

Diatoms of the genus *Navicula* from waterbodies of the Voronezh Region, Russia

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Abstract. The diversity of the genus *Navicula* including 29 species, one species new to science (*Navicula trophicatrixoides* Chudaev, sp. nov.), one new to the flora of Russia (*N. alineae*), and 15 species new for the Voronezh Region, is documented from waterbodies located in the museum-reserve “Divnogorye” and areas in its vicinity. It is supposed that *N. antonii* as currently understood represents a complex with at least two semicryptic species. The most frequent taxa in the studied materials are *Navicula* cf. *antonii*, *N. capitatoradiata* and *N. cryptotenella*. The majority of the species found prefer waters with higher electrolyte content.

Keywords: diatoms, *Navicula*, Voronezh Region, Don basin, diversity, new records, new species.

Диатомовые водоросли рода *Navicula* из водных объектов Воронежской области, Россия

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Резюме. В результате изучения проб из водных объектов музея-заповедника «Дивногорье» и прилегающих территорий было выявлено 29 видов диатомовых водорослей рода *Navicula*, в том числе один вид, новый для науки (*Navicula trophicatrixoides* Chudaev, sp. nov.), один — новый для флоры России (*N. alineae*), и 15 — новых для Воронежской обл. Выдвинуто предположение, что вид *N. antonii* в современной трактовке представляет собой комплекс минимум из 2 семикриптических видов. Наиболее частыми в исследованных материалах являются *Navicula* cf. *antonii*, *N. capitatoradiata*, *N. cryptotenella*. Основная масса обнаруженных видов предпочитает воды с повышенным содержанием электролитов.

Ключевые слова: диатомовые водоросли, *Navicula*, Воронежская область, бассейн Дона, разнообразие, новые находки, новые виды.

The museum-reserve “Divnogorye” is an area to protect and enhance natural, architectural and archaeological heritage of the Liskinsky District in the Voronezh Region and is located at the confluence of the rivers Tikhaya Sosna and Don. The physico-geographical and geological characteristics of the area have been studied and described, for example, in the monograph by Berezhnoi *et al.* (1994). However, the diatoms of the diverse water bodies of the museum-reserve have until now not

been studied in detail. There is only one study that found three species of diatoms belonging to the genera *Hantzschia* Grunow, *Humidophila* (Lange-Bert. et Werum) R. L. Lowe, Kociolek, J. R. Johansen, Van de Vijver, Lange-Bert. et Kopalová and *Tabellaria* Ehrenb. ex Kütz. in chalk caves (Mazina *et al.*, 2016). With respect to the genus *Navicula* s. str. in the Voronezh Region references to 24 taxa can be found in the literature: *N. capitatoradiata* H. Germ. ex Gasse (= *N. cryptocephala* var. *intermedia* Grunow), *N. cari* Ehrenb., *N. cincta* (Ehrenb.) Ralfs, *N. cryptocephala* Kütz., *N. cryptocephala* var. *hankensis* Skvortsov, *N. cryptocephala* var. *lata* Poretzky et Anisimova, *N. gottlandica* Grunow, *N. gregaria* Donkin, *N. hasta* Pant., *N. johnsoni* D. M. Williams [= *N. lanceolata* var. *cymbula* (Donkin) Cleve], *N. lanceolata* (C. Agardh) Ehrenb., *N. lanceolata* var. *tenella* Cleve, *N. lanceolata* var. *tenuirostris* Skvortsov, *N. menisculus* Schum., *N. meniscus* Schum., *N. oblonga* (Kütz.) Kütz., *N. radiosa* Kütz., *N. reinhardtii* (Grunow) Grunow, *N. rhynchocephala* Kütz., *N. rhynchocephala* var. *hankensis* Skvortsov, *N. rostellata* Kütz., *N. tripunctata* (O. F. Müll.) Bory (= *N. gracilis* Ehrenb.), *N. veneta* Kütz. [= *N. cryptocephala* var. *veneta* (Kütz.) Rabenh.], *N. viridula* (Kütz.) Ehrenb., *N. vulpina* Kütz. (Antsiferova, 2005; Antsiferova *et al.*, 2006, 2014; Antsiferova, Bespalova, 2016). Most of the records belong to the Khopersky Nature Reserve (Antsiferova *et al.*, 2014) but the species were not illustrated.

Material and methods

Material for the study was collected by D. A. Chudaev in the territory of the State Budgetary Institution of Culture "Natural, architectural and archaeological museum-reserve "Divnogorye", as well as in its surrounding areas from 6 to 12 VI 2016 during a practical for students of the Faculty of Biology of Moscow State University. Most samples were either washings from aquatic plants or bottom sediments from the Tikhaya Sosna and Don rivers. The samples were preserved immediately at the collection site with a 4% formaldehyde solution. A total of 12 samples were taken and analyzed. All samples are stored at the diatom collection of the Department of Mycology and Algology, Faculty of Biology, Moscow State University. The numbers listed below correspond to their numbers in the collection.

List of samples analyzed in this study

Voronezh Region, Liskinsky District, vicinities of Divnogorye Khutor: 513 – Tikhaya Sosna River, 50.96425°N, 39.29216°E, bottom sediment near bank among the reeds, 6 VI 2016; 514 – Tikhaya Sosna River, 50.97606°N, 39.30282°E, washings from *Cladophora* from lime stones at rift, 7 VI 2016; 515 – Don River, 50.98135°N, 39.31021°E, bottom sediment on clay ground under high clay bank, 7 VI 2016; 516 – Don River, 50.98135°N, 39.31021°E, washings from *Cladophora*, 7 VI 2016; 517 – Don River, 50.98132°N, 39.31142°E, bottom sediment among the reeds on clay ground, 7 VI 2016; 518 – Tikhaya Sosna River, 50.97500°N, 39.30010°E, bottom sediment in a creek among aquatic plants (mainly *Butomus*), 7 VI 2016; 519 – Tikhaya Sosna River, 50.95556°N, 39.26858°E, washings from *Myriophyllum*, 7 VI 2016; 520 – oxbow in floodplain of Tikhaya Sosna River, 50.96646°N, 39.23004°E, washings from plants, 7 VI 2016; 521 – Tikhaya Sosna River, 50.97600°N, 39.30281°E, washings from mosses from limestones at rift, 9 VI 2016; 522 – Tikhaya

Sosna River, 50.97539°N, 39.29934°E, scrapings from *Glyceria maxima*, creek with almost no current, 9 VI 2016; 523 — Tikhaya Sosna River, 50.95321°N, 39.24820°E, bottom sediment on sandy ground, creek, 10 VI 2016; 524 — Don River, 50.98157°N, 39.30863°E, bottom sediment, creek with *Butomus* and *Sagittaria*, 12 VI 2016.

