Botanica SERBICA 40 (2): (2016) 167-178

Original Scientific Paper

Revision of the *Stauroneis smithii* Grunow (Bacillariophyceae) species complex from Macedonia

Zlatko LEVKOV[1*], Slavica TOFILOVSKA[1], Elena JOVANOVSKA[2], Aleksandra CVETKOSKA[3] and Ditmar METZELTIN[4]

1 Institute of Biology, Faculty of Natural Sciences, Saints Cyril and Methodius University, Arhimedova 3, 1000 Skopje, R. Macedonia

2 Department of Animal Ecology and Systematics, Justus–Liebig University, Heinrich–Buff–Ring 26–32, 35392 Giessen, Germany

3 Deptartment of Physical Geography, Faculty of Geosciences, Utrecht University, Willem C. van Unnikgebouw 028, Heidelberglaan 2, NL – 3584 CS Utrecht, The Netherlands

4 Am Stegskreuz 3b, D-65719 Hofheim, Germany

ABSTRACT: *Stauroneis smithii* is considered to be a widely distributed and highly variable species complex. So far, more than 20 infraspecific taxa have been described. In the present study, six members of this complex were observed. *Stauroneis smithii* is widely distributed in Macedonia, recorded from various aquatic habitats. Minor morphological variations were observed between the populations found in oligotrophic, slightly acidic habitats and ones found in meso- to eutrophic ponds and rivers. *Stauroneis separanda* and *S. prominula* were infrequently observed in mountain habitats and always at low abundance. In previous studies, *Stauroneis borgei* and *S. balatonis* were found in both the modern flora and the fossil diatom record from Lakes Ohrid and Prespa. In those studies, these two taxa were identified as varieties of *S. smithii*, designated *elliptica* and *incisa,* respectively. In the present study, one form with unique morphological features was observed and is here described as a new species, *Stauroneis blazenciciae* sp. nov. The new species can be easily differentiated from *S. smithii* by the valve shape: elliptical-lanceolate with weakly undulate margins in the largest specimens to linear-lanceolate with valve margins gradually narrowing towards the abruptly protracted to acute apices.

KEYWORDS: diatoms, Macedonia, new species, *Stauroneis blazenciciae*, *Stauroneis smithii* complex.

Received: 14 June 2016 Revision accepted: 29 August 2016

UDC: 582.261.1(497.7)
DOI: 10.5281/zenodo.162215

INTRODUCTION

The genus *Stauroneis* Ehrenberg was described by C.G. EHRENBERG (1843) and initially comprised two species, *S. phoenicenteron* (Nitzsch) Ehrenberg and *S. angusta* Ehrenberg. The protologue, however, was not accompanied by a designated generitype, which was later provided by BOYER (1928). Since establishment of the genus, interest in the taxonomy of *Stauroneis* has continuously increased. The genus now contains more than 800 taxa (FOURTAINER & KOCIOLEK 2011), inhabiting various habitats, including marine, coastal, brackish and freshwater environments. According to ROUND *et al.* (1990), the genus should comprise only species living in freshwater habitats, while the taxa known from marine or brackish waters should be transferred to other genera, for example *Stauropsis* Meunier or *Staurophora* Mereschkowsky. The main morphological features of the genus *Stauroneis* are: i) presence of a "stauros" extending from the proximal raphe endings (raphe sternum) to the valve mantle; and

*correspondence: zlevkov@pmf.ukim.mk

ii) uniseriate striae composed of small round to slightly elongated areolae.

Although the genus is considered to be large (with more than 800 names), its diversity has been neglected. For example, a few species, like *S. phoenicenteron* and *S. anceps* Ehrenberg, were considered to have highly variable morphological features (valve shape and size, stria density, etc.), and thus these names were applied to many different and sometimes very distinct taxa. More recently, several authors tried to solve this issue, mainly by splitting different forms, which resulted in description of many new species. According to Fourtainer & Kociolek (2011), almost 80 new species have been described during the first decade of the 21st century. However, recent studies indicate that diversity of the genus is still underestimated (Bahls 2010, 2012; Zidarova *et al.* 2014).

Species of the genus *Stauroneis* are generally widely distributed in various freshwater habitats. Although most of them are characteristic of oligotrophic waters in the temperate zone (Lange-Bertalot & Metzeltin 1996), they are also frequently found in Arctic and sub-Antarctic regions (Van de Vijver *et al.* 2005; Zidarova *et al.* 2014). Species also can be found in subaerial habitats (Van de Vijver *et al.* 2004; Joh 2014) or even in caves (Falasco *et al.* 2015). Additionally, it is one of the most frequently recorded genera in high mountain peat-bogs (Levkov *et al.* 2005).

In Macedonia, for example, around 20 *Stauroneis* taxa have been recorded (Levkov unpubl. data), but as in other regions, most of the earlier records refer to *S. phoenicenteron*, *S. anceps* and *S. smithii*. The majority of records are from the country's mountain regions (Petrovska & Stojanov 1976; Stojanov & Petrovska 1980; Stojanov 1982, 1983), but many *Stauroneis* species have been reported from the ancient Lakes Ohrid and Prespa (Hustedt 1945; Jurilj 1954) as well. Most of the taxa recorded in Macedonia are considered to be cosmopolitan (Hustedt 1930; Krammer & Lange-Bertalot 1986), with only a few, such as *S. palustris* Hustedt (Hustedt 1945, p. 914, figs. 42: 30–32), *S. lychnidis* Jurilj (Jurilj 1954, p. 131–132; figs. 31d–e) and *S. smithii* var. *elliptica* Hustedt (Hustedt 1945, p. 914, figs. 42: 34–36), having limited distribution. The latter two taxa have been found only in Lakes Ohrid and Prespa, while *S. palustris* was found in the Katlanovo wetland.

A revision of the diatom flora of Macedonia has been recently initiated and several genera, including *Amphora* Ehrenberg (Levkov 2009), *Eunotia* Ehrenberg (Pavlov & Levkov 2013), *Hippodonta* Lange-Bertalot, Metzeltin & Witkowski (Pavlov *et al.* 2013), *Diploneis* Ehrenberg (Jovanovska *et al.* 2013), *Luticola* D.G. Mann (Levkov *et al.* 2013), *Odontidium* Kützing (Jüttner *et al.* 2015) and *Mastogloia* Thwaites (Pavlov *et al.* 2016), were observed in more detail. This has resulted in many new species distribution records and additional descriptions of new taxa. In the present paper, we provide a revision of the *S. smithii* species complex, as part of ongoing comprehensive research on the genus *Stauroneis* in Macedonia.

