Th.: 12–13.5.
P.r.: No exist.
Loc.: 2, very rare.
Com.: Cells 1.3 times longer than broad; sinus closed, linear. Semicells subpyramidal in frontal view, in apical view broadly elliptic and swollen in the midregion. Cells exhibit small degrees of isthmal torsion. Lateral margins of semicells straight, at first diverging than converging to narrow and truncate apex. Cell wall smooth.

***Staurastrum* Meyen ex Ralfs**

29. *S. chaetoceras* (Schröder) G. M. Smith (Plate 1.14, 15)
Ref.: Palamar–Mordvintseva (1982), p. 211, pl. 52: 7, 9; Brook and Johnson (2003), p. 568, pl. 139: P.
Dim.: L.: 25–57.5; L. (excluding processes): 12–19; B.: 25–55.5; I.: 4–6.
P.r.: Guelmino (1973); Đukić *et al.* (1994); Pujin *et al.* (1999); Subakov (2001); Ržaničanin (2004); Ržaničanin *et al.* (2005).
Loc.: 1 and 3, common.
Com.: Several specimens from two localities were characterized by proportionally small dimensions, as compared to the description of the nominal variety (Brook & Johnson 2003). Lenght excluding processes shorter by 7 µm, lenght including processes shorter by 21 µm and breadth including processes shorter by 25 µm. 2-radiate and 3-radiate specimens of *S. chaetoceras* were commonly encountered on investigated sites; dichotypic forms were also observed.

30. *S. gracile* Ralfs ex Ralfs
Ref.: Lenzenweger (1997), p. 91, pl. 34: 7, 8; Brook and Johnson (2003), p. 569, pl. 139: N.
Dim.: L.: 35.5–37.5; B.: 47.5–50; I.: 8.5–9.
P.r.: Szabados (1966); Pujin *et al.* (1999); Subakov (2001); Ržaničanin (2004); Ržaničanin *et al.* (2003); Ržaničanin *et al.* (2005).
Loc.: 1, rare.

*31. *S. manfeldtii* Delponte (Plate 1.12)
Ref.: Lenzenweger (1997), p. 102, pl. 36: 3; Brook and Johnson (2003), p. 572, pl. 140: C.
Dim.: L.: 52.5–53; B.: 67–68; I.: 10–11.
P.r.: No exist.
Loc.: 1, rare.
Com.: Typical 3-radiate specimens of *S. manfeldtii* were recorded in Martonoš site. Semicells cup-shaped with a shallow notch-like sinus. Processes slightly converging, ended with 3 spines. Apex convex with 2 pairs of intramarginal denticulations extending onto upper surface of the processes. Groups of granules clearly visible immediately above the isthmus.

32. *Staurastrum* sp. (Plate 2.9)
Dim.: L.: 52.5; L. (excluding processes): 39; B.: 72.5; I.: 13.
Loc.: 2, very rare.
Com.: A single specimen of the genus was not enough for a reliable determination. It morphologically corresponded to *S. anatinum* Cooke & Wills. Cells 3-radiate, deeply constricted with a wide open, internally acute sinus. Semicells broadly cup-shaped; apex slightly convex. Processes long, diverging and gradually attenuating, furnished with concentric rings of denticulations, tipped with 3 short divergent spines. Apex and each side of cell body covered with short emarginate spines.

33. *S. tetracerum* (Kütz.) Ralfs var. *tetracerum* (Plate 1.16)
Ref.: Lenzenweger (1997), p. 137, pl. 34: 15; Brook and Johnson (2003), p. 576, pl. 140: L.
Dim.: L.: 25–32.5; L. (excluding processes): 9–16.5; B.: 28–45; I.: 5–6.
P.r.: Guelmino (1973), Kojčić *et al.* (1988), Đukić *et al.* (1994), Pujin *et al.* (1999).
Loc.: 1, common; 3, frequent.
Com.: Cell size considerably larger than in the nominal variety, after Lenzenweger (1997) (including processes, length deviated from the type dimensions by 9.5, and breadth by 25 µm). Length without processes exceeded the nominal values by 4.5 µm, as compared to the dimensions given by Brook and Johnson (2003). Cells 2-radiate in apical view, semicell body shallow cup-shaped, sinus V-shaped. Processes divergent and slender with denticulate margins, ends tipped with 4 minute spines. Apex concave and smooth, sometimes with a small granule in the middle. Cell wall irregularly ornamented with very small granules.