Cleaning of the material from organic matter was carried out by heating the sample in concentrated hydrogen peroxide, followed by the addition of several drops of hydrochloric acid and repeated washing with distilled water by centrifugation (Kelly *et al.*, 2001). Naphrax® was used for the preparation of slides. The slides were studied using a Leica DM2500 light microscope (LM) equipped with an immersion planapochromatic lens with a magnification of $\times 100$ and a 1.40 numeric aperture, and a Leica DFC495 digital camera. The slide number 517 was studied with a Leica DM750 LM, with a planachromatic lens with an aperture of 1.25 and a Leica EC3 camera. Scanning electron microscopy (SEM) was performed using a JEOL JSM-6380LA 20kV microscope. The obtained digital micrographs were processed with the ImageJ 1.45s and GIMP 2.10.10 computer programs. The density of the striae was counted along the raphe branch on the primary side of the valve. The length of the segment containing 10 striae was determined, followed by the conversion of the number of striae in 10 μm . The density of areolae was determined within the striae adjacent to the central area on the primary side of the valve.

Results

Below we list the species of *Navicula* found in the studied materials. For each taxon, morphometric measurements are given, and it is indicated in which samples they were recorded.

“**” marks species new to the Voronezh Region.

****Navicula alineae* Lange-Bert.** (Plate I: 1–2)

Valve length 42.0–43.0 μm , width 9.1–9.2 μm , striae 10.8–10.9/10 μm . Samples 518, 522.

****N. amphiceropsis* Lange-Bert. et Rumrich** (Plate I: 3–7)

Valve length 29.4–37.0 μm , width 8.5–9.0 μm , striae 10.9–11.6/10 μm , areolae 29–31/10 μm . Samples 514, 516, 517, 519, 523.

****N. antonii* Lange-Bert.** (Plate I: 8–13)

Valve length 13.2–26.3 μm , width 6.3–7.5 μm , striae 12.3–14.3/10 μm , areolae 30–33/10 μm . Samples 517, 519, 523.

***Navicula* cf. *antonii* Lange-Bert.** (Plate I: 14–19)

Valve length 14.8–24.6 μm , width 5.9–6.6 μm , striae 10.9–12.8/10 μm , areolae 31–35/10 μm . Samples 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524.

Differences with *N. antonii* are difficult to describe clearly, but are revealed by comparing the series of microphotographs of the two species.

N. capitatoradiata H. Germ. ex Gasse (Plate I: 20–23)

Valve length 29.8–37.4 μm , width 7.1–8.2 μm , striae 12.3–14.5/10 μm , areolae 33–36/10 μm . Samples 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524.

N. cari Ehrenb. (Plate II: 1–4)

Two morphotypes of this species, separated by Lange-Bertalot (2001), present in our material.

Morphotype 1 (Plate II: 1–2). Valve length 28.6–30.5 μm , width 6.5–7.2 μm , striae 10.1–10.5/10 μm . Sample 513.

Morphotype 2 (Plate II: 3–4). Valve length 22.6–25.5 μm , width 5.7–5.9 μm , striae 10.3–11.6/10 μm , areolae 33–35/10 μm . Samples 517, 519, 522.

N. cryptocephala Kütz. (Plate II: 5–10)

Valve length 21.7–37.1 μm , width 4.8–6.0 μm , striae 14.6–16.3/10 μm . Samples 518, 520, 523.

N. cryptotenella Lange-Bert. (Plate II: 11–17)

Valve length 14.5–31.6 μm , width 4.6–6.0 μm , striae 12.9–14.9/10 μm , areolae 33–36/10 μm . Samples 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524.

N. gregaria Donkin (Plate II: 18–23)

Valve length 16.2–26.3 μm , width 4.9–6.5 μm , striae 16.4–19.6/10 μm , areolae 27–34/10 μm . Samples 513, 514, 515, 516, 517, 518, 523.

N. lanceolata (C. Agardh) Ehrenb. (Plate II: 24–26)

Valve length 44.7–58.6 μm , width 9.9–11.3 μm , striae 10.9–11.4/10 μm , areolae 32–33/10 μm . Samples 515, 516, 517.

***N. libonensis** Schoeman (Plate III: 1–3)

Valve length 29.0–34.9 μm , width 6.4–6.8 μm , striae 11.6–12.0/10 μm , areolae 28–30/10 μm . Samples 516, 517, 520, 523, 524.

***N. moskalii** Metzeltin, Witkowski et Lange-Bert. (Plate III: 7–8)

Valve length 23.2–26.6 μm , width 6.8–7.5 μm , striae 12.3–13.0/10 μm , areolae 32/10 μm . Samples 517, 520.

***N. novasiberica** Lange-Bert. (Plate III: 4–6)

Valve length 28.5–36.6 μm , width 7.6–8.1 μm , striae 9.7–10.4/10 μm , areolae 31/10 μm . Samples 515, 516, 517, 524.

N. oblonga (Kütz.) Kütz. (Plate III: 19)

Valve length 111.1–117.5 μm , width 16.1–17.6 μm , striae 6.6–6.8/10 μm , areolae 29–31/10 μm . Samples 518, 523.

***N. oppugnata** Hust. (Plate III: 9–10)

Valve length 32.3–35.2 μm , width 9.0–9.4 μm , striae 9.3–9.8/10 μm , areolae 24/10 μm . Samples 519, 524.

***Navicula pseudowiesneri** Chudaev et Kulikovskiy (Plate III: 11–16)

Valve length 19.1–27.5 μm , width 4.9–5.5 μm , striae 11.6–12.8/10 μm . Samples 513, 514, 518, 519, 521, 523.

N. radiosua Kütz. (Plate III: 17–18)

Valve length 44.2–102.4 μm , width 9.7–12.1 μm , striae 9.6–10.7/10 μm , areolae 32–33/10 μm . Samples 513, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524.

***N. reichardtiana** Lange-Bert. (Plate IV: 1–4)

Valve length 13.3–19.0 μm , width 4.7–5.4 μm , striae 15.1–16.4/10 μm . Samples 513, 514, 515, 516, 517, 518, 522, 523.

N. reinhardtii (Grunow) Grunow (Plate IV: 5–6)

Valve length 32.8–51.0 μm , width 14.8–16.0 μm , striae 7.4–8.9/10 μm , areolae 22–23/10 μm . Samples 513, 514, 515, 516, 517, 518, 519, 524.