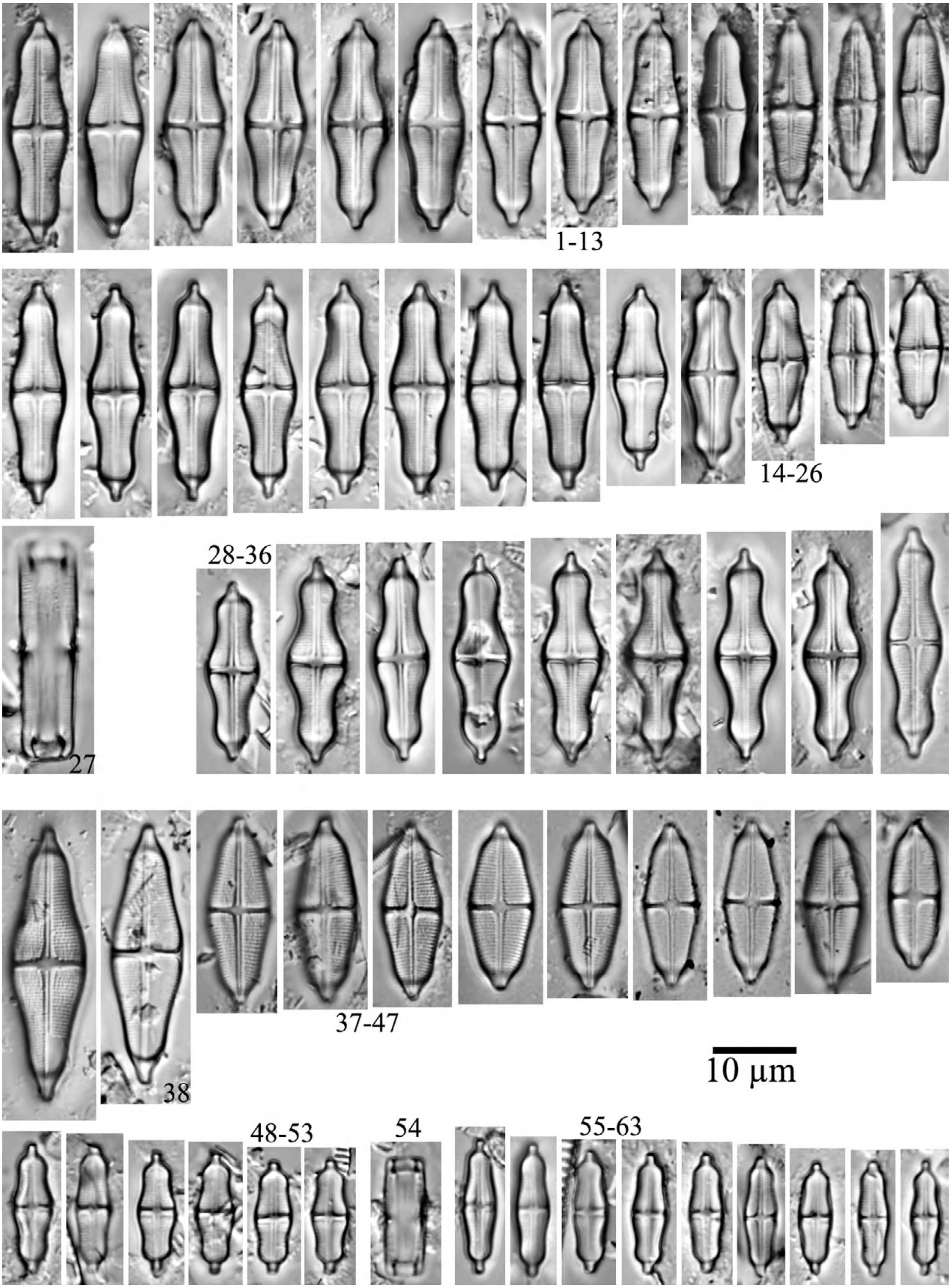
MATERIAL AND METHODS

The samples examined in this study were collected during various field campaigns, from 1995 to the present day. They were collected annually, during the period of June-August. The altitude at the different sampling sites varies in the range of ca. 200–2500 m a.s.l. Samples from the aquatic habitats include sediments at various depths (0.5–50 m) from Lakes Ohrid, Prespa and Dojran; and sediment, stones and macrophytes from rivers, small springs, streams and rivulets, high-altitude glacial and non-glacial lakes, ponds and pools of various size, peat bogs, fens and mires, as well as wet walls and rocks with permanent, temporary and occasional aqueous periods. Diatom samples were cleaned by acid digestion using K_2MnO_4/HCl, and permanent slides were mounted in Naphrax®. Photomicrographs were taken using a Nikon E-80i microscope and a Nikon Coolpix 600 digital camera. For scanning electron microscope (SEM) analyses, cleaned material was dried onto aluminium stubs and coated with gold/palladium using a sputter coater. The SEM micrographs were produced with a Cambridge Instrument S4 Steroscan electron microscope operated at 5 kV. Slides are deposited in the Macedonian National Diatom Collection (MKNDC), Institute of Biology, Skopje, Macedonia (holotype); and the Friedrich Hustedt Centre for Diatom Research (BRM) in Bremerhaven, Germany (isotype).

RESULTS AND DISCUSSION

Six species from the *S. smithii* species complex were observed during the study. The morphology of each taxon is comprehensively described. The external and internal ultrastructure of the valves, as observed in the obtained SEM micrographs, are described for most of the taxa. For the new species *Stauroneis blazenciciae* sp. nov., a formal description is provided. The LM images represent most of the size diminution series of each taxon.

***Stauroneis smithii* Grunow (Figs. 1–36, 112–115).** Frustule in girdle view rectangular (Figs. 27, 112). Valves linear-lanceolate with triundulate margins and abruptly protracted to acute apices (Fig. 113). Central undulation distinctly wider. Valve length 21.0–29.0 µm, valve width 6.0–7.5 µm. Pseudosepta distinct, present at both poles reaching valve ends base (Fig. 114). Axial area very narrow, slightly widened towards valve central area. Central area with distinct stauros, narrow, not expanded towards valve margins. Central area (stauros) externally flat, internally strongly inwardly thickened (Fig. 115). Raphe fissures almost straight, filiform. Proximal raphe ends slightly expanded and weakly deflected towards the



Figs. 1–63. Light micrographs (LM) of three different *Stauroneis* species. Figs. 1–26. Diminution series of *S. smithii* from an unnamed river near the village of Manastir, Mariovo. Fig. 27. Frustule in girdle view. Figs 28–36. Diminution series of *S. smithii* from the Ciganska River, Shara Mountain. Figs. 37–47. Diminution series of *S. blazenciciae* from the type locality, Lake Vevcansko, Mt. Jablanica. Figs. 48–63. Diminution series of *S. separanda* from an unnamed river near the village of Manastir, Mariovo. Scale bar = 10 µm.

Table 1. Main morphometric features of infraspecific taxa within the *S. smithii* species complex.