General remarks. In total, 33 desmid taxa were recorded. Qualitatively, in the desmid community the genus *Closterium* was dominant (18 taxa; 54,54 %), subdominant was *Cosmarium* (10 taxa, 31.43%), whereas the genus *Staurastrum* was represented by 5 taxa (15.15 %). The dominance of the genus *Closterium* was expected, since the mesotrophic representatives of this genus had been commonly encountered in large Pannonian rivers and prevailed in a desmid assembly (Milovanović and Živković 1950; Uherkovich 1971; Obušković 1979; Pujin *et al.* 1998). No representatives of other desmid genera were observed in this one-year study. Besides representatives of the genera *Closterium*, *Cosmarium* and *Staurastrum*, only *Hyalotheca dissilens* (Schmith) Bréb. were recorded in the river Tisa, although it has not been designated as frequent (Guelmino 1973).

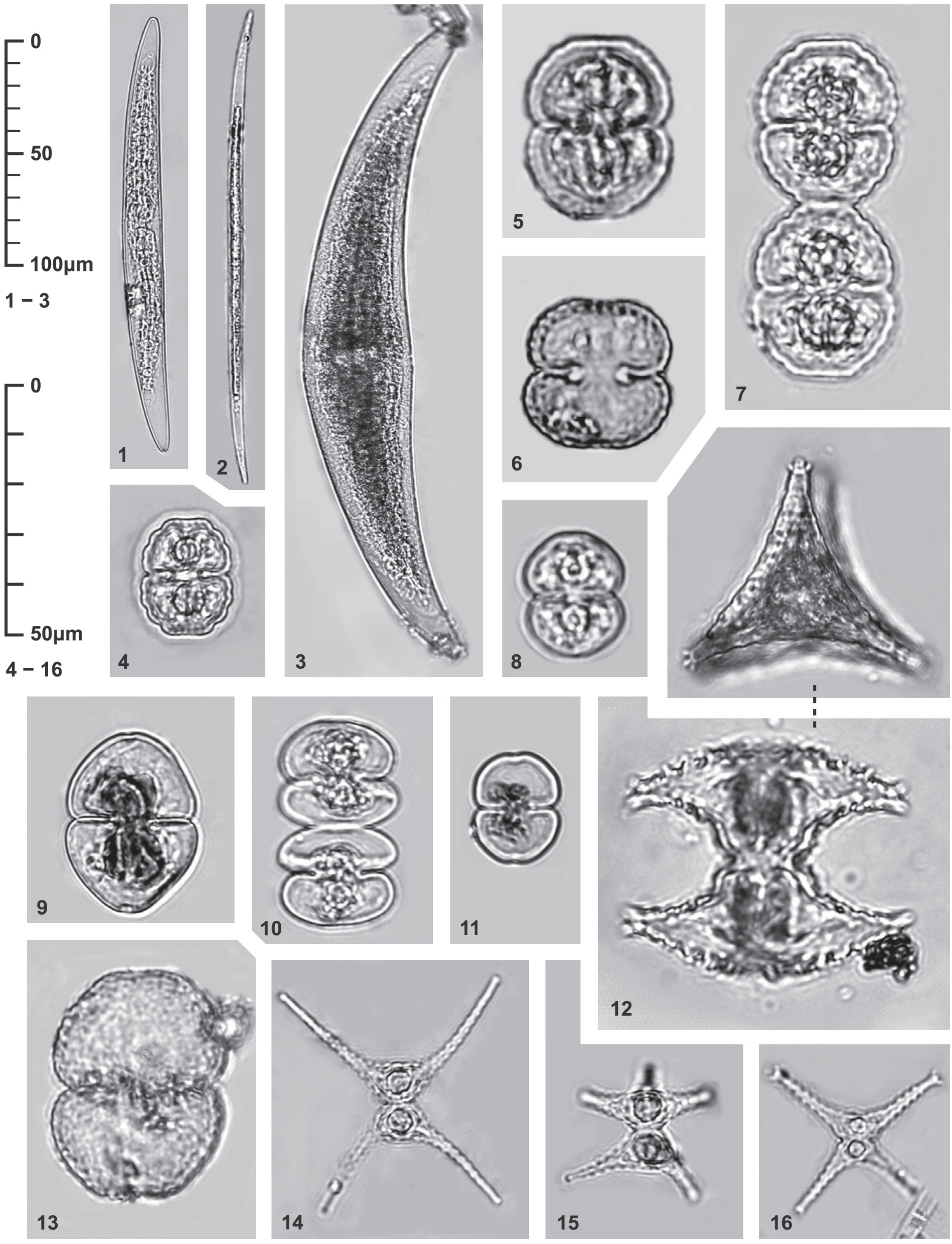

Plate 1. 1 – Closterium acerosum var. minus, 2 – C. pronum, 3 – C. ehrenbergii, 4 – Cosmarium subprotumidum, 5 – C. subcostatum, 6 – C. punctulatum, 7 – C. subcostatum var. beckii, 8 – C. wembaerense, 9 – C. granatum, 10 – C. depressum var. planctonicum, 11 – C. laeve, 12 – Staurastrum manfeldtii, 13 – Cosmarium vexatum var. rotundatum, 14, 15 – Staurastrum chaetoceras, 16 – S. tetracerum var. tetracerum