***N. rhynchotella** Lange-Bert. (Plate IV: 9–10)

Valve length 49.4–53.4 μm , width 12.4–12.6 μm , striae 9.6–10.0/10 μm , areolae 22/10 μm . Samples 513, 518, 523.

***N. slesvicensis** Grunow (Plate IV: 7–8)

Valve length 32.4–53.9 μm , width 9.6–10.6 μm , striae 8.7–9.0/10 μm , areolae 24–26/10 μm . Samples 513, 514, 516, 517, 518, 519, 520, 522, 523, 524.

***N. streckerae** Lange-Bert. et Witkowski (Plate IV: 11–15)

Valve length 27.3–44.7 μm , width 7.8–8.7 μm , striae 10.7–11.2/10 μm , areolae 21–23/10 μm . Samples 513, 514, 516, 517, 518, 521, 523.

N. tripunctata (O. F. Müll.) Bory (Plate V: 1–3)

Valve length 37.9–75.1 μm , width 7.8–8.9 μm , striae 9.5–10.3/10 μm , areolae 33–36/10 μm . Samples 513, 514, 515, 516, 517, 518, 519, 521, 522, 523, 524.

***N. trivialis** Lange-Bert. (Plate V: 4–7)

Valve length 29.6–55.1 μm , width 8.2–12.1 μm , striae 11.0–12.5/10 μm , areolae 28–30/10 μm . Samples 513, 514, 516, 517, 518, 520, 521, 522, 523, 524.

***Navicula trophicatrixoides** Chudaev, sp. nov. (Plate V: 8–18; VII: 1–2)

LM. Valves lanceolate with acutely rounded, sometimes slightly protracted ends, length 27.3–37.5 μm , width 5.6–6.7 μm , length to width ratio 4.5–5.6. Axial area very narrow, slightly widening towards valve centre; central area small, indistinct, variable in shape. Striae radiate, becoming parallel only close to the poles, 11.9–13.6/10 μm , in valve centre striae distinctly more widely spaced. Areolae are well distinguishable

in LM, 26–29/10 µm. Raphe filiform to narrowly lateral, straight; terminal fissures indistinct, curved to the secondary valve side; central pores clearly deflected to the secondary valve side.

SEM, external valve surface. Areolae apically elongate, areola openings at the same level as valve surface, near the apices connected by very shallow furrows. Apical areolae not discernible. Raphe-sternum elevated above valve surface. Raphe branches straight. Central raphe endings of complex structure with a small projection at the proximal margin and a larger lateral projection. Terminal raphe fissures curved to the secondary valve side.

SEM, internal valve surface. Striae lie almost at same level as virgae, virgae are wider than striae. Areolae occluded with hymenes, two isolated areolae present at valve apex. Raphe opens obliquely to secondary valve side, raphe slits discernible only near centre and apices. Accessory rib very poorly developed, completely absent at centre. Central raphe endings simple, straight, connected with a very shallow furrow. Distal raphe endings well developed straight helictoglossae.

Diagnosis. *N. trophicatrixoides* differs from all taxa of the group around *N. trophicatrix* Lange-Bert. (*N. krsticci* Levkov, *N. mitrofanovae* Metzeltin, Kulikovskiy et Lange-Bert., *N. praeterita* Hust., *N. subtrophicatrix* Tuji, *N. trophicatrix* Lange-Bert. subsp. *trophicatrix*, *N. trophicatrix* ssp. *vixtrophicatrix* Kulikovskiy, Lange-Bert. et Metzeltin, *N. usoltsevae* Metzeltin, Kulikovskiy et Lange-Bert.) by more densely spaced areolae (26–29/10 µm).

Holotype: specimen depicted on Plate V: 10, from slide 518s1, diatom collection of the Department of Mycology and Algology, Faculty of Biology, Lomonosov Moscow State University, Moscow.

Type locality: Russia, Voronezh Region, Liskinsky District, vicinities of Divnogorye Khutor, Tikhaya Sosna River, 50.97500°N, 39.30010°E, bottom sediment in small creek, 7 VI 2016, D. A. Chudaev.

Distribution. The species has so far been recorded only from the Tikhaya Sosna River (samples 513, 514, 518, 521, 522, 524).

Etymology: The name is given due to the similarity with *Navicula trophicatrix*.

****N. upsalensis* (Grunow) Perag.** (Plate VI: 1–4)

Valve length 21.4–38.6 µm, width 9.2–10.6 µm, striae 10.3–10.7/10 µm, areolae 29–31/10 µm. Samples 517, 518, 519, 520, 523, 524.

***N. veneta* Kütz.** (Plate VI: 7–13)

Valve length 18.3–23.5 µm, width 5.1–5.6 µm, striae 13.8–14.8/10 µm, areolae 31–36/10 µm. Samples 513, 514, 516, 517, 518, 519, 522, 523.

***N. viridula* (Kütz.) Ehrenb.** (Plate VI: 5–6)

Valve length 52.9–74.1 µm, width 12.6–13.7 µm, striae 8.7–9.4/10 µm, areolae 27–28/10 µm. Samples 517, 518, 519, 524.

Navicula sp.

(Plate VI: 14–23)

Valve length 11.5–22.1 μm , width 4.1–4.6 μm , striae 14.6–17.1/10 μm . Samples 514, 516, 518, 519, 521, 522.

The species is very similar morphologically to *N. skabitchewskaya* Kulikovskiy, Lange-Bert. et Metzeltin in the shape and size of the valves, as well as in the density and arrangement of the striae, however, it differs from the latter in the straight, non-curved axial area and the central pores of the raphe which are deflected to the secondary side of the valve.

Discussion

As a result of our taxonomic investigation, 29 species of the genus *Navicula* were identified, of which one, *N. trophicatrixoides*, is new to science, and one, *N. alineae*, is a new record for Russia, 15 species are new records for the territory of the Voronezh Region.

Navicula trophicatrixoides belongs to the group of species morphologically similar to *N. trophicatrix*, characterized by a complex of distinct features: lanceolate valve outline, relatively sparse areolae, characteristic widely spaced striae in the valve centre, unusual structure of the external central raphe endings (Lange-Bertalot, 2001, pl. 72: 1–2), although the latter feature remains unexplored in SEM for some species. The differences between the taxa of this complex relate primarily to the ranges of quantitative characters (only *N. praeterita* is distinguished by the rostrate shape of the valve ends), and the new species described by us is no exception. Quantitative characters of all taxa similar to *N. trophicatrixoides* are summarized in Table 1. It is obvious that the new species has denser lineolae in comparison to all other taxa. In addition to this *N. krsticci* and *N. mitrofanovae* both have larger valves and *N. trophicatrix* subsp. *trophicatrix* has wider valves. The other taxa are similar to *N. trophicatrixoides* with respect to valve size.