Taxon	Valve shape	Apices	Length (µm)	Width (µm)	Striae (in 10 (µm))
Stauroneis smithii Grunow (Grunow 1860, p. 564, fig. 4: 16)	rhombic-lanceolate	rostrate, apiculate to acuminate	30.0	10.0	-
Stauroneis smithii f. *acuminata* Cleve-Euler (Cleve-Euler 1939, p. 17, fig. 33)	elliptical-lanceolate	long protracted	24.0–38.0	6.0–9.0	-
Stauroneis smithii var. *balatonis* (Pantocsek) Kobayasi & Ando (Kobayasi & Ando 1978, p. 15, figs. 2: 21–25)	lanceolate to rhombic-lanceolate	Acute	27.0–46.5	7.0–9.5	22–30
Stauroneis smithii var. *balatonis* (Pantocsek) Cleve-Euler (Cleve-Euler 1953, p. 217, fig. 957i)	rhombic-lanceolate	not protracted and acutely rounded	up to 45.0	6.0–9.0	-
Stauroneis smithii var. *borgei* (Manguin) Hustedt (Hustedt 1959, figs. 1157h–k)	elliptical-lanceolate	bluntly rounded	12.0–20.0	4.5–6.0	more than 30
Stauroneis smithii var. *elliptica* Hustedt (Hustedt 1945, p. 914, figs 42, 34–36)	ellongate-elliptical	bluntly rounded	14–21	4.0–6.0	20–24
Stauroneis smithii f. *emarginata* Cleve-Euler (Cleve-Euler 1953, p. 216, fig. 957c)	rhombic-lanceolate constricted in mid-valve	rostrate, apiculate to acuminate	26.4	6.4	-
Stauroneis smithii var. *genuina* Cleve-Euler (Cleve-Euler 1953, p. 216, figs. 957a–b)	triundulate	rostrate to apiculate	28.0	8.0	28-35
Stauroneis smithii f. *incisa* (Pantocsek) Hustedt (Hustedt 1957, p. 262)	-	-	-	-	-
Stauroneis smithii var. *incisa* Pantocsek (Pantocsek 1902, p. 27, fig. 2: 45)	strongly convex, constricted in mid-valve	rostrate	18.9	5.4	33
Stauroneis smithii var. *karelica* Wislouch & Kolbe (Wislouch & Kolbe 1916, p. 267, fig. 3: 8)	rhombic-lanceolate	acuminate	33	9	18
Stauroneis smithii var. *minima* Haworth (Haworth 1974, p. 51; figs. 12, 21)	lanceolate	subcapitate	14.0–15.0	5.0	c. 40
Stauroneis smithii f. *minor* Cleve-Euler (Cleve-Euler 1953, p. 217, fig. 957f)	elliptical-lanceolate	slightly protracted	19.0	5.4	-
Stauroneis smithii var. *minor* Fusey (Fusey 1948, p. 11, fig. 40)	linear, slightly expanded in mid-valve	slightly protracted	8–11	2.5–3.5	28–32
Stauroneis smithii var. *nipponica* Skvortzow (Skvortzow 1936, p. 33; pl. 10, fig. 23)	lanceolate, slightly triundulate	long, acuminate	34	6.8	28-30
Stauroneis smithii var. *pantocsekii* Cleve-Euler (Cleve-Euler 1953, p. 217, figs. 957k–l)	rhombic-lanceolate	not protracted and rounded	25–35	6–7	-
Stauroneis smithii var. *sagitta* (Cleve) Hustedt (Hustedt 1959, p. 811, fig. 1158)	lanceolate	protracted and narrowly rounded	25–55	4.0–5.0	c. 20
Stauroneis smithii var. *tibetica* (Mereschkowsky) Wislouch & Kolbe (Wislouch & Kolbe 1927, p. 40)	lanceolate	acutely rounded	25–31.5	6.0–7.0	-

same side (Fig. 112). Distal ends bent, long, passing onto valve mantle (Fig. 113). Transapical striae fine, indistinctly punctate, parallel throughout, 25–30 in 10 µm. Striae uniseriate, composed of small, round to slightly elongated areolae (Figs. 112, 113). Internally areolae occluded with hymens (Figs. 114, 115). Areolae hardly discernible in LM, about 40 in 10 µm.

Distribution and ecology: *Stauroneis smithii* is a widely distributed species and recorded from many localities in Macedonia. It was observed in a wide range of habitats: oligotrophic and slightly acidic bogs, moderately eutrophic lowland rivers, (hyper-) eutrophic ponds, rivers and wetlands. In general, the species was observed at high abundance in eutrophic habitats.

Taxonomic remarks: Two morphotypes of *S. smithii* were observed in the present study. The first morphotype (Figs. 1–26), which is more common in eutrophic waters, is characterised by less pronounced undulations of the valve margin. The second morphotype (Figs. 28–36) was usually found in oligotrophic, slightly acidic waters, and appears similar to the original illustration of *S. smithii* (Grunow 1860, fig. 4: 16) by virtue of having distinctly triundulated valves with more pronounced central undulation.

The *Stauroneis smithii* species complex is considered to be highly diverse; around 20 different infraspecific taxa have been recognised up to now (Table 1). The unifying characters for all these taxa are: relatively small size (length 10–50 µm; width 2.5–9.0 µm); presence of distinct pseudosepta at the apices; and narrow stauros. However, these taxa differ in other important characters, viz., valve shape and size; shape of the valve apices; and stria density. It is therefore very likely that they represent distinct biological entities (species).

***Stauroneis blazenciciae* sp. nov. (Figs. 37–47, 116–118)**

Description: Valves lanceolate to elliptical-lanceolate with weakly undulated margins in largest specimens to linear-lanceolate with valve margins gradually narrowing towards abruptly protracted to acute apices in smaller specimens (Figs. 37–47, 118). Valve length 17.0–33.0 µm, valve width 6.5–9.5 µm. Pseudosepta distinct, present at both poles reaching base of valve ends (Fig. 117). Axial area very narrow, slightly widened near valve central area (Fig. 118). Central area with distinct stauros, narrow, slightly expanded towards valve margins. Central area (stauros) externally flat, internally strongly inwardly thickened (Fig. 116). Raphe fissures almost straight, filiform. Externally, proximal raphe ends simple, straight, not expanded (Fig. 118). Internally, proximal ends straight, terminating just before the strongly thickened stauros (Figs. 116, 117). Externally, distal raphe ends deflected first towards one side, and then deflected to opposite side in same direction, extending onto valve mantle (Fig. 118). Transapical striae finely punctate, parallel throughout, 24–26 in 10 µm. Striae uniseriate, composed of small, round to slightly elongated areolae (Fig. 118). Internally, areolae occluded by hymens (Fig. 116). Areolae hardly discernible in LM, about 30–35 in 10 µm.

Holotype (designated here): Slide MKNDC 002449/A. The holotype specimen is represented by Fig. 38.
Isotype: Slide BRM Zu10/70.

Type locality: Mt. Jablanica, Lake Vevchansko, sediment 2.5 m depth. Leg. Z. Levkov. Coll. date: 11.08.2005.

Etymology: The species is named in honor of Prof. Dr. Jelena Blaženčić, University of Belgrade, for her great contribution to algal taxonomy and ecology.

Distribution and ecology: *Stauroneis blazenciciae* was recorded from several localities on Mt. Jablanica and in the Shara Mountains. The type locality is a small, shallow, oligotrophic mountain lake of glacial origin. Other localities include small mountain streams and peat-bogs at an altitude above 1900 m.

Differential diagnosis: *Stauroneis blazenciciae* can be easily differentiated from *S. smithii* by the valve shape. *Stauroneis smithii* has triundulate valves with two distinct constrictions of the valve margin towards the valve apices, while *S. blazenciciae* has elliptical-lanceolate valves with weak undulations. *Stauroneis blazenciciae* can be confused with S. *smithii* var. *karelica* Wislouch & Kolbe (1916, p. 267, fig. 3: 8), but it can be distinguished from the latter by the valve shape (rhombic-elliptical in var. *karelica*) and the stria density (~18 in 10 µm in var. *karelica*). *Stauroneis smithii* var. *karelica* sensu Hirano (1971, fig. 2: 17) has distinctly undulated valve margins. Valves with similar outline as *S. blazenciciae* are presented in Cleve-Euler (1953, fig. 957e) as *S. smithii* var. *karelica,* but they are lanceolate and with undulated valve margins. *Stauroneis tibetica* Mereschkowsky (Mereschkowsky 1906, p. 14, fig. 2) = *S. smithii* var. *tibetica* (Mereschkowsky) Wislouch & Kolbe (Wislouch & Kolbe 1927, p. 40) has lanceolate valves without undulate margins and with smaller valve width (6.0–7.0 µm). *Stauroneis smithii* f. *emarginata* Cleve-Euler (Cleve-Euler 1953, p. 216, fig. 957c) has rhombic-lanceolate valves, but it can be easily distinguished from *S. blazenciciae* by the distinctly triundulated valve margins with a constriction in the mid-valve. *Stauroneis smithii* var. *pantocsekii* Cleve-Euler (Cleve-Euler 1953, p. 217, figs. 957k–l) = *S. legumen* var. *balatonis* Pantocsek (Pantocsek 1902, p. 28, fig. 2: 43, 44) has rhombic-lanceolate valves with similar size as in *S. blazenciciae*, but it can be separated from the latter by the shape of the valve apices (not protracted but rounded in var. *pantocsekii*). *Stauroneis blazenciciae* appears similar to *S. smithii* var. *nipponica* Skvortzow (Skvortzow 1936, p. 33, fig. 10: 23) in the valve outline and size, but clearly differs in shape of the valve apices (long and acuminate in var. *nipponica*). *Stauroneis legumen* var. *elliptica* Kobayasi & Ando (Kobayasi & Ando 1978, figs. 1: 11–13) has similar valve size (length 20–31 µm, width 7.0–8.0 µm) as in *S. blazenciciae*, from which it differs by the valve outline (elliptical in var. *elliptica*) and shape of the apices (slightly rostrate in var. *elliptica*).