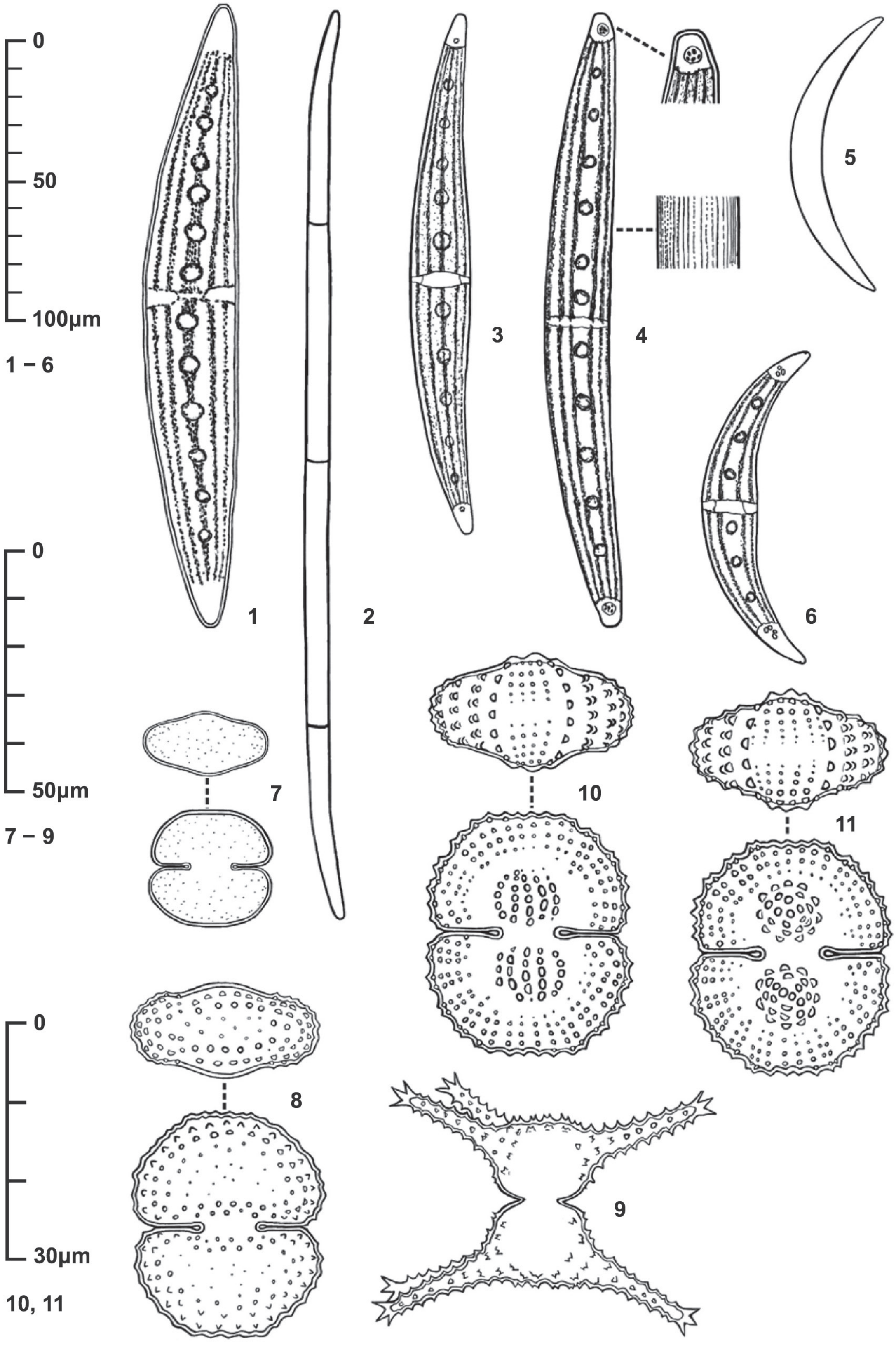

Plate 2. 1 – Closterium acerosum var. minus, 2 – C. macilentum, 3 – C. littorale, 4 – C. pseudolunula, 5 – Closterium sp., 6 – C. tumidulum, 7 – Cosmarium depressum var. planctonicum, 8 – C. vexatum var. rotundatum, 9 – Staurastrum sp., 10 – Cosmarium subcostatum, 11 – C. subcostatum var. beckii.

The present study revealed 12 desmid taxa as new to the Vojvodina stretch of the river Tisa, whereas *C. subcostatum* var *beckii* and *C. vexatum* var. *rotundatum* were new to the algal flora of Serbia.

In contrast to the desmid flora from the Danube (several of 70 taxa were know as generally rare – Stamenković & Cvijan 2008), inhabitants of the river Tisa are predominantly cosmopolitan and wide-spread desmids. The exceptions are *Cosmarium subcostatum* and C. sub*costatum* var *beckii* – they are known as inhabitants of oligotrophic lakes and pools from a boreal part of Northwestern Europe (Palamar–Mordvintseva 1982). Brook and Johnson (2003) considered *C. subcostatum* as an inhabitant of nutrient-poor lakes and as an element of the arctic-alpine flora. So, the find of this species in the river Tisa was remarkable. *C. subcostatum* (including the nominal variety and var. *subcostatum*) was rarely to frequently encountered, although the river Tisa is not their appropriate natural environment according its chemical composition of the water. It is assumed that specimens of this desmid reached the Vojvodina basin of the river Tisa by its mountain tributaries and adapted succesfully to the mesotrophic and alkaline water of this lowland river. The finding of this taxon in the Vojvodina strech of the river Tisa is new not only to the algal flora of Serbia, but probably new to the rest of the Balkan Peninsula, excluding Bosnia and Herzegovina. This taxon has been orriginally described from oligotrophic habitats in Bosnia and Herzegovina by Gutwinski (1896) as *C. beckii* Gutwinskii 1896. West & West (1908) added Gutwinski's species description to *C. subcostatum*, but as a new variety. This form is hardly to be separated from the typical variety, as the granulation of the central tumor may significantly vary. Schmidle (1892, after West and West 1908) provided a drawing which possesed the same form of semicell as Gutwinski's *C. beckii* combined with a central tumor corresponding to that of a nominal variety. The water samples from the river Tisa, however, contained both clearly separated varieties. So far, Gutwinski's record of this variety was unique regarding the whole territory of the former Yugoslavia.