Navicula alineae was originally described from Lake Kinneret in Israel (Tsarenko *et al.*, 2000), later there were records in Albania (Lange-Bertalot, 2001), Sardinia (Lange-Bertalot *et al.*, 2003), South Korea (Joh, 2017). That is, the species has a wide geographical range and tends to occur in southern regions of Eurasia, while being quite rare. Our record in Russia is the first.

The find of *Navicula streckerae* is also interesting. Until now, in Russia this species has been recorded once in the Tyumen Region, with incomplete certainty in the identification (cf.) (Genkal, Yarushina, 2018).

Our data indicate the heterogeneity of the species *N. antonii* in its modern concept. Populations were found, the characters of which are completely consistent with the characteristics of the type material of the species (Lange-Bertalot, 1993, taf. 64: 1–6), as well as morphologically dissimilar populations, designated here as *Navicula* cf. *antonii*. Although the differences between them are quite subtle and difficult to formally describe, it is possible to assign an individual specimen to *N. antonii* or *N. cf. antonii*. It may be noted that *N. antonii* has a distinct small rounded central area

Table 1

Comparison of *Navicula trophicatrixoides* with morphologically similar taxa

Taxon	Valve length, μm	Valve width, μm	Length to width ratio	Number of striae in 10 μm	Number of areolae in 10 μm	Reference
<i>Navicula trophicatrixoides</i> sp. nov.	27.3–37.5	5.6–6.7	4.5–5.6	11.9–13.6	26–29	This study
<i>N. krsticii</i> Levkov	42–61	7–9.5	5.0–6.5*	12–14	24–26	Levkov <i>et al.</i> , 2007
<i>N. mitrofanovae</i> Metzeltin, Kulikovskiy et Lange-Bert.	46–53.5	7.3–8	5.8–7.5	11–12	22–23	Kulikovskiy <i>et al.</i> , 2012
<i>N. praeterita</i> Hust.	20–40	5.5–8.5	4.4–5.2*	12–14	22–25	Lange-Bertalot, 2001
<i>N. subtrophicatrix</i> Tuji	22–31	5–9	4.2–5.2*	10–13	20–25	Tuji, 2003
<i>N. trophicatrix</i> Lange-Bert. ssp. <i>trophicatrix</i>	25–50	7.5–10	3.3–5.5*	11–13	21–24	Lange-Bertalot, 2001
<i>N. trophicatrix</i> ssp. <i>vixtrophicatrix</i> Kulikovskiy, Lange-Bert. et Metzeltin	36.7–44	6–7	5.3–6.6*	12–13	20–24	Kulikovskiy <i>et al.</i> , 2012
<i>N. usoltsevae</i> Metzeltin, Kulikovskiy et Lange-Bert.	30–44	5.6–6.8	5.3–8.4	12–14	ca. 25	Kulikovskiy <i>et al.</i> , 2012

Note. * – calculated from the published micrographs.

whereas *Navicula* cf. *antonii* has no central area in smaller valves and a small elliptical central area in the larger valves. Apparently, *N. antonii* in the modern interpretation (Lange-Bertalot, 2001) is a complex of at least two semicryptic species.

The following can be said about the flora of *Navicula* in the water bodies of Divnogorye in general. The most common species (found in 10–12 samples) were *Navicula* cf. *antonii*, *N. capitatoradiata*, *N. cryptotenella*, *N. tripunctata*, *N. trivialis* and *N. slesvicensis*. The rarest (found in 2 samples) were *N. alineae*, *N. moskalii*, *N. oblonga*, *N. oppugnata*. The rest were characterized by an intermediate occurrence frequency. The majority of species were taxa that prefer water with a high electrolyte content (Lange-Bertalot, 2001). The species composition was quite similar in all samples taken from the rivers but the sample from the oxbow in the floodplain of the Tikhaya Sosna River (520) was different, *N. trivialis*, *N. cryptocephala* and *N. radiosa* were the most abundant species.

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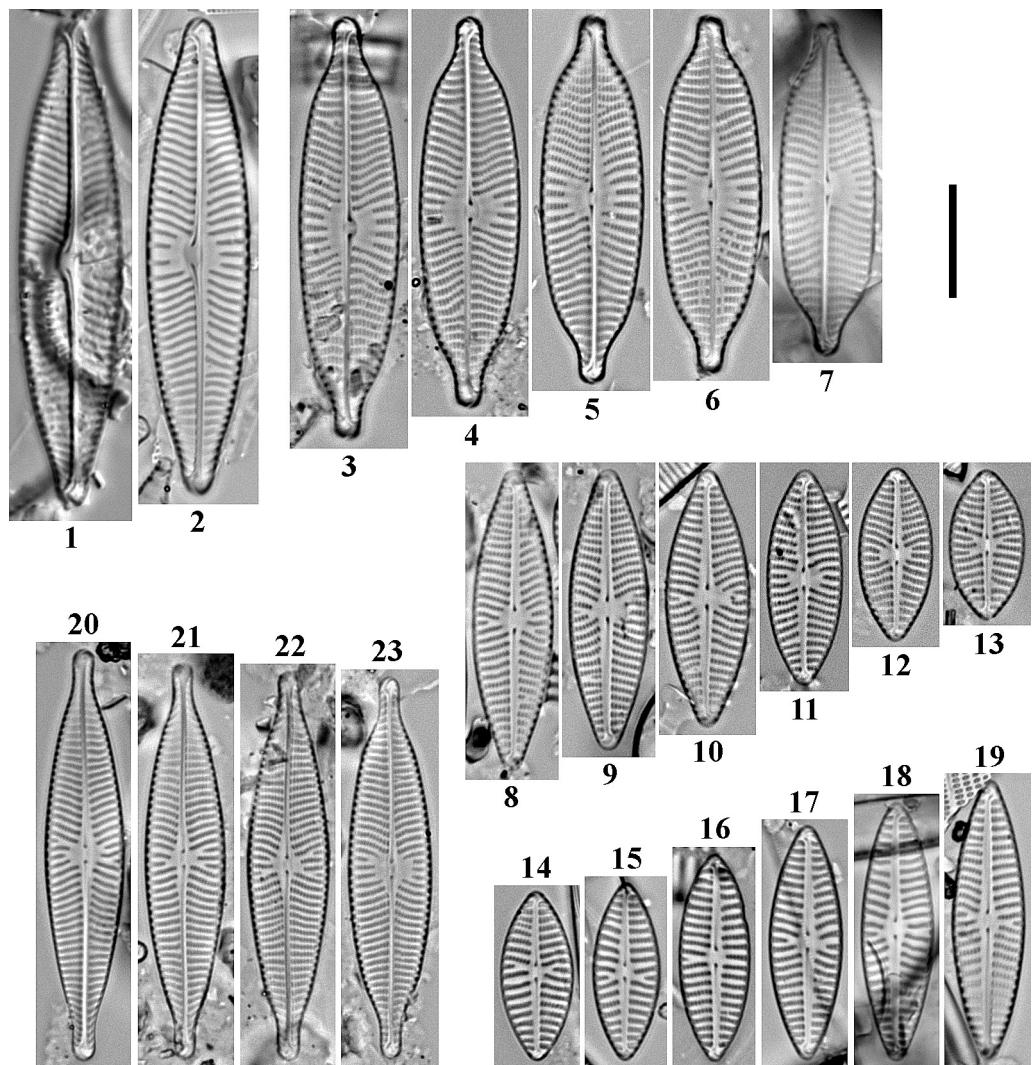