Stauroneis separanda **Lange-Bertalot & Werum (Figs. 48–63).** Frustule in girdle view rectangular. Valves linear to linear-lanceolate with triundulate margins and abruptly protracted apices. Central undulation distinctly wider. In larger specimens, valves slightly constricted in middle. Valve length 13.0–15.5 µm, valve width 3.5–5.5 µm. Pseudosepta distinct, present at both poles reaching base of valve ends. Axial area very narrow, slightly widened towards valve central area. Central area with distinct stauros, narrow, not expanded towards valve margins. Raphe fissures almost straight, filiform. Transapical striae fine, indistinctly punctate, parallel throughout, 28–30 in 10 µm. Striae uniseriate, composed of small, round areolae. Areolae hardly discernible in LM, about 40 in 10 µm.

Distribution and ecology: According to Werum & Lange-Bertalot (2004), *S. separanda* is widely distributed in calcareous springs with high conductivity. In Macedonia, the species is infrequently recorded and always characterised by low abundances. Most of the records originate from mesotrophic, calcareous waters (rivers and ponds). It almost always co-occurs with *S. smithii* at most sites.

Taxonomic remarks: Two morphotypes of *S. separanda* were observed in the present study. The first morphotype (Figs. 48–53) is characterised by having wider central undulations of the valve margin than in the second morphotype (Figs. 55–63).

Stauroneis balatonis **Pantocsek (Figs. 64–89).** Frustule in girdle view rectangular. Valves lanceolate, rhombic-lanceolate to elliptical-lanceolate with short, slightly protracted apices. Depending on the focus, some specimens appear to have a slight mid-valve constriction. Valve length 21.0–52.0 µm, valve width 5.0–10.0 µm. Pseudosepta distinct, present at both poles reaching base of valve ends. Axial area very narrow, slightly widened towards valve central area. Central area with distinct stauros, narrow, not expanded towards valve margins. Raphe fissures almost straight, filiform. Transapical striae fine, indistinctly punctate, parallel to weakly radiate, 25–30 in 10 µm. Areolae hardly discernible in LM, about 40 in 10 µm.

Distribution and ecology: *Stauroneis balatonis* was recorded only in Lakes Ohrid and Prespa, where it occurs in sediment from various water depths (2–30 m). It is infrequently observed in the samples and always with a low abundance. The species is also observed in the fossil diatom flora of both Lake Ohrid and Lake Prespa (Cvetkoska *et al.* 2016; Jovanovska *et al.* 2016). This species (under the name var. *incisa*) has broad distribution as a fossil in Europe (Krasske 1932; Khursevich & Loginova 1980; Loseva 1982; Tynni 1982; Temniskova-Topalova & Ognjanova-Rumenova 1997) and Asia (Moisseeva 1967, 1971). The range is Early-Middle Miocene to Quaternary.

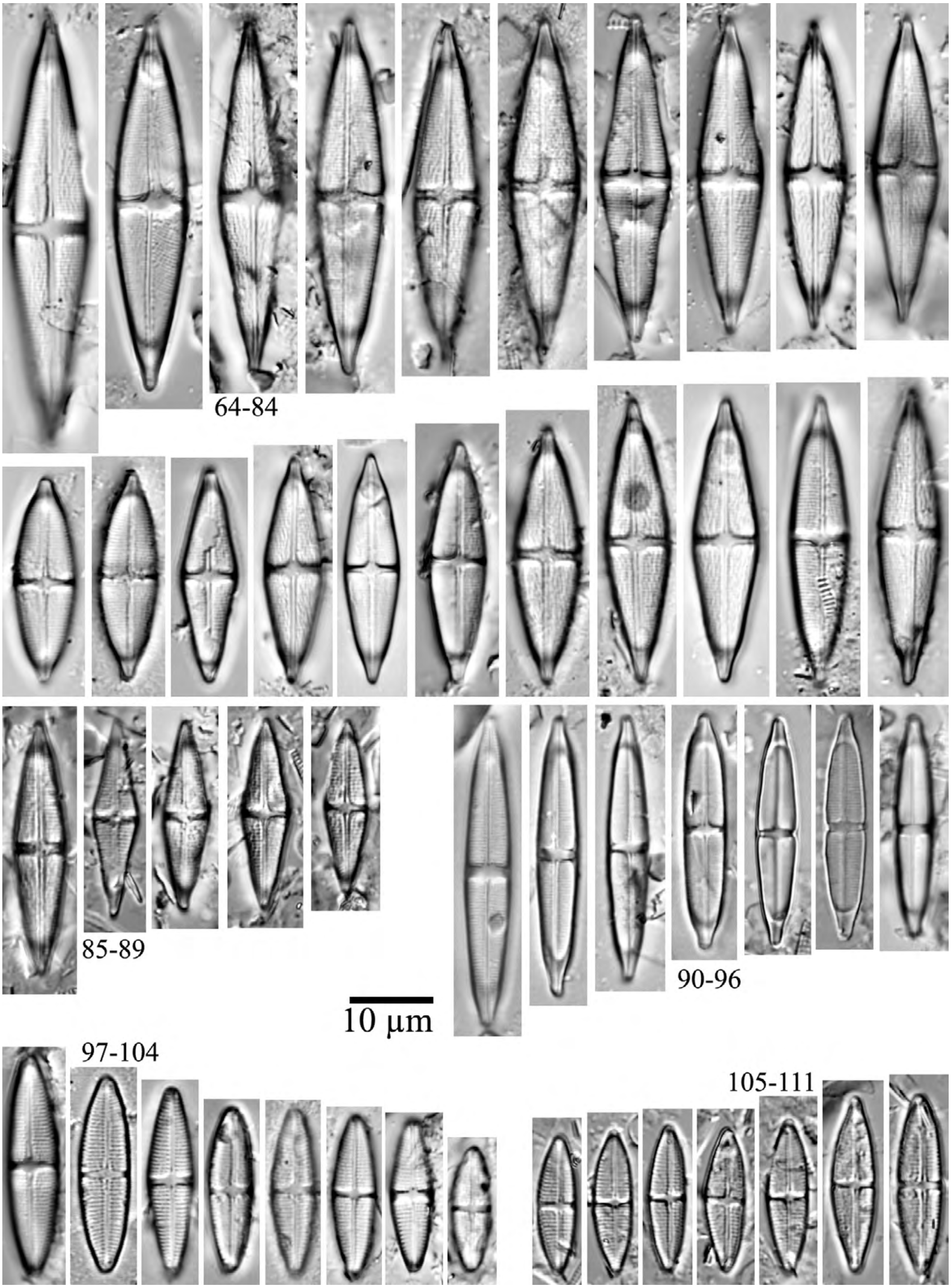
Remarks: In previous studies of the diatoms of Lakes Ohrid and Prespa (Jurilj 1954; Levkov *et al.* 2007), this taxon was identified as *S. smithii* var. *incisa* Pantocsek. However, the identity of the given taxon has not been precisely established. In his work on Lake Balaton diatoms, Pantocsek (1902) described three very similar taxa: *S. balatonis* Pantocsek (Pantocsek 1902, p. 27, figs. 39, 40), *S. smithii* var. *incisa* Pantocsek (Pantocsek 1902, p. 27, fig. 2: 45) and *S. legumen* var. *balatonis* Pantocsek (Pantocsek 1902, p. 27, figs. 2: 43, 44). All three taxa have similar valve outline but different size, and thus it is very likely that they represent different stages of the life cycle of a single species. A similar opinion was expressed by Hustedt (1959), who synonymised all these taxa under the variety *incisa*. Kobayashi & Ando (1978) recognised two of the above-mentioned taxa, *S. balatonis* [= *S. smithii* var. *balatonis* (Pantocsek) Kobayashi & Ando] and *S. smithii* var. *incisa*, but for the latter taxon they depicted a single specimen, which hampers a proper identification.