In current investigations, the most of desmid algae were founded as rare (36.36%, 12 taxa) or very rare (36.36%, 12 taxa). Only a few of them are generally known as low-spread and rare in Europe, e.g. *Closterium pseudolunula*, *C. tumidulum*, *Cosmarium depressum* var. *planctonicum*, *C. subcostatum*, *C. subcostatum* var. *beckii*, *C. vexatum* var. *rotundatum* and *C. wembaerense*. Commonly encountered taxa (18.18% of all recorded taxa) involving mainly typical planktonic taxa, e.g. *Closterium pronum*, *Cosmarium granatum*, *Staurastrum chaetoceras* and *S. tetracerum*. Frequently recorded taxa comprised 6.06% of all recorded taxa, while only *Closterium limneticum* was designated as very frequent in two sites along the river Tisa.

An almost regular seasonal dynamics of the desmid community of the river Tisa was observed during one-year study. Generally, desmid taxa were unequally distributed on the investigated sites during the examined months. The average flow rates of the river Tisa were significantly high (up to 1420 $m^3 s^{-1}$, according to RHSS 2003) and caused the dispersed qualitative composition of the desmid community.

The highest diversity of desmids was observed in summer months (June and July 2002), when pH, conductivity, and total hardness were low, being lower in comparison to other months. Although the WQI values were low in summer period, showing the poor water quality of the river Tisa, the diversity of the desmids was high. However, the periodic enrichment of water with ammonium ion, phosphorus compounds, mineral salts and evaporable phenols caused the qualitative impoverishment and changes in the desmid community. The indicators of α and α–β-mesosaprobic levels (*Closterium acerosum* var. *minus* and *C. strigosum*) were presented in the algal community together with numerous representatives of Cyanoprokaryota and Euglenophyta. Despite of the relatively high WQI values calculated, showing the improvement of water quality in autumn, lower diversity of desmids was recorded. Progressive lowering of water temperature and moderately high conductivity and total hardness resulted in the qualitative impoverishment of the desmid community. In addition, the indicators of β- and o–β-mesosaprobity (e.g. *Closterium limneticum*, *Cosmarium granatum* and *Staurastrum gracile*; after Sev 1977 & Gulyas 1998) qualitatively dominated in the desmid community.

Winter months were characterized with a rather poor desmid community, when only *Closterium limneticum*, *Cosmarium granatum*, *Staurastrum chaetoceras* and *S. tetracerum* were recorded. These taxa survived the exceptionally high amount of suspended solids, recorded in Martonoš and Padej sites. Also, relatively high conductivity as well as HCO_3^-, SO_4^{2-}, Cl^-, Na^+ and Fe concentrations did not disrupt the development of these taxa.

Parallelly with the rise in water temperature in spring 2003, the desmid community became ever more diverse on all the investigated sites

In accordance with the reduction of the average WQI values for the localities situated downstream the border site Martonoš (Picture 1), the number of desmid taxa decreased along the river Tisa. Thus, the highest number of taxa was encountered on the border site (23), while localities Padej and Titel were characterized with qualitatively poorer desmid community (11 and 13 taxa, respectively). It is noteworthy that a positive correlation among the average WQI values and the qualitative composition of desmid community was observed in the river Tisa, with regard to both parameters – investigated localities and investigated months (Stamenković 2006).

Only *Closterium limneticum* and *C. limneticum* var. *tenue* were encountered on all the investigated localities. Therefore, they may be considered as typical euplanktonic elements of the river Tisa.