Plate I. 1–2 — *Navicula alineae*, 1 — slide 518, 2 — slide 522; 3–7 — *N. amphiceropsis*, slide 523; 8–13 — *N. antonii*, slide 523; 14–19 — *Navicula cf. antonii*, slide 519; 20–23 — *N. capitatoradiata*, slide 520. Scale bar: 10 μm .

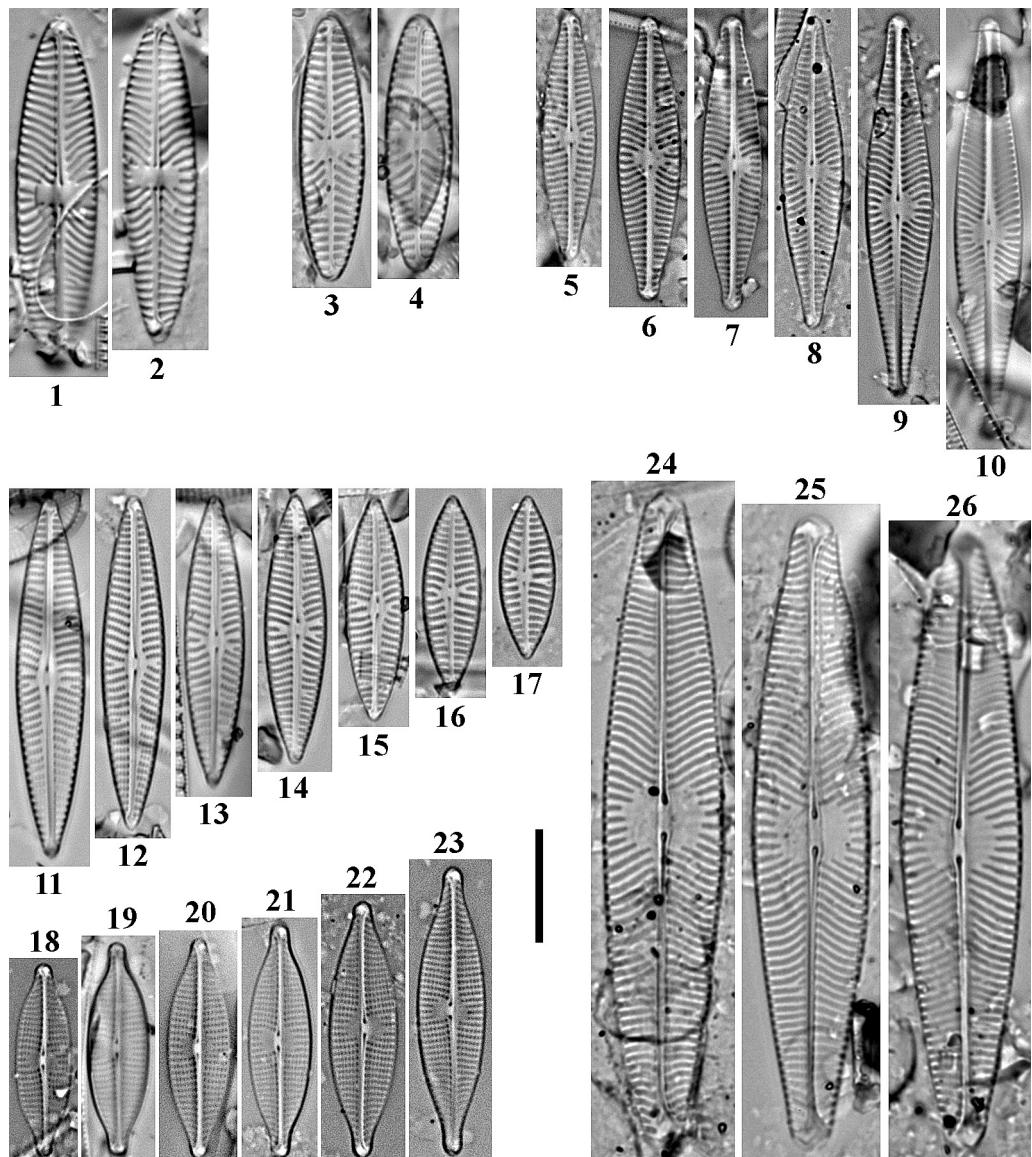


Plate II. 1–4 – *Navicula cari*, 1–2 – morphotype 1, slide 513, 3–4 – morphotype 2, 3 – slide 522, 4 – slide 519; 5–10 – *N. cryptocephala*, slide 520; 11–17 – *N. cryptotenella*, slide 519; 18–23 – *N. gregaria*, slide 523; 24–26 – *N. lanceolata*, slide 517. Scale bar: 10 μm .