We here consider that *S. balatonis*, *S. legumen* var. *balatonis* and *S. smithii* var. *incisa* are conspecific, but significantly different from *S. smithii*, and should be treated as a separate entity on the species level. Priority is therefore given to the name *S. balatonis*, instead of the two varieties.

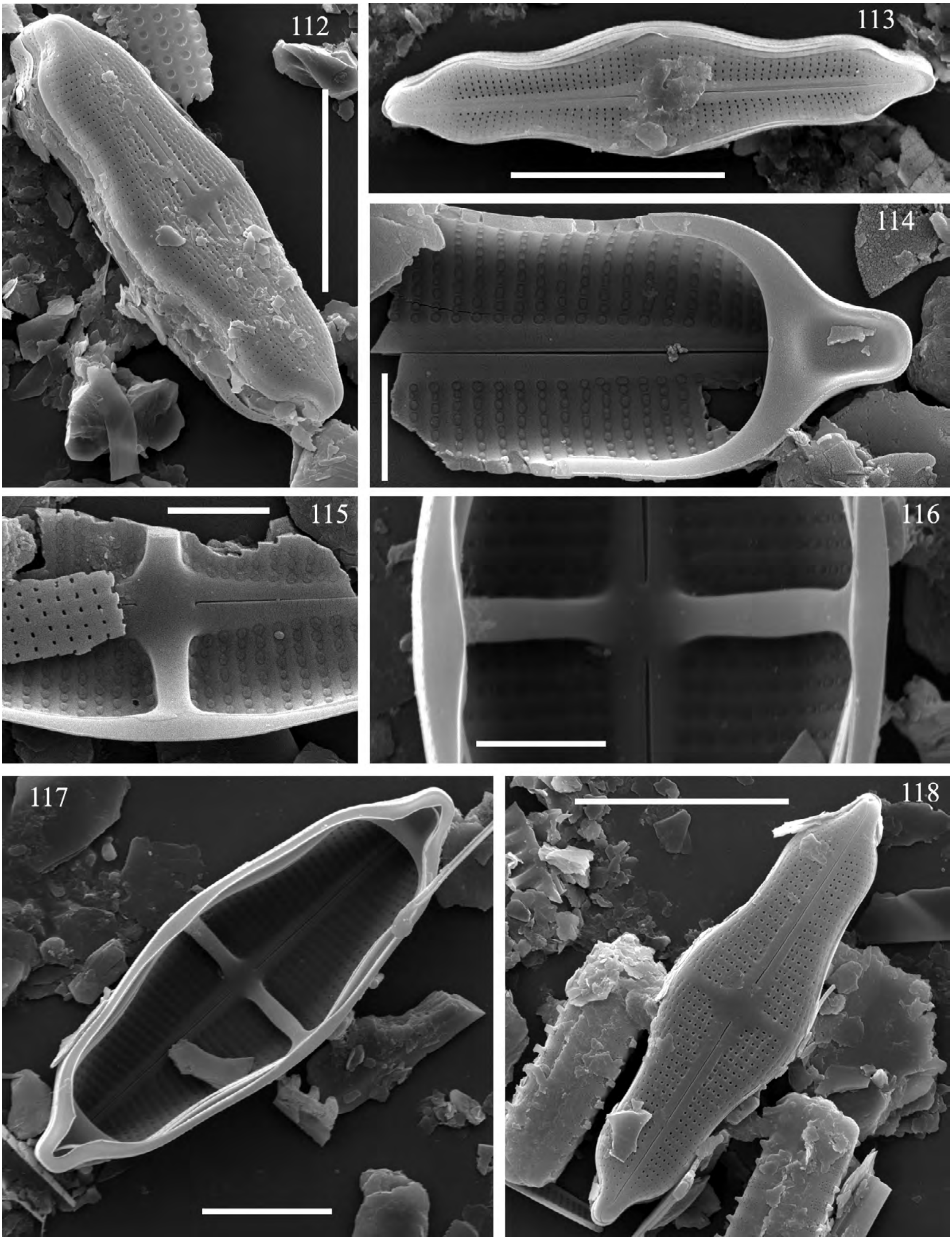
Two morphotypes of the species *S. balatonis* were observed in the present study. The first morphotype (Figs. 64–84) was observed in the contemporary flora of Lake Ohrid and is characterised by larger valves than in the second morphotype (Figs. 85–89), which was observed in core samples of sediment from Lake Prespa. Differences between these two morphotypes are especially noticeable in the smaller specimens: whereas the first morphotype has valves with an elliptical outline, the second one has rhombic-lanceolate valves. Since these features are not clearly distinctive, we consider that such differences most likely reflect a form of morphological plasticity of the species. There are several examples where the same species observed in Lakes Ohrid and Prespa have slightly different morphometric characteristics (Levkov *et al.* 2007).

Stauroneis prominula **(Grunow) Hustedt (Figs. 90–96).** Frustule in girdle view rectangular. Valves linear to linear-lanceolate with abruptly protracted apices. In smaller specimens valves slightly constricted in the middle. Valve length 26.0–37.5 µm, valve width 3.5–5.5 µm. Pseudosepta distinct, present at both poles, reaching base of valve ends. Axial area very narrow, slightly widened towards valve central area. Central area with distinct stauros, narrow, not expanded towards valve margins. Raphe fissures almost straight, filiform. Transapical striae fine, indistinctly punctate, parallel throughout, 28–30 in 10 µm. Striae uniseriate composed of small, round areolae. Areolae hardly discernible in LM, about 40 in 10 µm.