Some desmid taxa which had been previously reported from the river Tisa, as: *Closterium acerosum* (Schrank) Ehrenb. ex Ralfs, *C. aciculare* T. West, *C braunii* Reinsch, *C. gracile* Bréb. ex Ralfs var. *elongatum* W. & G. S. West, *C. nordstedtii* Chodat., *C. setaceum* Ehrenb. ex Ralfs, *C. sublaterale* Růžička, *C. idiosporum* W. & G. S. West, *C. lineatum* Ehr. ex Ralfs, *C. navicula* (Bréb.) Lütkem., *Cosmarium botrytis* Menegh. ex Ralfs, *C. clepsydra* Nordst. var. *dissimile* Krieg. & Gerlof, *Staurastrum cingulum* (W. & G. S. West) G. M. Smith, *S. hexacerum* (Ehrenb.) Wittrock and *S. inflexum* Bréb. (Guelmino 1973; Pujin *et al*. 1999; Subakov 2001; Ržaničanin 2004) were not recorded during the recent investigation. Unfortunatelly, no illustrations or taxonomic remarcs had been provided for some poorly-known taxa, as *Closterium sublaterale*, *C. nordstedtii*, *Cosmarium clepsydra* var. *dissimile*, *Staurastrum cingulum* and *S. hexacerum* are, and so the verification of the identification was not possible.

The mesotrophic desmids predominated in the desmid community of the river Tisa (approximatelly 57.57% of all desmid taxa). Inhabitants of eutrophic biotopes, e.g. *Closterium acutum* and *C. acutum* var. *variabile* (indicators of β–α-mesosaprobity) were marked as rare, however *C. strigosum*, which is an indicator of α–β-mesosaprobity (after Sev 1977 & Gulyas 1998), was frequently recorded and pointed to a poor water quality of the river Tisa. In total, meso-eutrophic and eutrophic inhabitants comprised 15.15% of all taxa. On the other hand, meso-oligotrophic and oligotrophic desmids were recorded, too. They also took up a small ratio in the desmid community (27.27%).

Interestingly, *Closterium acerosum* var. *minus* was commonly recorded in the river Tisa during the whole period of investigation, whereas a nominal variety was not encountered at all. The previous studies of this river have confirmed the finds of a nominal variety solely and the finds of both varieties on the same locality (Uherkovich 1971; Guelmino 1973; Ržaničanin *et al*., 2005). There is a possibility that var. *minus* represents an ecomorph of the nominal variety, but the further investigation is needed to confirm this supposition.

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REZIME

Flora dezmidialnih algi (Chlorophyta, Zygnematophyceae) reke Tise u Vojvodini (Srbija)

Marija Stamenković i Mirko Cvijan

U ranijim algološkim i saprobiološkim istraživanjima reke Tise zabeležena je niska procentualna zastupljenost dezmidialnih algi u fitoplanktonu. Pri tom, u najvećem broju slučajeva dezmidialne alge nisu bile determinisane do nivoa vrste. Imajući prethodno u vidu, detaljna istraživanja flore dezmidialnih algi vojvodjanskog dela reke Tise, vršena su tokom 2002. i 2003. godine.

Istraživanjima je utvrđeno prisustvo ukupno 33 taksona u okviru rodova *Closterium*, *Cosmarium* i *Staurastrum*. Od toga je za vojvođanski deo Tise novo 12 taksona dok su *Cosmarium subcostatum* var *beckii* i *C. vexatum* var. *rotundatum* novi za floru Srbije. U zajednici dezmidialnih algi dominirale su mezotrofni taksoni (57.57 %) u odnosu na mezo-oligotrofne i oligotrofne (27.27 %), odnosno mezo-eutrofne i eutrofne (15.15 % od ukupnog broja taksona). Izuzetak od ostalih taksona čine *Cosmarium subcostatum* i C. *subcostatum* var *beckii*. Budući da navedeni takosni uobičajeno naseljavaju ologotrofna jezera i manje vodene basene borealnog pordučja severo-zapadne Evrope, za njih se posebno navode ekološke primedbe. Najveći broj taksona zabeležen je u toku leta, uz preovladavanje indikatora α- i α–β-mezosaprobnog nivoa, zajedno sa brojnim pripadnicima Cyanoprokaryota.

Ključne reči: Dezmidialne alge, Tisa, Vojvodina, Serbia