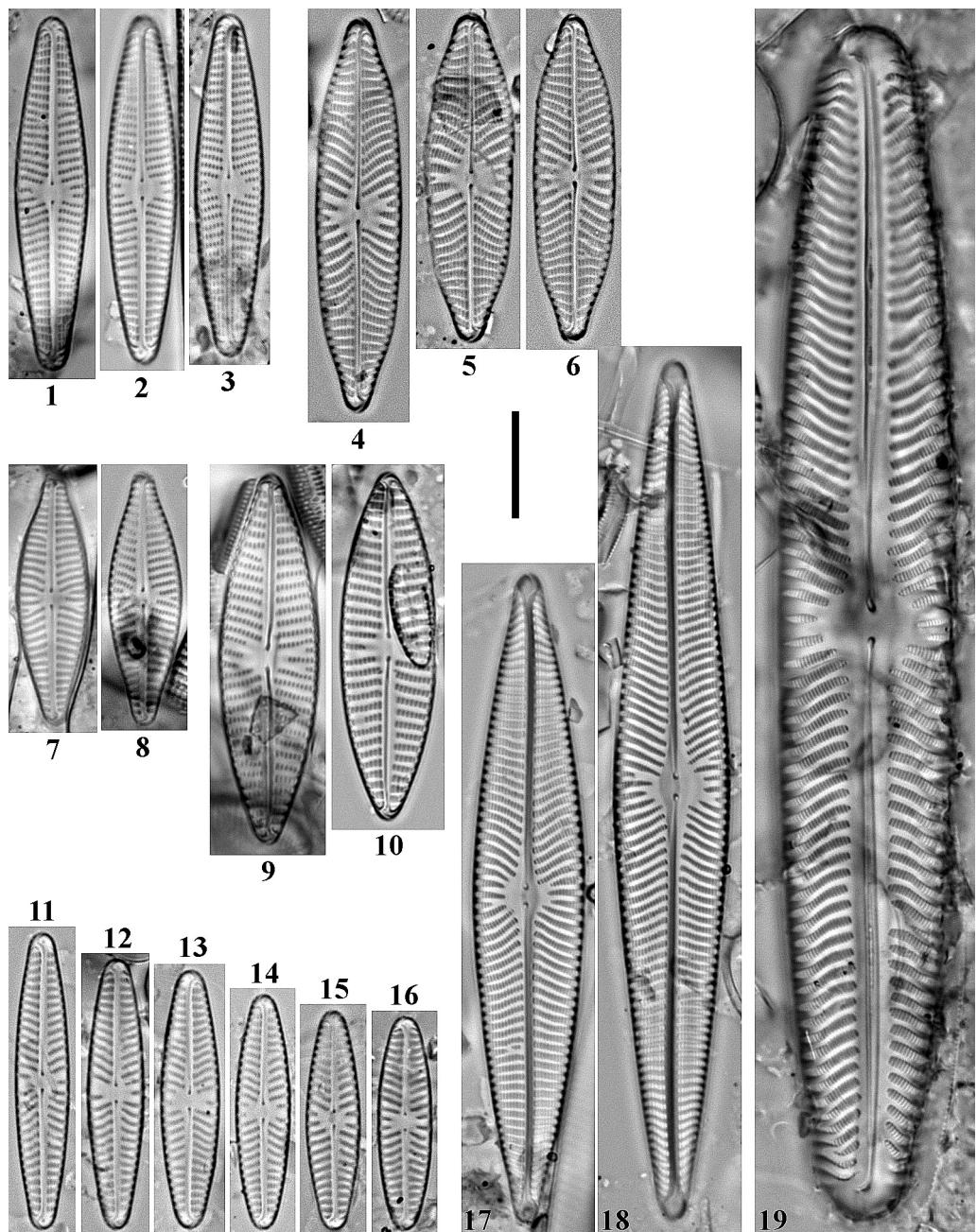


Plate III. 1–3 — *Navicula libonensis*, slide 520; 4–6 — *N. novaeiberica*, slide 524; 7–8 — *N. moskalii*, slide 520; 9–10 — *N. oppugnata*, slide 519; 11–16 — *N. pseudowiesneri*, slide 523; 17–18 — *N. radiosa*, slide 520; 19 — *N. oblonga*, slide 523. Scale bar: 10 μm .

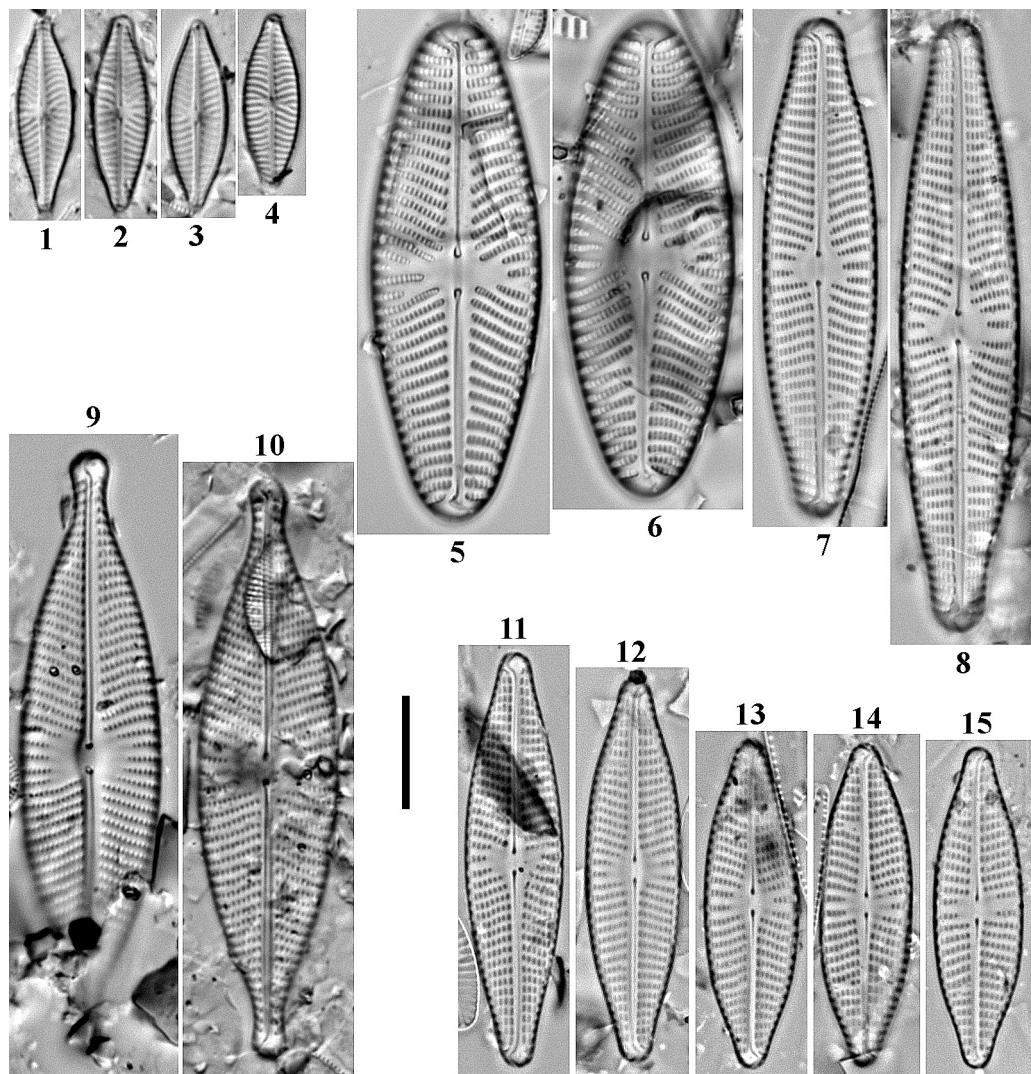


Plate IV. 1–4 — *Navicula reichardtiana*, slide 513; 5–6 — *N. reinhardtii*, slide 519;
7–8 — *N. slesvicensis*, slide 523; 9–10 — *N. rhynchotella*, slide 513; 11–15 — *N. streckerae*, slide 523.
Scale bar: 10 μm .