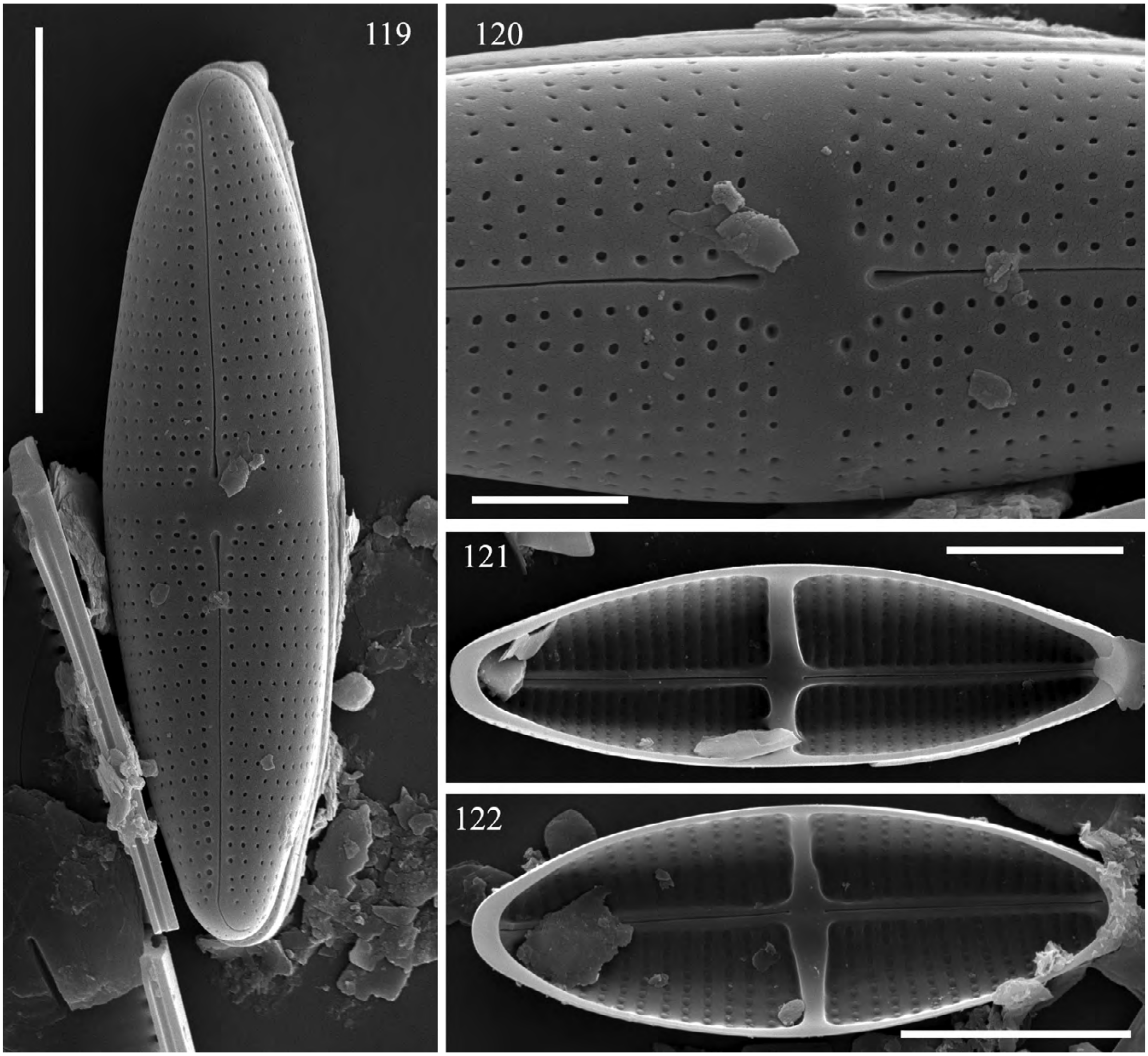
Distribution and ecology: *Stauroneis prominula* has been infrequently recorded in Macedonia. There are a



Figs. 64–111. Light micrographs (LM) of three different *Stauroneis* species. Figs. 64–84. Diminution series of an extant population of *S. balatonis* from Lake Ohrid. Figs. 85–89. Diminution series of a fossil population of *S. balatonis* from Lake Prespa. Figs. 90–96. Diminution series of *S. prominula* from various habitats. Figs. 97–104. Diminution series of an extant population of *S. borgei* from Lake Ohrid. Figs. 105–111. Diminution series of a fossil population of *S. borgei* from Lake Prespa. Scale bar = 10 µm.



Figs. 112–118. Scanning electron microscope (SEM) microphotographs of two *Stauroneis* species. Figs. 112–115. SEM microphotographs of *S. smithii*. Figs. 116–118. SEM microphotographs of *S. blazenciciae*. Figs. 112, 113. External view of the whole valve. Fig. 114. Internal view of the valve end showing the well developed pseudosepta. Figs. 115, 116. Internal view of the mid-valve showing the strongly thickened stauros and the proximal raphe endings. Fig. 117. Internal view of the whole valve. Fig. 118. External view of the whole valve. Scale bar = 10 µm in Figs. 112, 113, 118; 5 µm in Fig. 117; 2 µm in Figs. 114–116.



Figs. 119–122. Scanning electron microscope (SEM) microphotographs of *S. borgei*. Fig. 119. External view of the whole valve. Fig. 120. Detailed view of the mid-valve showing the central area and the proximal raphe endings. Figs. 121, 122. Internal view of the whole valve. Scale bar = 10 µm in Fig. 119; 2 µm in Fig. 120; 5 µm in Figs. 121, 122.

few records of this species from an unnamed river in Mariovo, a small pond and an unnamed river on Kozuf Mountain, a spring on Mt. Pelister and the Kozjak River. In all observed samples, *S. prominula* is extremely rare (with 1–3 observed valves per slide).

Stauroneis borgei **Manguin (Figs. 97–111, 119–122).** Valves linear lanceolate, to lanceolate elliptical-lanceolate and slightly dorsiventral with rounded to narrowly rounded apices (Fig. 119). Valve length 15.0–17.0 µm, valve width 4.0–6.0 µm. Pseudosepta present at both poles small, indistinct (Figs. 121, 122). Axial area very narrow, slightly widened near valve central area. Central area with distinct stauros, narrow, not expanded towards valve margins (Fig. 120). Central area (stauros) externally flat, while internally strongly thickened inwardly (Figs. 121, 122). Raphe fissures almost straight, filiform. Externally, proximal raphe ends straight and expanded into proximal pores shaped like a tear drop (Fig. 120). Internally, proximal ends straight, terminating just before the strongly thickened stauros (Figs. 121, 122). Externally, distal raphe ends deflected, strongly curved in same direction, extending onto valve mantle (Fig. 119). Transapical striae finely punctate, parallel throughout, 24–28 in 10 µm. Striae uniseriate, composed of small, round to slightly elongated areolae (Figs. 119, 120).

Internally, areolae occluded with hymens (Figs 121, 122). Areolae hardly discernible in LM, about 45–50 in 10 µm.

Distribution and ecology: *Stauroneis borgei* was observed from Lakes Ohrid and Prespa. It usually occurred on a sandy substrate close to the shore (at a water depth of 1–3 m).

Remarks: *Stauroneis borgei* appears quite similar to *S. smithii* var. *elliptica* Hustedt (Husted 1945, p. 914; figs. 42: 34–36), which is described from Lake Ohrid. Hustedt (1959) considered the latter taxon to be a synonym of *S. borgei* Manguin (in Allorge & Manguin 1941, p. 179, fig. 69). However, in previous studies (Levkov *et al.* 2007, Levkov & Williams 2012), it was still treated as a separate entity. After observing the type materials, we conclude that both taxa share many characters and should be considered conspecific, with priority given to *S. borgei*.

As in the case of *S. balatonis*, two morphotypes of *S. borgei* were observed in the present study. The population from Lake Ohrid (Figs. 97–104) has slightly broader valves (4.5–6.0 µm) with rounded apices, while the population from Lake Prespa (Figs. 105–111) has narrower (4.0–5.0 µm), slightly dorsiventral valves with more pointed apices.

CONCLUSIONS

Six species from the *S. smithii* complex have been observed in Macedonia. They occurred in various habitats: slightly acidic high-mountain peat-bogs, meso- to eutrophic ponds and rivers and the oligotrophic ancient Lake Ohrid. Two species, *S. borgei* and *S. balatonis*, have also been observed from fossil records of Lakes Ohrid and Prespa. One new species, *S. blazenciciae*, is described in the present study. The species is characterised by lanceolate to elliptical-lanceolate valves with weakly undulated margins and abruptly protracted to acute apices. The given species is comparable with *S. smithii* and *S. smithii* var. *karelica*, but can be differentiated from the latter taxa by the valve shape and stria density. *Stauroneis blazenciciae* was recorded from several localities in the Shar Mountains and on Mt. Jablanica, where it occurrs in oligotrophic high-mountain (over 1900 m asl) habitats such as glacial lakes, peat-bogs and streams.

Acknowledgement — This research received support from the SYNTHESYS Project http://www.synthesys.info/, which is financed by European Community Research Infrastructure Action under the FP7 Integrating Activities Programme.

REFERENCES:

Allorge P & Manguin E. 1941. Algues d'eau douce des Pyrénées basques. *Bulletin de la Société Botanique de France* **88**(1): 159–191.

Bahls LL. 2010. *Stauroneis* in the Northern Rockies: 50 species of *Stauroneis* sensu stricto from western Montana, northern Idaho, northwestern Washington and southwestern Alberta, including 16 species described as new. *Northwest Diatoms* **4**: 1–173.

Bahls LL. 2012. Five new species of *Stauroneis* (Bacillariophyta, Stauroneidaceae) from the northern Rocky Mountains, USA. *Phytotaxa* **67**: 1–8.

Boyer CS. 1928. Synopsis of the North American Diatomaceae **1-2**. *Proceedings of the Academy of Natural Sciences of Philadelphia* **78**: 1–583.

Cleve-Euler A. 1939. Bacillariaceen-Assoziationen im Nördlichsten Finnland. *Acta Societatis Scientiarum Fennicae, Nova Series B. Helsingfors, Akademische Buchhandlung* **2**(3):1–41.

Cleve-Euler A. 1953. Die Diatomeen von Schweden und Finnland. Part III. Monoraphideae, Biraphideae 1. Kongliga *Svenska Vetenskaps-Akademiens Handligar, ser. 4*, **4**(**5**):1–255.

Cvetkoska A, Jovanovska E, Francke A, Tofilovska S, Vogel H, Levkov Z, Donders TH, Wagner B & Wagner-Cremer F. 2016. Ecosystem regimes and responses in a coupled ancient lake system from MIS 5b to present: the diatom record of lakes Ohrid and Prespa. *Biogeosciences* **13**: 3147–3162.

Ehrenberg GC.1843. Mittheilungen über 2 neue asiatische Lager fossiler Infusorien-Erden aus dem russischen Trans-Kaukasien (Grusien) und Sibirien. *Bericht über die zur Bekanntmachung geeigneten Verhandlungen der Königlich-Preussischen Akademie der Wissenschaften zu Berlin* 43–49.

Falasco E, Bona F, Isaia M, Piano E, Wetzel CE, Hoffmann L & Ector L. 2015. *Nupela troglophila* sp. nov., an aerophilous diatom (Bacillariophyta) from the Bossea cave (NW Italy), with notes on its ecology. *Fottea* **15**(1): 1–9.

Fourtanier E & Kociolek JP. 2011. *Catalogue of diatom names*. California Academy of Sciences. Available at http://research.calacademy.org/research/diatoms/names/index.asp

Fusey P. 1948. Contribution à la flore algologique du Jura. **I**. Florule algologique de la Tourbière de Frasne (Doubs). *Revue Générale de Botanique* **55**: 338–359.

Grunow A. 1860. Ueber neue oder ungenügend gekannte Algen. Erste Folge, Diatomeen, Familie Naviculaceen. *Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien* **10**: 503–582.

Haworth EY. 1974. Some problems of diatom taxonomy in Scottish Lake sediments. *British Phycological Journal* **9**(1):47–55.

Hirano M. 1971. Freshwater Algae of the Northwestern Himalayas. *Contributions from the Biological Laboratory, Kyoto University* **23**(2): 81–100.

Hustedt F. 1930. *Die Süsswasser-Flora Mitteleuropas (Jena). **10**: Bacillariophyta (Diatomeae)*, Verlag von Gustav Fischer.

Hustedt F. 1945. Diatomeen aus Seen und Quellgebieten der Balkan-Halbinsel. *Archiv für Hydrobiologie* **40**(4): 867–973.

Hustedt F. 1957. Die Diatomeenflora des Flußsystems der Weser im Gebiet der Hansestadt Bremen. *Abhandlungen des Naturwissenschaftlichen Verein zu Bremen* **34**(3): 181–440

Hustedt F. 1959. Die Kieselalgen Deutschlands, Österreichs und der Schweiz unter Berücksichtigung der übrigen Länder Europas sowie der angrenzenden Meeresgebiete. In: Rabenhorst L (ed.), *Kryptogamen Flora von Deutschland, Österreich und der Schweiz*, pp. 737–845, Akademische Verlagsgesellschaft m.b.h. Leipzig.

Joh G. 2014. Diatom flora of genus *Stauroneis* (Bacillariophyta) from mainly the mountain peatlands of Korea. *Journal of ecology and environment* **37(4)**: 257–270.

Jovanovska E, Cvetkoska A, Hauffe T, Levkov Z, Wagner B, Sulpizio R, Francke A, Albrecht C & Wilke T. 2016. Differential resilience of ancient sister lakes Ohrid and Prespa to environmental disturbances during the Late Pleistocene. *Biogeosciences* **13**: 1149–1161.

Jovanovska E, Nakov T & Levkov Z. 2013. Observations of the genus *Diploneis* (Ehrenberg) Cleve from Lake Ohrid, Macedonia. *Diatom Research* **28**(3): 237-262.

Jurilj A. 1954. Flora and vegetation of diatoms from Ohrid Lake in Yugoslavia. *Prirodoslovnih istraživanja* **26**: 99–190.

Jüttner I, Williams DM, Levkov Z, Falasco E, Battegazzore M, Cantonati M, Van de Vijver B, Angele C & Ector L. 2015. Reinvestigation of the type material for *Odontidium hyemale* (Roth) Kützing and related species, with description of four new species in the genus *Odontidium* (Fragilariaceae, Bacillariophyta). *Phytotaxa* **234**(1): 1–36.

Khursevich GK & Loginova LP. 1980. *The fossil diatom flora of Belarus (the systematic review)*. Nauka i tekhnika Minsk.

Kobayasi H & Ando K. 1978. New species and new combinations in the genus *Stauroneis*. *Japanese Journal of Phycology* **26**: 13–18.

Krammer K & Lange-Bertalot H. 1986. Bacillariophyceae, **1**. Teil: Naviculaceae. In: Ettl H, Gerloff J, Heying H & Mollenhauer D (eds.), *Süßwasserflora von Mitteleuropa* **2/1**, pp. 876, Gustav Fischer, Stuttgart.

Krasske K. 1932. Diatomeen aus dem Oberpliocän von Willershausen. *Archiv für Hydrobiologie* **24**(3): 431–448.

Lange-Bertalot H & Metzeltin D. 1996. Indicators of oligotrophy - 800 taxa representative of three ecologically distinct lake types, Carbonate buffered - Oligodystrophic - Weakly buffered soft water. *Iconographia Diatomologica* **2**: 1–390.