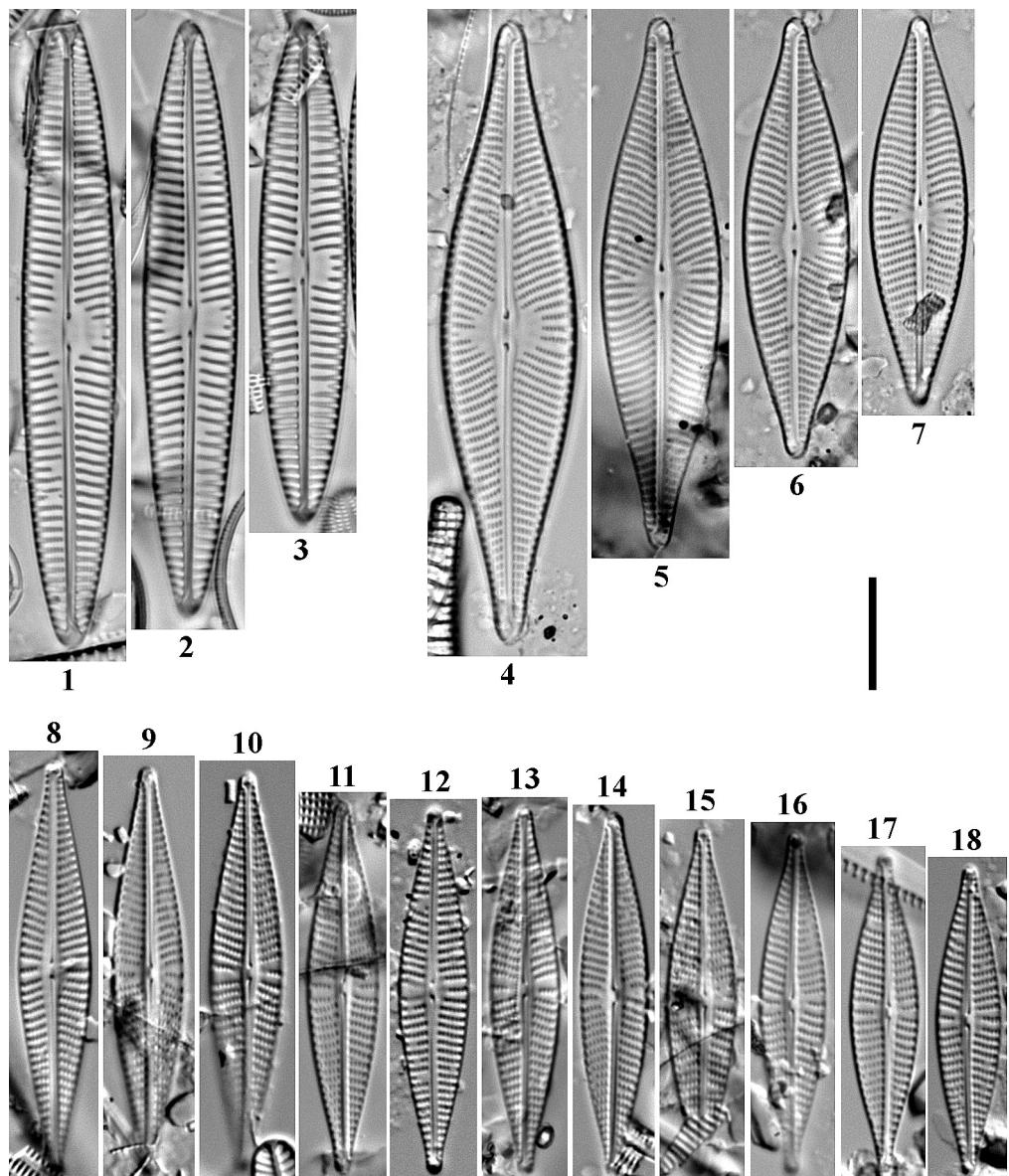


Plate V. 1–3 — *Navicula tripunctata*, slide 519; 4–7 — *N. trivialis*, slide 520;
8–18 — *N. trophicatrixoides* sp. nov., type material, slide 518s1. Scale bar: 10 μm .