Levkov Z. 2009. *Amphora sensu lato. Diatoms of Europe, Diatoms of the European Inland waters and comparable habitats*, Vol. **5**. A.R.G. Gantner Verlag, Ruggell.

Levkov Z, Krstic S, Metzeltin D & Nakov T. 2007. Diatoms of Lakes Prespa and Ohrid (Macedonia). *Iconographia Diatomologica* **16**: 1–603.

Levkov Z, Krstic S, Nakov T & Melovski Lj. 2005. Diatom assemblages on Shara and Nidze Mountains, Macedonia. *Nova Hedwigia* **81**(3–4): 501–538.

Levkov Z, Metzeltin D & Pavlov A. 2013. *Luticola* and *Luticolopsis*. *Diatoms of Europe*, *Diatoms of the European Inland waters and comparable habitats* Vol **7**. Koeltz Science Books.

Levkov Z & Williams DM. 2012. Checklist of diatoms (Bacillariophyta) from Lake Ohrid and Lake Prespa (Macedonia), and their watersheds. *Phytotaxa* **45**: 1–76.

Loseva EI. 1982. *Atlas of late Pliocene diatoms of the Kama region*. Union for Quaternary Research. Congress 1982, Moscow.

Mereschkowsky C. 1906. *Diatomées du Tibet. Imperial Russkoe geograficheskoe obshchestvo*. St. Petersburg.

Moisseeva AI. 1967. Continental Neogene diatoms from the South of the Far East and their straigraphic significance. In: Martinson GG (ed.), *Stratigraphy and Paleontology of Mesozoic and Paleogene-Neogene continental deposits from the Asian part of the U.S.S.R.*, pp. 267–280, Leningrad, Nauka.

Moisseeva AI. 1971. *Atlas Neogenovykh Diatomovykh Vodoroslei Primorskoga Kriya*. Trudy Vsesoiunogo neftianogo nauchno-issledovatelskogo geologo-razvedochnogo instituta (VSEGEI) **171**: 152 pp.

Pantocsek J. 1902. *Kieselalgen oder Bacillarien des Balaton. Resultate der Wissenschaftlichen Erforschung des Balatonsees, herausgegeben von der Balatonsee-Commission der Ung. Geographischen Gesellschaft.* Commissionsverlag von Ed. Hölzel. Wien.

Pavlov A, Jovanovska E, Wetzel CE, Ector L & Levkov Z. 2016. Freshwater *Mastogloia* (Bacillariophyceae) taxa from Macedonia, with a description of the epizoic *M. sterijovskii* sp. nov. *Diatom Research* **31**(2): 1–29.

Pavlov A & Levkov Z. 2013. Diversity and distribution of *Eunotia* Ehrenberg in Macedonia. *Phytotaxa* **86**: 1–117.

Pavlov A, Levkov Z, Williams DM & Edlund MB. 2013. Observations on *Hippodonta* (Bacillariophyceae) in selected ancient lakes. *Phytotaxa* **90**: 1–53.

Petrovska Lj & Stojanov P. 1976. Contribution to the knowledge of algal microflora of wet rocks on mountains Osogovo and Plachkovica. *Godišen Zbornik Biologija* **29**: 229–238.

Round FE, Crawford RM & Mann DG 1990. *The diatoms: Biology and Morphology of the genera*. Cambridge University Press, Cambridge.

Skvortzow BW. 1936. Diatoms from Kizaki Lake, Honshu Island, Nippon. *Philippine Journal of Science* **61**(1): 9–73.

Stojanov P. 1982. Diatom microflora in some water ecosystems on mountain Jakupica, Macedonia. *Godišen Zbornik Biologija* **35**: 115–129.

Stojanov P. 1983. Diatom flora in peat-bogs in National Park Mavrovo. *Godišen Zbornik Biologija* **36**: 87–94.

Stojanov P & Petrovska Lj. 1980. Algal flora in peat-bogs in Eastern Macedonia (Bukovic – Pehchevo). *Godišen Zbornik Biologija* **33**: 143–158.

Temniskova-Topalova D & Ognjanova-Rumenova N. 1997. Description, comparison and biostratigraphy of the nonmarine Neogene diatom floras from Southern Bulgaria. *Geologica Balcanica* **27**(1–2): 57–81.

Tynni R. 1982. The reflection of geological evolution in Tertiary and interglacial diatoms and silicoflagellates in Finnish Lapland. *Geological Survey of Finland Bulletin* **320**: 1–40.

Van de Vijver B, Beyens L & Lange-Bertalot H. 2004. The genus *Stauroneis* in the Arctic and (Sub-) Antarctic Regions. *Bibliotheca Diatomologica* **51**: 1–317.

Van de Vijver B, Gremmen NJM & Beyens L. 2005. The genus *Stauroneis* (Bacillariophyceae) in the Antarctic region. *Journal of Biogeography* **32**: 1791–1798.

Werum M & Lange-Bertalot H. 2004. Diatoms in springs from Central Europe and elsewhere under the influence of hydrologeology and anthropogenic impacts. *Iconographia Diatomologica* **13**: 3–417.

Wislouch SM & Kolbe RW. 1916. Novye diatomovye vodorosli iz vodoemov Rossii. *Zhurnal Mikrobiologii* **3**(3–4): 263–275.

Wislouch SM & Kolbe RW. 1927. Materialy po diatomovym Onezhskogo i Lososinskogo ozer. *Trudy Olonetzkoi nauchnoi ekspeditsii, gosudarstvennyi gidrologicheskii institut* **5**(1): 3–66.

Zidarova R, Kopalová K & Van de Vijver B. 2014. The genus *Stauroneis* (Bacillariophyta) from the South Shetland Islands and James Ross Island (Antarctica). *Fottea* **14**(2): 201–207.

Botanica SERBICA

REZIME

Revizija kompleksa vrste *Stauroneis smithii* Grunow (Bacillariophyceae) iz Makedonije

Zlatko Levkov, Slavica Tofilovska, Elena Jovanovska, Aleksandra Cvetkoska i Ditmar Metzeltin

Stauroneis smithii se smatrala široko rasprostranjenim i vrlo varijabilnim kompleksom. Do sada je opisano više od 20 infraspecijskih taksona. U ovoj studiji je razmatrano 6 članova ovog kompleksa. *Stauroneis smithii* je široko rasprostranjen u Makedoniji, zabeležen na različitim tipovima vodenih staništa. Manje morfološke varijacije su uočene između populacija nađenih na oligotrofnim, blago kiselim staništima i mezo- do eutrofnim jezerima i rekama. *Stauroneis separanda* i *S. prominula* su retko bili zabeleženi na planinskim staništima i često sa malom brojnošću. U predhodnim studijama *Stauroneis borgei* i *S. balatonis* su nađene kako u savremenoj flori, tako i u fosilnim nalazima dijatomeja iz jezera Ohrid i Prespa. U ovim studijama su ove dve vrste identifikovane kao varijeteti *S. smithii*, odnosno kao *elliptica* i *incisa*. Tokom ovih studija uočena je jedna vrsta sa jedinstvenim morfološkim karakteristikama i ona je ovde opisana kao nova, *Stauroneis blazenciciae* sp. nov. Nova vrsta se lako može razlikovati od *S. smithii* po obliku valve: eliptično-lancetaste sa slabo talasastim marginama kod najvećeg broja predstavnika, do linearno-lancetastih sa marginama valve koje se postepeno sužavaju ka naglo produženim do uglastim vrhovima.

Ključne reči: Dijatomeje, Makedonija, nova vrsta, *Stauroneis blazenciciae*, *Stauroneis smithii* kompleks