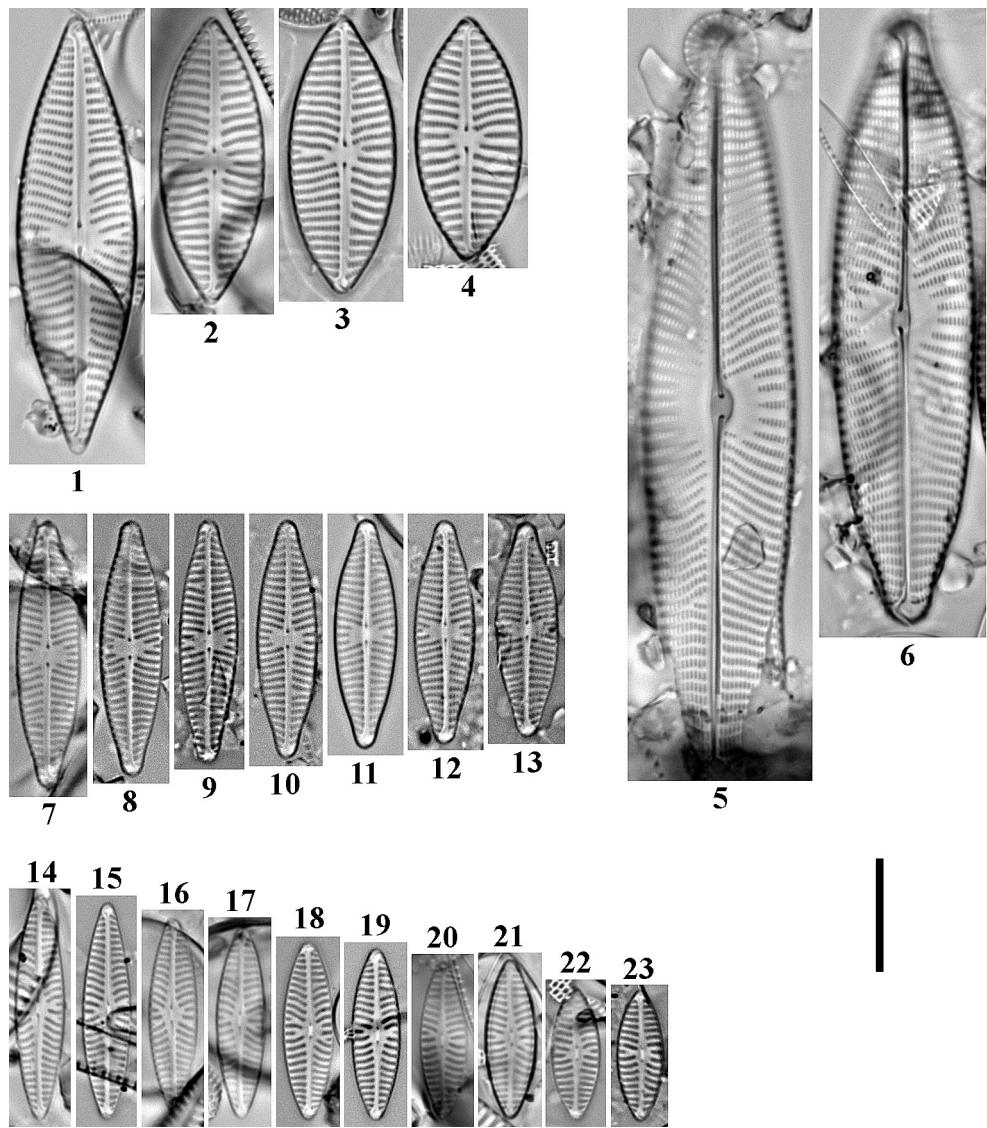


Plate VI. 1–4 — *Navicula upsalensis*, slide 519; 5–6 — *N. viridula*, 5 — slide 524, 6 — slide 519; 7–13 — *N. veneta*, slide 523; 14–23 — *Navicula* sp., slide 519. Scale bar: 10 μm .

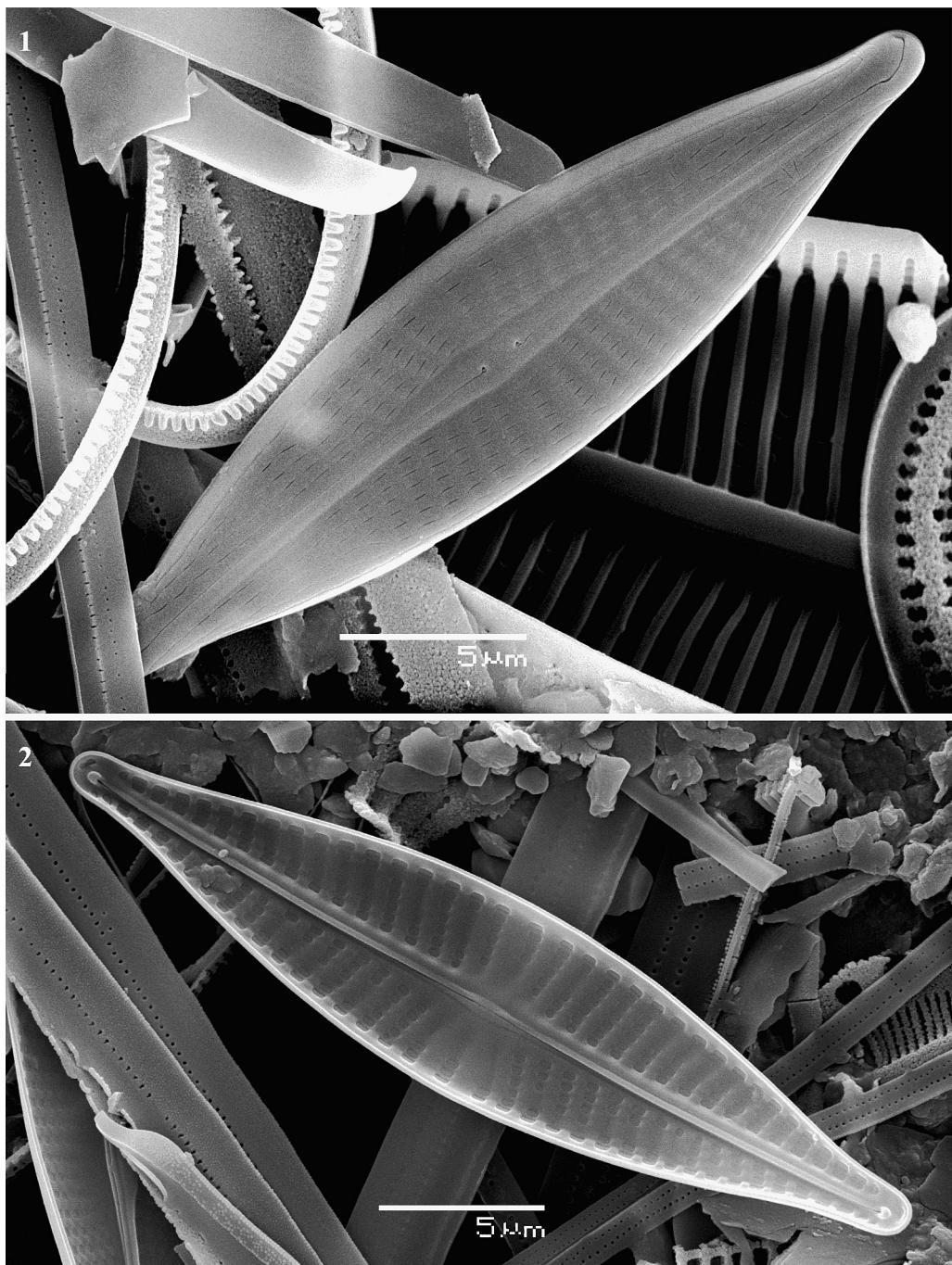


Plate VII. *Navicula trophicatrichoides* sp. nov., SEM, type material, sample 518.

1 — external valve surface; 2 — internal valve surface. Scale bars: 5 μm.